

What is the potential of virtual reality in architecture?

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Name: Michelle Benalcazar Murillo

Student Number: 2008160

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Abstract

For most people, the term Virtual Reality (VR) is automatically associated only with the use of video games, and not with other fields, such as medicine, the military or architecture. This is because today there is better exposure in terms of information such as the presentation of elements related to the use of VR in video games such as the Meta Quest 2 VR headset for the use of the Play Station 5 console.

This dissertation focuses on understanding what VR technology is, how it works, and what differences and similarities it has with Augmented Reality (AR) technology. It also explains the different types of VR that exist, and examples of which fields best suit the user.

Moreover, the study of the use of VR technology in the field of architecture, how it did originate, how it works, and its popularity among architects in the United Kingdom and architects from the rest of the world will be compared.

Case studies were carried out with architects Dennis Hellyar and David Darkin, who will explain how VR is used in their architectural practices on a day-to-day basis.

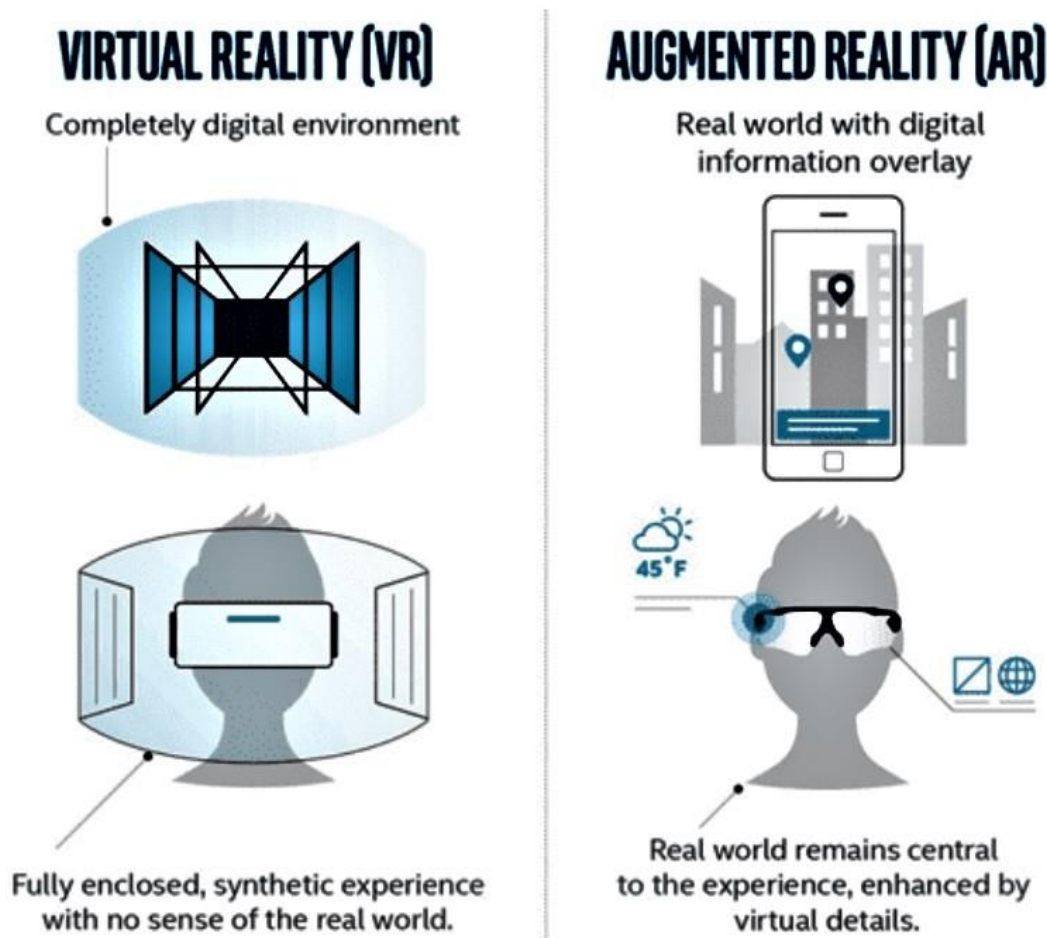


Figure 1: A brief explanation of what VR and AR are. (Photo credit: R. Williams)

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Secondly, I would like to thank the architects Dennis Hellyar and David Darking who, despite their busy schedules, have been able to arrange an interview for me, which have been very helpful.

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Introduction

“The use of virtual reality is more universal and can evoke a positive reaction in the same way physical architecture can” (Joson, 2022).

When virtual reality technology is mentioned in conversation, the first thing that comes to people's minds is video games, since they generally have a more obvious connection to this technology than the other professions that use it. Its generally used in such fields as the military, NASA or in this case, architecture.

This dissertation explains what virtual reality technology is, how many types there are, what is the difference between VR and AR, and most importantly what is the potential of VR in architecture.

Methodology

For the writing of this dissertation, various qualitative research methods have been used, due to the nature of the information required. These methods included:

Books

Interviews with architects that use VR in their practises.

Various online magazines.

Online papers research.

Books.

To search for relevant information about this dissertation, the author resorted to several books on VR and AR. The most informative subject is '*Practical Augmented Reality*' by Aukstakalnis.

Interviews with architects that use VR in their practises.

For the information of the case studies of this dissertation, the author resorted to interviews with architects such as Dennis Hellyar of Hellyar Architects and David Darkin of Darkin Architects who use VR in their practices. While for the Lampeter case study information, the author was a listener in one of the meetings via Teams that the organising team had.

Various online magazines and web pages.

The subject of this dissertation deals with a current issue; the best place to obtain information is online magazines such as 'Arch Daily', 'Parametric Architecture' or 'My tech mag' among others.

Online papers research.

The author also resorted to papers written by other experts on the subject, such as the 1992 conference paper 'Augmented reality: An application of heads-up display technology to manual manufacturing processes' written by Caudell and Mizell or the 1999 conference paper 'Virtual reality in the design studio: the Eindhoven perspective' written by Achten.

Aims and objectives

Aim

The aim of the research is to assess the application of VR in the architectural universe, to improve the current process of design and construction.

Objectives

1. To define what Virtual Reality is and how it works.
2. To analyse where the development of Virtual Reality is at present and what is proposed for the future.
3. Examine how Virtual Reality is being utilised within construction and architecture.
4. Address the benefits and weaknesses of using Virtual Reality in architecture.
5. Investigate the experiences of using Virtual Reality within architecture.

Definition of keywords

In this dissertation, a few keywords need to be mentioned and explained.

AR	Augmented Reality
BIM	Building Information Modelling
CAAD	Computer-aided Architectural Design
CRT	Cathode-ray Tube
FPS	Frame per Second
HMD	Head Mount Display
INSPIRE	The Institute for Sustainable Practise, Innovation, Research, and Enterprise
NPC	Non-playable Character
PPI	Pixels per Inch
UWTSD	The University of Wales Trinity Saint David
VR	Virtual Reality

The term VR (virtual reality) was coined for the first time in 1987 by the father of virtual reality, Jaron Lanier.

The term AR (augmented reality) was coined for the first time in 1992 by two researchers from Boeing Aerospace, David Mizell and Tom Caudell.

What VR means in the field of architecture?

The use of virtual reality in the field of architecture is the need to be able to explain, feel and see a project, feel, and see a project as a complete block rather than in parts as is the case with rendered images, and no matter how beautiful and perfect a rendered image is, the user will never be able to convey the feeling that virtual reality has.

How popular is VR?

Every 5 of 20 studios use virtual reality in their practices in the United Kingdom, which represents 25% of all architecture studios in the country, this number is not so far from the 9 out of 20 architecture studios that use VR of all architecture studios in the world, representing a 45%. Of this 45%, there is 40% in Europe, 21% in the US and 11% in Asia. and 3% in the Middle East.

These numbers may seem lower than expected, but it is a relatively "new" technology, since there was a lot of information about it, and these percentages are increasing little by little.

In this dissertation, the author uses three case studies as examples of how VR is used in the field of architecture. The first and second case studies talk about how the architects Dennis Hellyar from Hellyar Architects and David Darkin for Darkin Architects use VR technology in their practises. While the third case study is about how VR technology can be used to recreate an existing building in the virtual world to be used in a videogame for educational purposes.

Within the literature review, the author found the book '*Practical Augmented Reality*, by Steve Aukstakalnis (2017) one of the most helpful resources. In this book the author found all the necessary information that explains in a very easy way to understand what VR is, how it works, how many types there are and a description of each one of them. Information about AR was also found, which is how it works, how many types there are and a description of each of them.

Chapter 1: Detailed examination of virtual reality

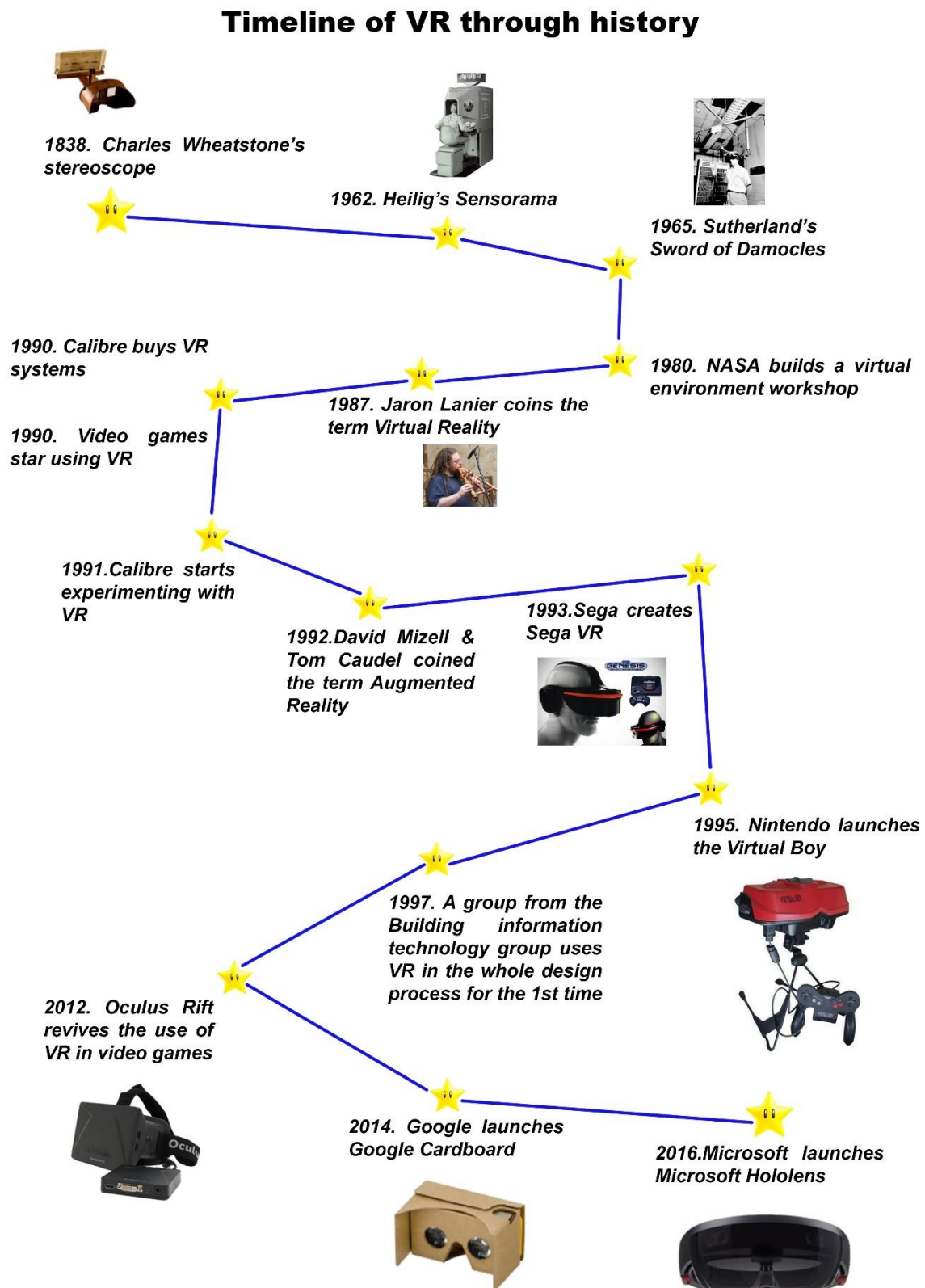


Figure 44: Timeline of VR through history. (Photo credit: the Author)

History of virtual reality

In 1965, a man called Ivan Sutherland set the wheel of virtual reality in motion. He did so with the creation of the ultimate display, the world's first head mount display or HMD, nicknamed the Sword of Damocles due to its room-filling size. This HMD was composed of 2 CRT monitors with mirrors and prisms, allowing the digital wireframe graphics to be superimposed over the real world (GameSpot, 2015).



Figure 45: Ivan Sutherland's first VR Head Mounted Display, The Sword of Damocles.
(Photo credit: C. Elaine)



Figure 46: Image of what the user could experience when using the Sword of Damocles.
(Photo credit: Ultimate History of Video Games)

It is argued that the use of what is known as virtual reality (VR) today began in 1955, with the invention of the Sensorama by the American cinematographer and inventor Morton Heilig, a 3D theatre called The Cinema of the Future. It allowed the user to watch a movie while having their senses stimulated. By 1962 he had a working prototype, able to display stereoscopic 3D images in a wide-angle view, providing body tilting, playing stereo sound, and also triggering blasts of wind and aromas at specific points during each of the five purpose-built short films (GameSpot, 2015).

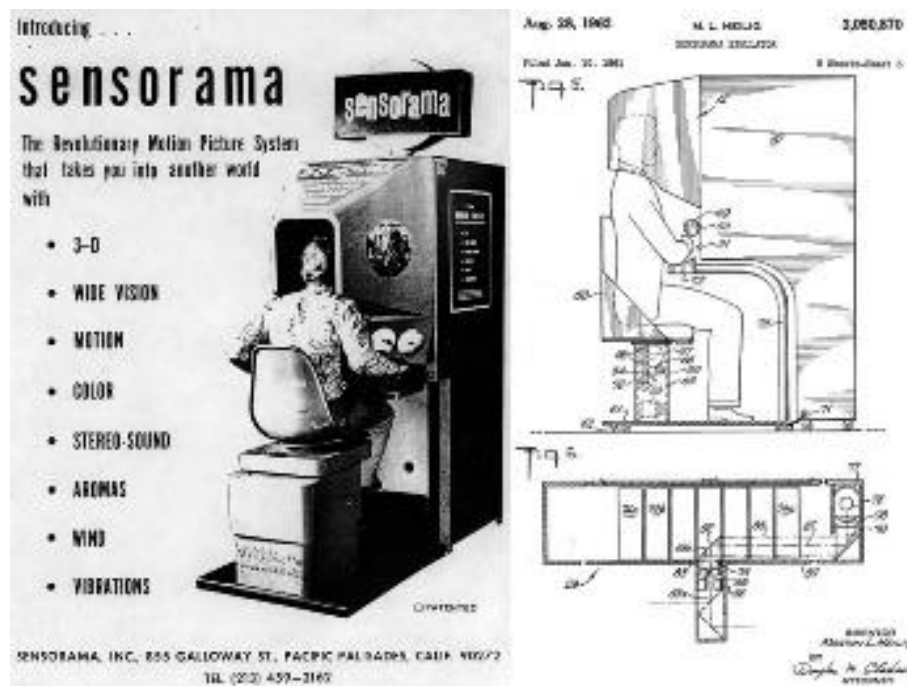


Figure 47: Image and diagram of a Sensorama machine. (Photo credit: M. Delphine)

Steady developments of early VR during the 60s and 70s were driven chiefly by the US military's work on vehicle simulators through specialist teams at NASA and researchers at the University of Utah. This progress in tandem with advancements in computer graphics, technology began to gain momentum. In the 1980s, a team at NASA made a virtual environment workstation, where they constructed two LCD TV displays, wide-angle stereoscopic optics, and a motorcycle helmet.

It was not until 1987 that the term virtual reality was coined for the first time by Jaron Lanier, considered the father of VR, he founded the company VPL Research in 1984, the first in history to sell VR products, along with the sale of VR products, VPL Research was dedicated to implement and create a programming language for the correct development of the first virtual reality applications. This company specialized in the development of specific software and

hardware for improved use of virtual reality such as The Data Glove, EyePhone, AudioSphere and Body Electric (Virtual Reality Society, 2017).

In the 90s, VR video games began to merge. The earliest publicly available VR games were in the form of special arcade machines. Between 1991 and 1993 the company Virtuality Group created a line of advanced VR machines with stereoscopic 3D visuals and 276 by 372 resolution. But success in early VR videogames was rare, a clear example of that was Sega VR (Horowitz, 2004).



Figure 48: Arcade machine by Virtuality Group. (Photo credit: J. Fowle)

In 1991 Sega announced its latest creation, SEGA VR, a console that would revolutionise video games. The game would allow almost total immersion of the player in the video game through two LCD screens, a pair of headphones stereos, and some movement sensors, all connected in a headband-shaped helmet that could be adapted to the size of the players' heads. Together, these three technologies made this console the most advanced VR technology at the time.

However, in 1993 as part of the litmus test for SEGA VR, the game was shown to the public for the first and last time. The console had very bad feedback from the few users who were able to try the console. The users were disappointed with the low quality of graphics and very limited hardware, which the games offered, making them lose interest in less than 10 minutes. By 1994, SEGA VR quietly disappeared and was never created again (Horowitz, 2004).



Figure 49: Promotional poster of the Sega VR console. (Photo credit: TechEBlog)

Another console that was not successful in the world of VR was The Virtual Boy, a 32-bit tabletop 3D video game console developed by Nintendo in 1995, which was marketed as the 1st portable video game console capable of displaying true 3D graphics, but the console was a commercial flop for different reasons, one of them it was the price \$179 dollars at launch (\$250 in today's money) a significant amount of money to spend on something new and strange, alongside this issue customers didn't like using the console because it was nigh impossible to game with the thing in a comfortable position, add to that the lack of software support, a death knell for any building system, there is no surprise that The Virtual Boy failed to live up to its promise in the 90s.

After all these failed attempts to create a console that meets the high expectations of users in terms of VR, either because the technology of the time was not developed enough to create such machines or the way companies oversold consoles with unrealistic expectations caused video game companies to stop investing in virtual VR. Until the 1st of August 2012 and the launch of a Kick starter project for a little device called Oculus Rift (GameSpot, 2015).



Figure 50: Nintendo's "Virtual Boy" virtual reality table-top video game console and a player using it.
(Photo credit: A. Cummings-Grady)

Define what is virtual reality

The definition of the term 'virtual reality' is somewhat contradictory, this is because the term comes from the conjunction of two antonyms; 'reality' comes from the Latin 'realitas', which expresses the abstract concept of the real (Significados, 2023), while 'virtual' comes from the Latin 'virtus' and this is associated with what has an apparent existence, as opposed to the real or physical (Edulat, 2023).

Aukstakalnis (2017, pp. 8-11), defines virtual reality as a form of visualisation of technologies that gives the user the sensation of being completely immersed in a 3D model, which has been created within a computer. Meanwhile, Pascual (2016), describes virtual reality as a three-dimensional environment, generated by a computer device, in which the user, through special glasses, plunges into this environment, where a sensation of realism is experienced. These special glasses' technology makes the viewer believe that they are inside the virtual environment, causing them to react to it as if it were real. Another way of explaining what virtual reality is, is that it is a sensation of freely navigating through a digitally created world, as if it were real, with the only difference that in this digital world, everything is possible (Ismail, 2023).

Until now, the most well-known and common way that we know of in which we can experience VR is through video games. To this day, VR is gaining more importance in other industries like medicine, engineering, science, and architecture (Metcalf, 2018).



Figure 51: Man using virtual reality headsets and joysticks. (Photo credit: P. Huguen)

There are two main features of VR: immersion and interaction. The most important objective of VR is to be able to immerse the user in the virtual world. For this, it is necessary to combine the peripheral vision with the surrounding sound, cancelling in one way or another, any sound or image that comes from the real world. This would then enable the user to feel totally immersed. Interaction, on the other hand, is to help the user move with the motions of the VR (Atria University, 2022).

Non-immersive virtual reality

In this type of VR, the user interacts with the virtual environment through a computer, where they can control what happens through indirect interaction. This type of VR depends on a computer and is very common for the use of video games, in which the user controls his character without direct interaction (Atria University, 2022).



Figure 52: Today's video games are a clear example of Non-immersive VR. (Photo credit: D. Lalseta)

Semi-immersive virtual reality

This type of VR uses a combination of non-immersive VR and fully immersive VR. The user can navigate the computer world without ceasing to be connected to the real world, this means that the user, with the help of special VR glasses, can experience the virtual environment without having any physical sensation of being in that virtual environment. This type of technology is generally used for simulators, as they can become very high-resolution and realistic (Atria University, 2022).



Figure 53: Simulators of any kind are a perfect example of Semi-immersive VR.
(Photo credit: The Redcliffe Aero Club)

Fully immersive

In this type of technology, the user feels that they are physically and mentally immersed in the digital world. It requires the use of special equipment such as VR glasses, body detectors, gloves, and sense detectors. It allows the user to feel full immersed by allowing for physical movements, such as walking, or walking up the stairs, thereby stimulating their senses in order to provide an experience as real as possible.

This type of technology is very common in video games, but over time industries such as education and architecture have taken an interest and started to use it in their respective industries (Atria University, 2022).



Figure 54: Players experimenting with a Fully immersive VR in a video game.
(Photo credit: D. Lalseta)

What is the difference/similarities between VR and AR?

When talking about virtual reality, augmented reality comes into the context, for that, an explanation of what augmented reality is, how it works and what the differences and similarities are with virtual reality must be made.

Aukstakalnis (2017) defines augmented reality (AR) as a digital medium in which the user is allowed to superimpose virtual content of digital information on the physical world in such a way that the digital content appears as if it were physically there.

Sir Howard Grubb was one of the first to create augmented reality technology in the early 1900s. The "New Collimation Telescopic Sight for Large and Small Artillery" was an invention created to better aim projectile-firing weapons. With this invention, Sir Howard solved one of the biggest design flaws in human sight, the impossibility of being able to focus two field distances at the same time (Aukstakalnis, 2017, pp. 2-3).

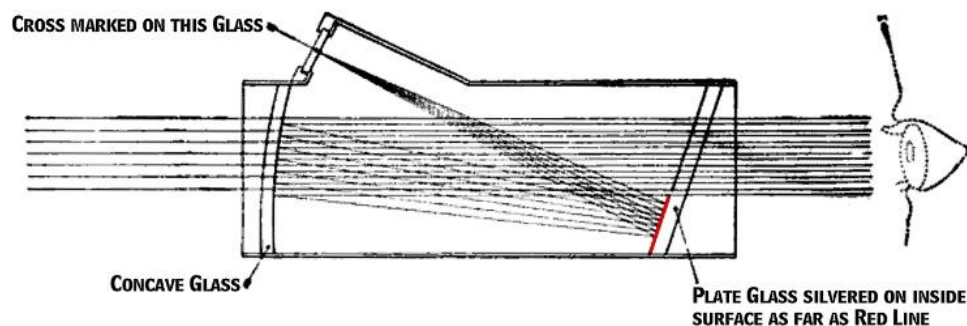


Figure 55: Diagram of the "New Collimation Telescopic Sight for Large and Small Artillery."
(Photo credit: S. Aukstakalnis)

David Mizell and Tom Caudell, two researchers from Boeing Aerospace coined the term augmented reality in 1992 when they created a head-mounted display which showed a digitally generated diagram of the industrial process of Boeing Aircrafts because according to David Mizell and Tom Caudell this type of technology 'augments the visual field of the user with the information necessary in the performance of the current task' (Caudell and Mizell, 1992).

This technology was displayed in real time by calculating the head position of the user (Reflection, 2023).

Similarities between VR and AR

<i>Augmented reality</i>	<i>Virtual reality</i>
Adds virtual elements to the world	Creates an immersive virtual experience
It is 75% real, 25% virtual	It is 75% virtual, 25% real
The user controls their senses	The system guides sensory controls
The user is partially involved	The user is completely immersed in the technology
It is used to enhance both real and virtual world experiences	It creates realistic experiences artificially
Requires high bandwidth and connectivity for proper operation	Requires standard bandwidth for practical experience
Does not require any extra device	Mandatory to use sensory devices and intelligent wearables for a better experience
It is oriented to the user's action	It simulates user action

Figure 56: A detailed comparison between AR and VR. (Photo credit: G. Johnson)

The most considerable difference is Isolation vs. integration. VR consists of introducing the user into a different world, replacing the real world with a digital one, this enables the user to immerse himself in this digital world, isolating him from reality and what happens around him. AR allows the user to see the real world with computer-generated images, allowing the user to interact with the world directly, this allows them to enjoy the benefits of the virtual world without losing connection with the real world (BBC, 2016).

The scenarios created in VR are generated on a computer device, while the AR scenarios are a combination of a real scenario and media such as people or objects created on a computer (Pascual, 2016). VR allows for the creation of a virtual world through 3D graphic design, a world in which the laws of physics do not exist. In this virtual world, everything is possible, the only limit of this world is in the imagination of its creator. While in AR, with the combination of the real world and computer details, there is not as much freedom of navigation, since in this world there are laws and regulations to follow (BBC, 2016).



Figure 57: Example of the use of augmented reality in construction. (Photo credit: E. Souza)

<i>Augmented reality</i>	<i>Virtual reality</i>
Wide variety of applications in different industries	An immersive experience in education and entertainment
User-centric technology to enhance the experience and knowledge.	The end-users don't feel insulted as the interface remains interactive at all times.
There is always a scope for constant improvement.	It creates a realistic experience that is created virtually.
Offers an innovation-based solution to the end-user.	Convenient for next-generation educational institutions leveraging AI, VR and virtual learning
The experience is shareable that also enables the third party to enrich their knowledge about the niche	Allows the end-user to gain a real-time outlook of the desired environment, such as commercial projects
Enhances the accuracy of product selection in e-commerce	

Figure 58: A comparison of the pros of AR and VR. (Photo credit: G. Johnson)

<i>Augmented reality</i>	<i>Virtual reality</i>
AR is not cost-efficient for all types of business	There is a lack of efficacy when it comes to training via virtual reality
There are still questions about AR's privacy protection	It has some ethical issues as VR promotes the idea of escapism indirectly
Not accessible to all people equally	It is 75% virtual and takes away the authenticity of real experiences
AR-based devices are still in the testing phase which makes them less efficient	

Figure 59: A comparison of the cons of AR vs VR. (Photo credit: G. Johnson)

What equipment do you use in virtual reality?

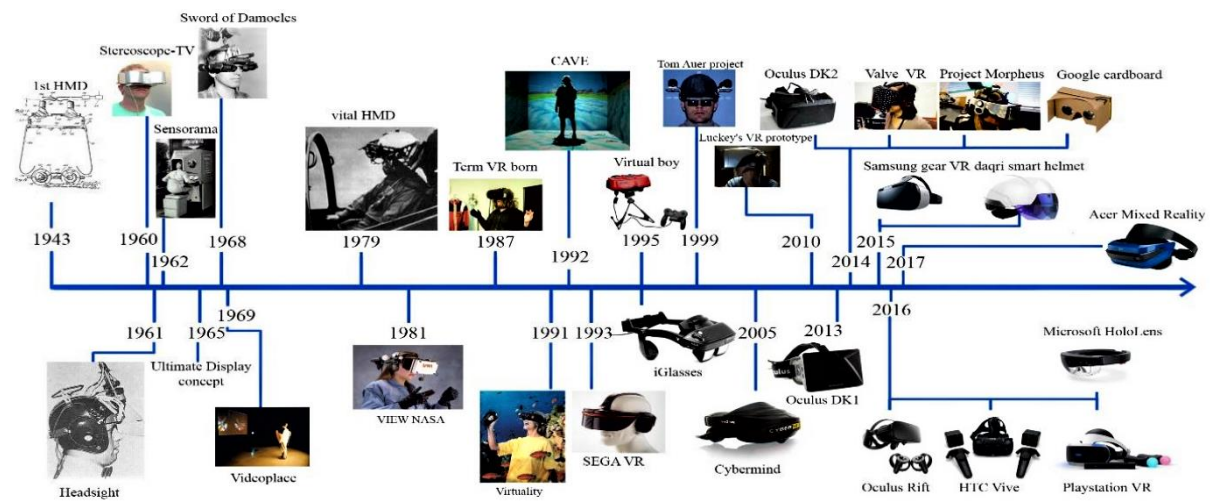


Figure 60: Timeline of the development of VR headset. (Photo credit: M. Al-Adhami)

From not needing any extra equipment, going through the cheap carton glasses to the HMD of maximum technology, each type of virtual reality; non-immersive, semi-immersive or fully immersive, requires different types of equipment to be used correctly and safely.

To be able to experience non-immersive VR in an adequate way, not much is required, this technology is the least demanding of the user. Having a computer with standard processor power and a high-resolution screen is enough to be able to experiment and work with this technology (The Tech Steam Center, 2023). According to the Tech Steam Center (2023), the use of high-performance computer graphics systems, along with one or more large screens, makes the semi-immersive virtual reality experience that much more "real." Fully immersive VR, on the other hand, is the one that requires the most equipment. In addition to needing high-performance computer graphics systems, it also requires head-mounted displays (HMD), with or without remote controls, and motion detection devices (these will help the user to move within the virtual world), but it depends on how fully immersed the user wants to experience the virtual reality.

	GOOGLE CARDBOARD	HOMIDO	ZEISS VR ONE	GEAR VR	LG 360 VR	PLAYSTATION VR	OCULUS RIFT	HTC VIVE
Type	Mobile	Mobile	Mobile	Mobile	Mobile	Tethered	Tethered	Tethered
Price	Varies by model, usually \$20-30	\$75	\$120	\$99	Unknown	\$399	\$599	\$799
Platform	Most smartphones	Most smartphones	Most smartphones	Samsung flagship phones	LG G5	PlayStation 4	PC	PC
Release Date	Available	Available	Available	Available	Unknown	Oct 2016	March 28th	April 5th
Positional Tracking	None	None	None	None	None	Camera	Camera	Laser towers
Controller	Single button	None	None	Trackpad	Two buttons	DualShock 4 and PS Move	Xbox One gamepad or Touch motion controllers	Primarily motion controllers

Figure 61: A comparison of different VR headsets, types, costs, kinds of position tracking, and controllers used. (Photo credit: Software Testing Help)

The figures below show the different types of equipment and qualities for VR that can currently be found on the market, and depending on what kind of realistic experience the user wants to have, one or the other equipment will be better.

Google cardboard.

Google Cardboard 3 is the simplest and cheapest option of all the options on the market the user only needs a mobile phone to attach to the display set. This option gives the user the chance to navigate in VR at a simpler level, which means that the user does not have movement control. Its best use is 3D videos (Mr Cardboard, 2023).

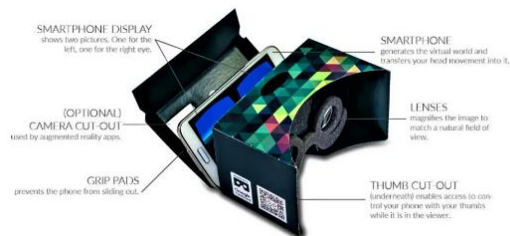


Figure 62: Google cardboard.
(Photo credit: Google)



Figure 63: User experimenting with virtual reality through the Google cardboard.
(Photo credit: Google)

Samsung Gear VR and Controller.

The Samsung Gear VR and Controller is designed to work with mobile phones, particularly the Galaxy S8. It is a more expensive version of the Google box, with the difference being that in this HMD, the user can navigate as it has a field of vision of 101 degrees and a controller movement, with a capacitive touch panel button, a fire button, thereby, giving the user the freedom to navigate and interact in the digital world (Ulanoff, 2017).



Figure 64: Samsung Gear VR and Controller. (Photo credit: Google)



Figure 65: User connecting the mobile phone to the Samsung Gear VR. (Photo credit: Google)

Meta Quest 2 (formerly the Oculus Quest 2).

Meta Quest 2 is one of the most popular products for use in VR, both in the world of video games and in the world of architecture. It requires a connection to a computer or a video console to work. This HMD has two remote controls and motion control sensors. This type of HMD gives the user the freedom of movement through the virtual world. With the remote controls, the user can move to any part of the virtual world, while the motion control sensors give the user the freedom to have a field 360-degree view (Cervantes, 2023).



Figure 66: Meta Quest 2 (formerly the Oculus Quest 2). (Photo credit: Google)

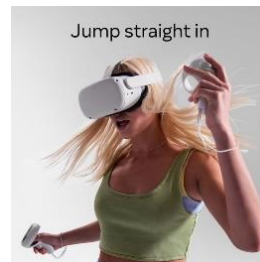


Figure 67: User experimenting with virtual reality through the Oculus Quest 2. (Photo credit: Google)

Chapter 2: Virtual reality in architecture

Architects have always used sketches, technical drawings, and models on a smaller scale as the only means of communication between professional colleagues and clients, but for most people who have no experience in architecture or design, a technical drawing or sketch is nothing less than lines drawn on paper. For people without knowledge of design and architecture, reading a technical drawing can be very complicated and frustrating. While a smaller scale model allows the client to get some idea of the scale and size of the building, it is not enough for them to fully understand how that building will work and look. This is leading to more and more architects investing in VR hardware and software that allows them to support their expression of ideas to their clients (Joson, 2022).

However, when virtual reality was relatively new, architects were with a couple of exceptions still using small scale models. One of these exceptions was the Dendriform column (tree shape or water lily shed) of SCJ headquarters. Architect designer Frank Lloyd Wright created the dendriform for an office in 1937. Due to its shape and measurements of 9 inches in diameter at the base and 18.5 feet in diameter at the top, no one believed it could work. As such, Frank Lloyd Wright built a life-size model of one of the columns which worked even better than planned, as it could hold ten times the weight of what was originally planned (S.C Johnson & Son, 2022).



Figure 68: Testing the strength of the full-scale model of one of the columns designed for the SCJ headquarters.
(Photo credit: S.C. Johnson & Son Inc.)



Figure 69: The completed columns rise along the half-acre Great Work Room, a forest of creativity and inspiration.
(Photo credit: S.C. Johnson & Son Inc.)

The use of VR in the field of architecture has been gaining more and more importance in recent years. This is due to the growing need to be able to explain, feel and see a project as a complete block, rather than in parts, as is the case with rendered images. No matter how beautiful and perfect a rendered image is, it will never be able to convey the feeling that virtual reality has (Buildner, 2016).

According to Achten et al. rendered images, are just "pretty images" to make the presentation more appealing to clients and fellow architects. But, the use of these "pretty images" was the beginning of the use of VR in the world of architecture. When architects started using rendered imagery in their practices, it was beneficial because the images gave the client more information about the building, such as its aesthetics or scale, instead of simplistic 2D plans realized.

At first, only individual images could be rendered, but, with time and technological development, it became possible to group these rendered still images into animations in the form of non-interactive videos that toured the building. This was a breakthrough for the world of architecture, since in this way, the client could better understand the architectural plans, in terms of scale and design. However, this posed a disadvantage for the architect since the lack of inactivity on the part of the rendered video meant extra work when making changes to the original design. The architect had to make changes in the plans, and the 3D model and once all these changes were made, start from scratch with the rendering of the images to create the video (Achten et al. 1999).



Figure 70: A rendered image can give more information about the building, such as its aesthetics or scale, than the plans do not. (Photo credit: Sky Arch)

Calibre is an institute that is part of the Faculty of Architecture of the Eindhoven University of Technology. It became the pioneer institution in rendering images based on VR technology and using them in presentations, especially for people without architectural training. They began to use the rendered images for presentations, usually to people with no knowledge of architecture, of the final designs and ready-to-build designs. Later, it began to be used during all stages of the design process, it also began to be used as a means of communication, evaluation, and reflection among colleagues on the design team (Achten et al. 1999).

In time, simulation tools were incorporated into VR for real-time evaluation of the logistical, constructive, technical, aesthetic, and ergonomic, amongst other qualities. This has a significant positive impact on the implementation and acceptance of VR-based tools. The opportunities of VR influenced a faculty-wide research programme, named VR-DIS (Virtual Reality Design Information Systems) created by Calibre. The purpose of the program, as it still is, was to merge communication and automation of knowledge and experience of construction and architecture (Achten et al. 1999). According to Achten et al., (1999), the creation of "VR-DIS" made possible one of the greatest discoveries in virtual reality, especially in the field of architecture. The provided the opportunity to share and present architectural designs online, anywhere in the world, giving the people involved in the presentation the power to make collaborative evaluations, without the need to travel to where the presentation takes place.

When did architects start using virtual reality?

The students of the construction information technology group began to use VR technology as an experimental tool in their projects in 1991. The purpose of the experiment was to evaluate the impact of VR technology on design, using the environment of the associated Calibre Institute, thus making Calibre one of the first to develop and use virtual reality in the field of architecture (Achten *et al.* 2015).

In the early 1990s, VR systems first went on sale, Calibre, for its research, was one of the first to obtain the technology, with this newly acquired technology, Calibre created the Division, now the world's largest company in VR software. These systems acquired by Calibre were of very low quality to be used in architecture, but this did not stop Calibre as they used them for the research and development of systems that are used today in the world of architecture. However, this technology was used only by students in parts of their projects. It was not until 1997 that virtual reality, with the help of various computer technologies, was first used in the whole process of creating a student project (Achten *et al.* 2015).

How does virtual reality work in the field of architecture?

Given that VR aims to transport the user to a digital world for a limited time, the use of VR in architecture is practically the same, the only difference is that the user is transported to the digital model of the project in which they are working, the "world" to which the user is transported is in the process of construction (Achten *et al.* 2015).

Joson (2022) states that the use of VR being fully immersed in the field of architecture provides both the architect and the client with a more real and accurate experience of what a project will be like once built. The advantage of this type of technology is that it can be used from the early stages of the design to the end, making it possible for both the client and the architect to visit the project whenever they want and see how it works, and if there are details that to be changed, this is where it is easier to make the changes.

As mentioned above, VR can be used in all phases of project design, design phase, project review and presentation.

Design and initial analysis

At this stage virtual reality is used as a tool to express the creativity of the architect in a simpler and easier way, allowing them to explore having a better understanding of the sizes and proportions of the spaces in which they are going to design. This also gives the architect the opportunity to use it as a tool to explore the relationship between different spaces, as well as the type of materials that can be used, the type of construction that can be carried out, the amount of light that can enter the building at different times of the day or the views from different rooms of the building, amongst other functionalities. An embedded representation at this stage of the design can give people not associated with the profession, a better understanding of the project, such as size and the relationship between spaces, compared to a 2D representation (Joson, 2022).

Project review

VR makes the project review process much easier and faster than designing in the traditional way. Instead of reviewing plans, elevations and sections and looking for errors, the architect along with their team can "navigate inside" the design, verifying that everything works correctly and that there are no errors that harm the design at the time of its construction (Biblus, 2022).

Furthermore, a more realistic perception of the designed spaces can be created. VR can also be used to analyse and detect potential risks within the building design before the design is built (Biblus, 2022).

Project submission

One of the most difficult part of architectural projects is delivering the presentation of the project, since presenting and communicating what a design is like and how it works to people, who generally have no knowledge of design and architecture, can become very complicated and even frustrating on some occasions. The use of VR has made this part of the process much easier than it was before. The architect, together with the client, is transported to the

virtual representation of the design that is being presented. In this way, both the client and the architect can navigate freely through the building and its surroundings, which provides a better understanding of the project. Thus, giving the client the perfect opportunity to make any last-minute changes to the design if they so wish (Biblus, 2022).



Figure 71: Team of architects presenting a proposed design to the client in virtual reality using HMD sets. (Photo credit: Biblus)

How do architects use virtual reality to help advance their designs?

"Architecture is the art of turning visions into reality" (Uppunda, 2022) So true and so challenging for an architect, especially when communicating it to the client, one of the most difficult challenges architects face when working on any project is communication with the client's side, especially if the client has no design experience at all. How does an architect explain to a client what the building will look like from the inside and outside, or how each space of the building will feel once it is finished with only 2D images, 3D images and a scale model of that building, for a non-designer the sense of scale is difficult to understand through small drawings and models?

But all this is changing, since the introduction of VR in the field of architecture has been one of the best inventions that the profession has been able to acquire, since this not only allows better communication between architect and client, but also adds a greater advantage when presenting an architectural project.

However, VR has shown that it is a very beneficial tool in the architectural design process, a questionnaire distributed by the author to a sample of 20 British architecture studios asking them if they use VR within their projects, only 5 of the 20 studios use virtual reality in their practices, which represents 25% of the total number of architecture studios in the country. Although this number is even lower than imagined, it is not so far from the questionnaire carried out worldwide by CGarchitect, where it seems that only 9 out of 20 architecture studios use virtual reality in their projects, representing 45% of all architecture studios in the world, of this 45% as the total number of architecture studios that use virtual reality there is 40% in Europe, 21% in the US and 11% in Asia. and 3% in the Middle East.

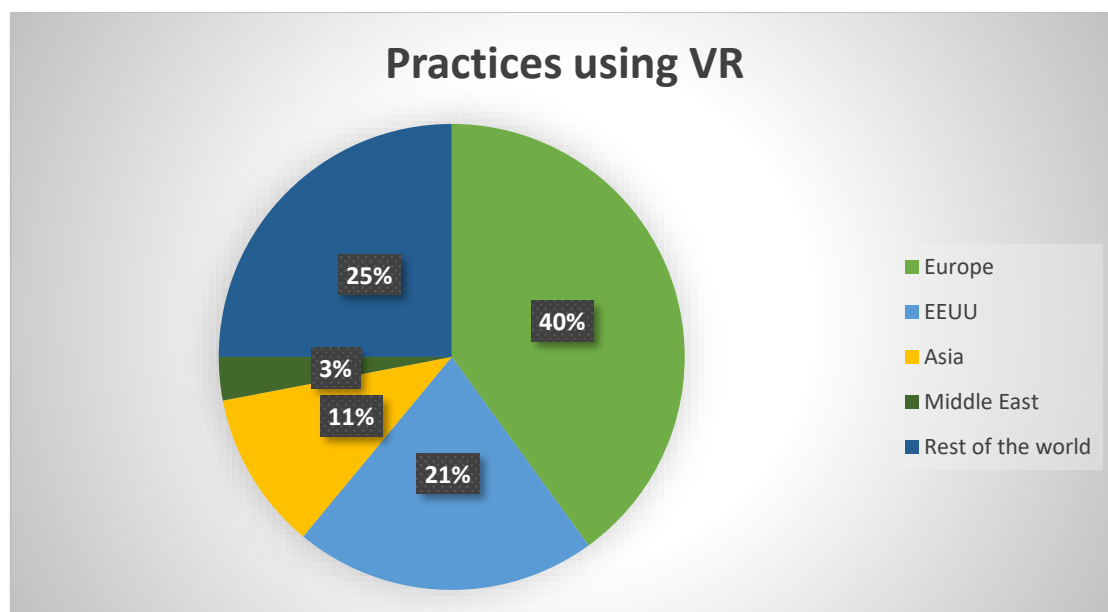


Figure 72: Diagram of the use of virtual reality in practices in different parts of the world.
(Photo credit: the Author)

This survey conducted by CGarchitect, also revealed that in recent years there has been an increase in architectural studios using VR, a number that will continue to increase over time, as more and more architecture studios discover the advantages of working with VR (Uppunda, 2022).

What are the advantages of using VR technology?

The introduction of the use of VR in architecture has been one of the biggest innovations.

There are several reasons why more and more architects are adopting technologies such as virtual or augmented reality in their companies. One such reason is that it offers a unique

customer experience. One of the main aspects of architecture is to offer a unique and incomparable experience to the client and with the emergence of VR this aspect has become easier to achieve. The fully immersed experience for example, allows the customer to navigate within the full-scale virtual model of the design, giving them the opportunity to have a more realistic understanding of the space, design and design concept so that the client can make the necessary changes until they are completely satisfied with the design of the project before it is built (Uppunda, 2022).

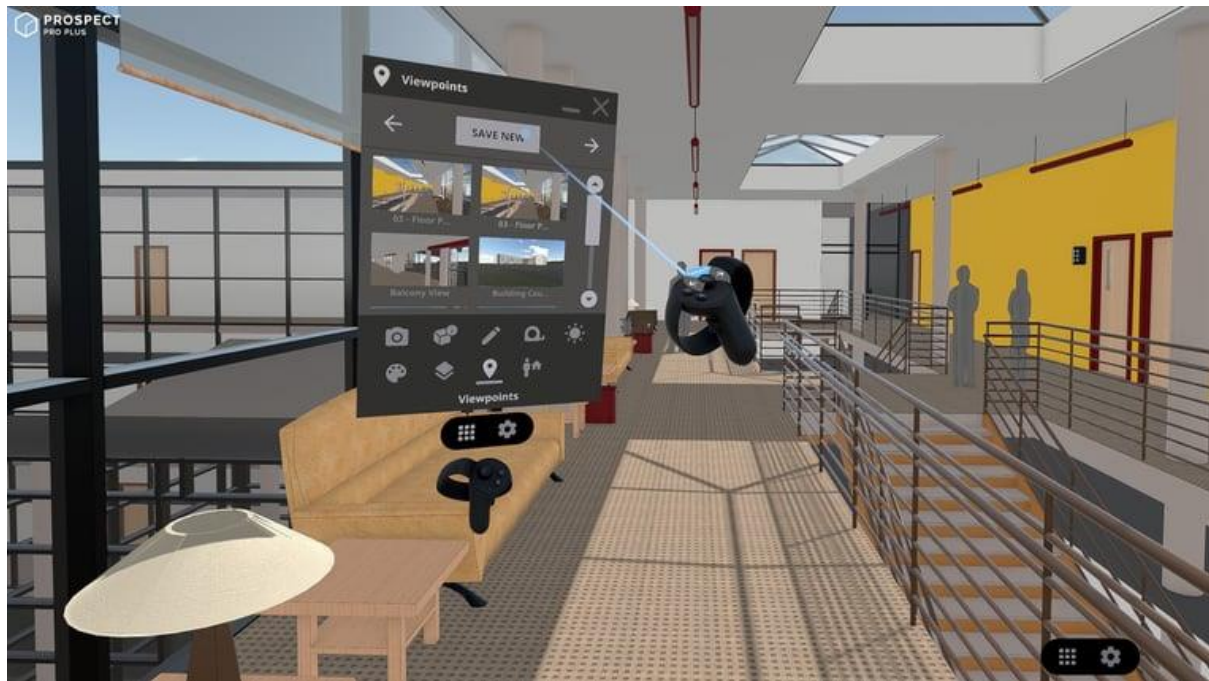


Figure 73: User viewing and making changes on the digital model of the project.
(Photo credit: Bru)

The perfect collaboration

VR has made it possible for architects, engineers, contractors, etc. to work on the same project in a much more efficient way, thanks to the real-time modelling tool. Any changes made by a person are saved in the project, allowing the rest of the team to see those changes directly in their files. Since the beginning of virtual reality in architecture, there is a better understanding of the project than just using the 2D drawings, from all parties interested in the project (Uppunda, 2022).

Improve work between partners

VR has eliminated physical distances, nowadays and with the help of VR and the internet, it is much easier to work with other architectural practices, regardless of where in the world they are. Technological advances have made working on the same project remotely much easier and cheaper, saving architects or anyone who is part of the project from having to travel hundreds of miles to work. This is also the case when it comes to communication between the architect and the client (Uppunda, 2022).



Figure 74: Two architects working on a project. (Photo credit: S. Uppunda)

A competitive advantage.

Both architectural firms and architects, like any other company, want to do something that differentiates them from the rest of their competitors. With the use of VR, this can be easier, as just by using virtual reality in their practices they are already one step ahead of the practices that choose not to use VR (Bru, 2022).

An easy-to-use investment.

At first, architecture studios did not invest in VR for fear of the new, this has changed over time. Today there is a lot of information about the use of VR in the world of architecture, making

it easier to use and more affordable for more and more architects to invest in this type of technology for their practices, regardless of their size (Bru, 2022).

The low costs.

If an architectural practice decides to invest in virtual reality technology, it does not have to spend too much money, since today, the price of both tools and programs is more affordable for everyone (Biblus, 2022).

An increase in customers.

When using virtual reality with clients, they make them have a better experience and therefore attract more clients to the practice and therefore more profits are obtained (Biblus, 2022).

Fewer revisions.

Projects do not need as many revisions as before to have good results, since with a virtual tour of the entire project they can accurately detect each of the design defects that could cause some type of delay or failure when building (Biblus, 2022).

Leader in the industry.

The architect who uses VR in his practice already has a beta when it comes to getting clients compared to the architect who does not use this technology, since the client, especially the one who is going to build something for the first time in his life, tends to choose the most attractive option, in this case, VR is what attracts attention. (Biblus, 2022)

Better communication. Another advantage of using VR in architecture, and probably the most important one, is that it allows better communication between team members and clients since this technology allows the user to transport themselves digitally to the project in which they are working and to be able to make all the changes that are necessary for the improvement of the project, instead of reviewing the project in 2D images and once built in real life, to discover design defects (Joson, 2022).

What are the disadvantages of using VR technology?

Not everything is advantages to the use of virtual reality in the field of architecture, in an interview between the author and the architect, he mentions a couple of disadvantages that the use of virtual reality in the field of architecture, these disadvantages are related to programs designed for the use of virtual reality in the field of architecture.

The programs that are needed for virtual reality can become very sophisticated, it needs at least one person in the practice to know how to use this kind of programme and needs to be used regularly to avoid forgetting how to use it.

Another of the disadvantages that architects face in the use of virtual reality, is that the program they use in the practice needs to know everything, from how thick a wall is to what kind of window is being installed. The programme requires information, that the architect may not have in the early stages of the design. The program can be very demanding, making it difficult to keep the flow of work, the architect constantly has to make decisions, and they only get what they put in (Hellyar, 2022).

Chapter 3: Case study 1

The use of Virtual Reality in Dennis Hellyar Architects

Dennis Hellyar Architects (DHA) (2022) is a Royal Institute of British Architects (RIBA) chartered practice located in the town of Barry- Wales which provides architectural services in the commercial, education, and domestic sector for the South of Wales and South West of England. With Dennis Hellyar as their CEO, this practice will provide information on how they use virtual reality in the practice, what programmes they use in their projects, and what are the advantages and disadvantages of using those programmes (See appendix 1).

Dennis Hellyar Architects does not have a specific architectural style; each project is unique, but they all share the need to be affordable and sustainable. The company acknowledges the UK and Welsh Government's requirement to adhere to BIM level 2 in publicly funded projects (Constructing Excellence in Wales, 2023) as a way to prevent mistakes made in the design process, and to be able to reduce the quantity of materials wasted in the construction due to potential mistakes, thereby making architecture a more sustainable career. The way the BIM program works is that the architect uploads their 2D plan into the program, then, they create all the elevations and sections related to the building. Then, the BIM connects the plans to the elevations and sections and is able to identify where any mistakes are by millimetres of the error margin. BIM gives the architect certainty that plans, sections and 3D will connect all together.

In 2016, Dennis Hellyar Architects made the decision to start using Virtual Reality in their practice. It enabled them to have a better understanding of each project and helped to show the clients how their project would look like and work as close to real life as possible. They use virtual reality in all the projects they work on, without any exceptions, from the smallest house extension to the full design of a building.



Figure 75: Example of one of the works of Dennis Hellyar Architects.
(Photo credit: Dennis Hellyar Architects)

In describing how virtual reality works in practice, Dennis Hellyar, the CEO of the company, explains that in the first stages of each design, the architects of the practice work along with the clients sketching the ideas and possible future designs. As soon as the client and the architect are happy with the sketches of the building, the architect then moves to the 2D part of the design, creating the floor plans with every detail that can be included, for this part, the program that works best is AutoCAD. This is a program widely used by architects for the professional creation and editing of 2D plans and 3D models (Marchante, 2022)

Once the floor plans and details are finished, they move onto the 3D part of the design, with the help of the program called ArchiCAD. This is a 3D, BIM designing program created for architects by architects (Graphisoft, 2023). Where all the sections, elevations, and interior and exterior details are added to the floor plans, thus, creating a 3D virtual model of the building. The creation of this model in virtual reality allows the architect and client to “navigate” through the building to see how it looks, and how it works and if necessary, make changes until the client and the architect are happy with the result, without the need of having a physical building.

Hellyar also noted that whilst there are benefits to using the ArchiCAD, there are also drawbacks to using it. The program to create the 3D is very sophisticated, it needs at least one person in the practice to know how to use this kind of programme and needs to be used regularly to avoid forgetting how to use it. Another disadvantage is that the program needs to know everything, from how thick a wall is to what kind of window is being installed. The programme requires information, which in the early stages of the design, the architect may not have yet. The program can be very demanding, making it difficult to keep the flow of work, the architect constantly has to make decisions, and they only get what they put in.

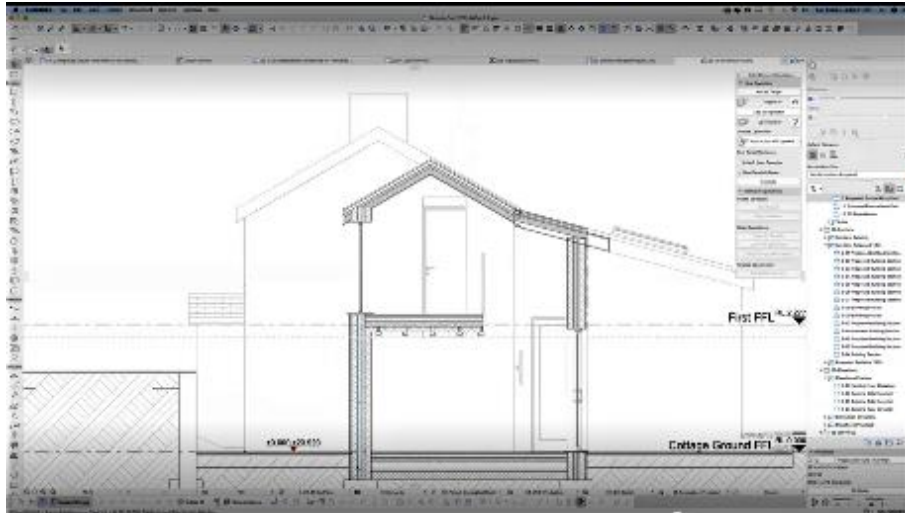


Figure 76: Section of one of Hellyar's projects. (Photo credit: Dennis Hellyar Architects)

In BIM (Building Information Modelling) a lot of details go in, but sometimes the way that some materials hit or meet each other is not very accurate. For example, in the image below, the way that the insulation goes all the way through the roof is not correct, since the roof is internal, it does not need insulation.

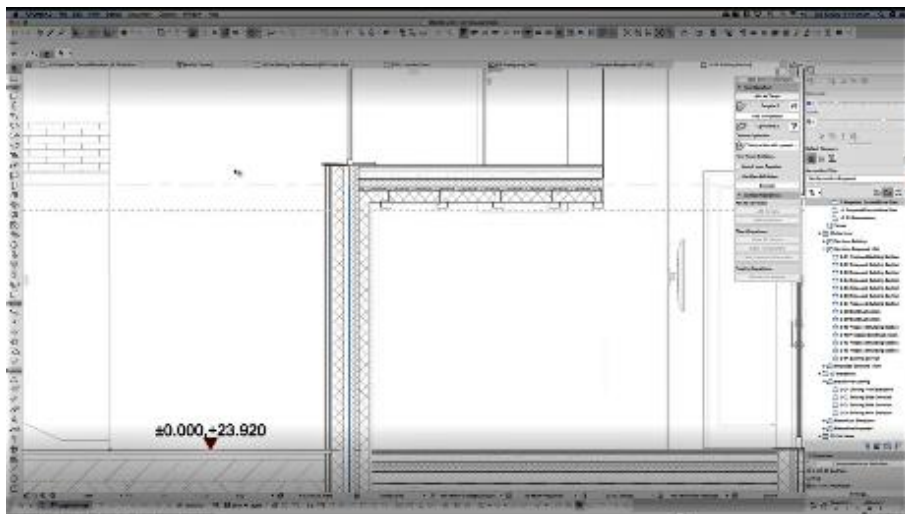


Figure 77: Section of one of Hellyar's projects. (Photo credit: Dennis Hellyar Architects)

In the image below, there is a wall, a foundation and a floor. The floor and the wall are a series of layers and the foundation is very simple, the problem in this example is that the plaster goes all the way through to the foundation, instead of stopping on the floor level.

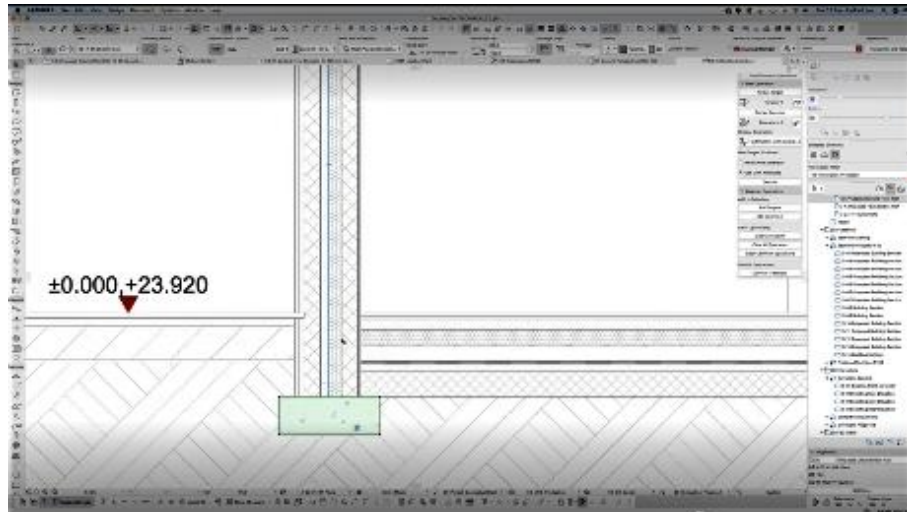


Figure 78: Section of one of Hellyar's projects. (Photo credit: Dennis Hellyar Architects)

There are two ways to fix these problems; either construct the wall up to the floor and then change to another type of construction, or, draw 2-Dimensional information on top and mask the things that do not match. This, however, will require a lot more information to be inputted in the design in order to make it work properly or result in 2D details on top of the design like a transfer. These mistakes happen because the program predicts what will happen in the junctions, normally the predictions are wrong, but according to Hellyar D. (2022) in the not-too-far future, this can be solved.

Chapter 4: Case study 2

The use of Virtual Reality in Darkin Architects

Darkin Architects (Darkin, 2023) is a Royal Institute of British Architects (RIBA) chartered practice located in the towns of Neath, Llanelli and Cardiff.

With David Darkin as their CEO, this practice will provide information on how they use VR in the practice, what programmes they use in their projects, and what are the advantages and disadvantages of using those programmes (See appendix 1).

Darkin Architects is an architectural practice created in 2008 by David Darkin. Darkin architects provide years of experience in the commercial, education, and domestic sector for the South of Wales, they have lots of experience in the design of new houses, house extensions, industrial buildings, offices and more and always providing a relaxing, and jet professional service to all customers, taking pride in the quality of their work. Because of their hard work, Darkin Architects was awarded Best LABC (Local authority Building control) partnership of the year. LABVC are an independent and impartial association in charge of reviewing the work of surveyors to guarantee high standards and thus maintain safety and protection when building buildings. (LABC, 2023)

David Darkin decided to give virtual reality a chance in their firm in 2014, starting with programmes such as Google SketchUp, which is a program for the design and construction of objects in 3 dimensions in real-time, this program allows us to convert a simple object, through simple transformation operations and 3D moulding, into a more complex object. (Hippolyte, 2011, p.2) and OBJ (Object) files, this is a standard easy-to-use 3D format compatible with various 3D design programs, this format allows easy file sharing between different programs. (Ekan, 2022) but the downfall of these programmes is that they don't show the materiality of the buildings that they are designing, for that reason instead of giving up on virtual reality, they decided to move to Revit (revise and edit), which is a program, generally widely used by architects and engineers, that allows users to create, edit, and review 3D models at an exceptional level of detail. These days, they use Revit for everything, from the smallest house extension to the creation of entire master plans. But the clients that this firm deals with are not that interested in the virtual reality experience.



Figure 79: Example of Darkin Architects' work. (Photo credit: Darkin Architects)

A few are the reasons why Darkin Architects decided for adopting the use of virtual reality and augmented reality in their firm, like it helps a lot to their clients to understand better how their project will look and work in real life, by navigating through the virtual version of the building, they can have a close idea on how the project will look and feel once is finished, so if they don't like something in the virtual model they can easily make the necessary changes until they are happy and can proceed to finalize the building processes.

"A lot of architects have a strong idea that we create just plans, and we don't, we, as architects design spaces and environments, and virtual reality is a huge help for that, but so far, we, as professionals, are not using it enough, on the larger buildings they should make a requirement on the planning application that you must have a full 3D design of the building" opinionated David (Darkin, 2022).

As mentioned before Darkin architects they are using the programme Revit in all stages of the design, they first create a 2D plan, and once it's all finished and agreed then they pass it to the design of the 3D views, once its finish they send the link to the client, allowing them to experience the building in the virtual model, with the use of their mobile phones, the client will be happy or will ask the architect in charge of the project for the necessary changes, as soon as the client is happy with all the changes made and how their project will finally look, then the architect will proceed to start to build the project.

As many advantages the use of virtual reality brought to the practice, there are some disadvantages like for example price for the software and training the staff in those programmes, it can be very expensive, and not all the practices can afford to invest in, especially the small ones. Another of the disadvantages is the reaction of the clients, the clients of this practice don't like to get involved in the full virtual reality experience, because they don't like the sensation of it, the majority said that they feel sick after using the full virtual reality experience, but they are more than happy using just the cardboard googles. Currently, the only use for the total immersive virtual reality experience in the practice is to give the clients a tour for large commercial buildings (Darkin, 2022).

Chapter 5: Case study 3

The Lampeter University campus VR project Information about the practice

In recent years the Lampeter campus has been suffering from a decline in student numbers. The aim of the Lampeter project is to relaunch the campus with a change of focus in the types of courses taught there and to engage with the local community. And to achieve this goal, it was decided that a virtual environment could be created to showcase the campus and its facilities to interested parties and at various events such as the Eisteddfod and the Royal Welsh Show.

This case study is based on the process of using VR technology to create a 3D model of the University of Wales Trinity Saint David (UWTSD) Lampeter campus. As part of the project, the INSPIRE team (The Institute for Sustainable Practice, Innovation, Research and Enterprise) from UWTSD asked architect and senior lecturer Ian Standen to create a video model and design a Minecraft game of Lampeter campus.

The main objective for the creation of this project, is to advertise the campus in a unique and innovative way, allowing potential students to experience and feel what it would be like to study at the campus, before visiting the campus itself. A secondary objective is the creation of a Minecraft video game, which would assist the university to engage with the local communities. The idea is that since video games are popular amongst children and young people, by creating a video game of the campus itself, it could potentially attract and draw interest of young students, who may consider applying to the university when they leave college. The video game will be sent to local schools.

The project is currently at the proof of concept/ development stage. The details of this case study were gathered from a meeting held with the INSPIRE team, Ian Standen and Brandon Roberts a graduate and Minecraft expert, the designer of the video game. For this project to be possible, both Ian and Brandon had to meet the requirements set by the INSPIRE team. For example, the virtual model should be limited to a two-minute video walk-around of the Lampeter campus and must include the UWTSD logo. Moreover, the Minecraft game must be aimed at children between 11 and 18 years old and it must have educational elements since this is to advertise a university. The theme of the game was also to be of a mystical nature. A detailed 3D world model has been created in Minecraft of the main historic campus building built in the 18th century. The model captures the architectural details, character, massing, and form of the building including many of the interior spaces such as the chapel and library. The

3D model in Minecraft has been generated from record drawings and photographs of the main building.



Figure 80: Aerial view of the Minecraft model of the inner courtyard of the Lampeter campus.
(Photo credit: B. Roberts)



Figure 81: Aerial view of the Minecraft model of the chapel of the Lampeter campus.
(Photo credit: B. Roberts)



Figure 82: Aerial view of the Minecraft model of the library of the Lampeter campus.
(Photo credit: B. Roberts)

In the meeting, Brandon described Minecraft as “a kind of virtual sandbox where the player can create and build, using cubes, essentially whatever is in the players’ imagination.” Even though in this game, the only limitation is in the player's imagination, what must be taken into account is the size of the blocks.



Figure 83: Example of an NPC (Non-playable character) interacting with the player.
(Photo credit: B. Roberts)

Given that the video game will be aimed at an audience between 11 and 18 years old, and is intended to be both fun and educational, Brandon developed the idea of allowing the players to go around the Lampeter campus. Currently, the game is focused on the main building of the campus, the player is required to complete different tasks and answer the questions that the NPCs of the game will present. It is themed around architecture and mystical nature.

However, once the game is up and running, the player can choose any educational subject area, such as nursing, or engineering, since the game matrix remains the same.

The questions will have different levels of difficulty, depending on the age of the player. If the answer is correct, the player will receive a golden spoon as a reward, once the player has obtained a minimum of five golden spoons, they can start to search for Lampy the dragon, who lives inside the cave of a mound located at the back of the campus. As the game proceeds, the player gives the dragon the golden spoons in exchange for a box with materials and a golden key, the more spoons the dragon is given, the more materials the player has in their box. With the materials in the box, the player can then build a tower in the front area of the campus. Once the tower is finished, the player climbs to the top where, with the help of the golden key, they turn on a beam of light that connects the Lampeter campus with the rest of the campuses that belong to UWTSD. At present, turning on the light in the tower means the end of the game, but in the future, it is expected to extend the game to the other UWTSD campuses. In this way, the player could move to any campus of the university and continue playing and learning.

Until now, the Minecraft game has been designed as a non-immersive virtual reality experience, but, months after starting to create the video game, Brandon has begun developing a version of the game for a fully immersive virtual experience.

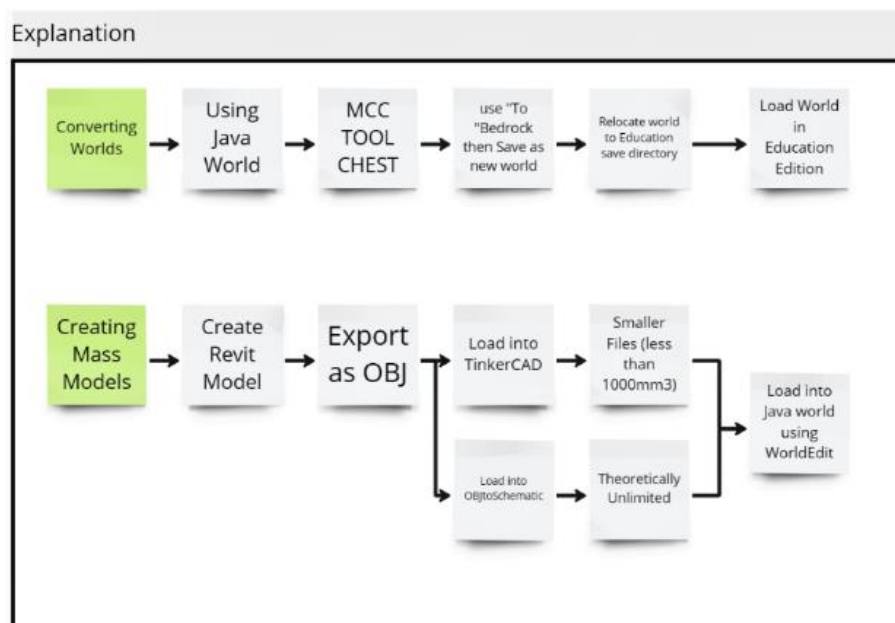


Figure 84: Diagram of how the Lampeter Minecraft is created.
(Photo credit: B. Roberts)

Before starting the process of creating the video game, Brandon made some extra investigation regarding some of the issues that the creation of the video game could have. Some of these issues were about how dialogues and quests can be added to Minecraft Education Edition, another possible problem that Brandon contemplated was to see if it was possible to use the Revit model as a template for the construction of the Lampeter campus in Minecraft, it turned out that this system is useful for the topography of the desired area, but when using it for buildings it is not helped a lot.

When building the building in the game, determining the appropriate scale was an issue, since these blocks have a specific size of 1m3 that cannot be altered, Brandon concluded that the 5:1 scale is the most appropriate. for a detailed presentation of the campus.

In terms of the technical aspects of the video game, with a series of photos as a reference alongside Coflein images, a digital model of the Lampeter campus is created on the popular construction digital modelling platform, Revit, this helps with the measurements, scales, and proportions of the elements of the building. Once the model has been created, the model is saved as an OBJ file. Once saved as an OBJ file, the document opens in an online program from the Autodesk family called Tinkercad, which converts the OBJ file into a file that Minecraft can use. A Schematic file, in Minecraft Java Edition, a tool called World Edit can be used, it can import the Schematic files to the Minecraft world, resulting in an accurate representation of the model created.

The disadvantage of this document transfer process is that when it reaches Minecraft, the model loses all the textures of the materials; all the details and textures of the materials created in Revit, appear as grey blocks when it reaches Minecraft. Therefore, a second recreation is necessary for OBJ, although the building's scales, measurements and details can be transferred and used from the primary creation.



Figure 85: A comparison of the same detail in different programmes.
(Photo credit: B. Roberts)

After the basic form of the exterior was constructed, the next step is to form the topography and context around the site, using Digimaps for reference, as well as photos of the site. While the construction of the interior areas were built with the help of videos/images from the staff on site.

With the creation of this video game, once again the importance of the use of virtual reality in the field of architecture is shown, since the creation of this video game is not only to entertain the user, but also serves to teach, since the buildings built in this video game are an exact scale representation of real buildings, in this case the Lampeter campus. Allowing the player to navigate and investigate a real building without having to travel hundreds of kilometres. This case study shows that the use of architecture, virtual reality and video games do not have to be separated and that by combining these three elements you can create great things.



Figure 86: Photo of the main façade of Lampeter campus. (Photo credit: Google Earth)



Figure 87: Image of the main façade of Lampeter campus created in Minecraft by Brandon. (Photo credit: B. Roberts)

Conclusion

Research suggests there is great potential for virtual reality in the world of architecture, so much so that it can be compared to VR's potential in the world of video games. Since the "discovery" of VR in the field of architecture, it has had a constant evolution. Calibre Institute has been the pioneer in terms of the introduction and development of VR technology in the world of architecture.

Virtual reality was an invention created by Morton Heilig, inventor, and filmmaker who, with The Sonorama, wanted the viewer, when watching a movie, not only to see it but also to feel as if he were part of it. What Heilig could not predict is that this invention would go on to become such an important part of the future technology, forming part of the day of fields such as education, medicine, NASA, the army, video games, and architecture among others.

Considering that VR technology was invented by a filmmaker, with the intention of giving the viewer an improved and more "real" experience of the movies, the truth is that VR technology in this field has not had a great evolution as in the case of architecture or video games. It could be that the reason why the use of VR in the world of cinema is less developed with respect to VR in architecture or video games, is that VR is for a more "active" use, the user is part of what happens in the digital world, while in a movie, whether normal or in VR, the user is nothing more than a mere spectator.

Several reasons have made filmmakers not adopt the use of VR technology in their movies, one of these reasons is the very high price it costs to create a movie in VR, another reason is that in a movie there are several stories to tell, they are not a single story seen from a single point of view, this makes it very difficult for the viewer to be part of the story, and the biggest problem is the duration of the movies, for the user to watch a two-hour movie continuously turning to follow the plot of the film would not only be exhausting, but would also cause a feeling of vertigo and dizziness.



Figure 88: Promotional image of the film "Ready Player One", 2018. (Photo credit: S. Joseph).

While in the world of cinema, the use of VR can be said to be a failure, in the 1960s and 1970s, some of the first special teams to develop VR technology were the US Army and NASA, making them the second to build an HMD, since the first HMD in history, the Sword of Damocles, was built by Ivan Sutherland in 1965.

In the 1990s both the world of video games and architecture decided to give VR technology a chance (Bitecc, 2022).

VR video games and video consoles appeared, but with the little developed technology in this field at the time, the expectations of both video games and consoles were higher than the results of these, causing people to lose interest very quickly in this technology. Seeing the almost zero interest in VR, video game companies stopped investing and researching in this technology until decades later. Today the use of VR in the field of video games is booming, and it seems that this increase in interest is not going to disappear, what is more, every day the public shows more and more interest in this type of technology.

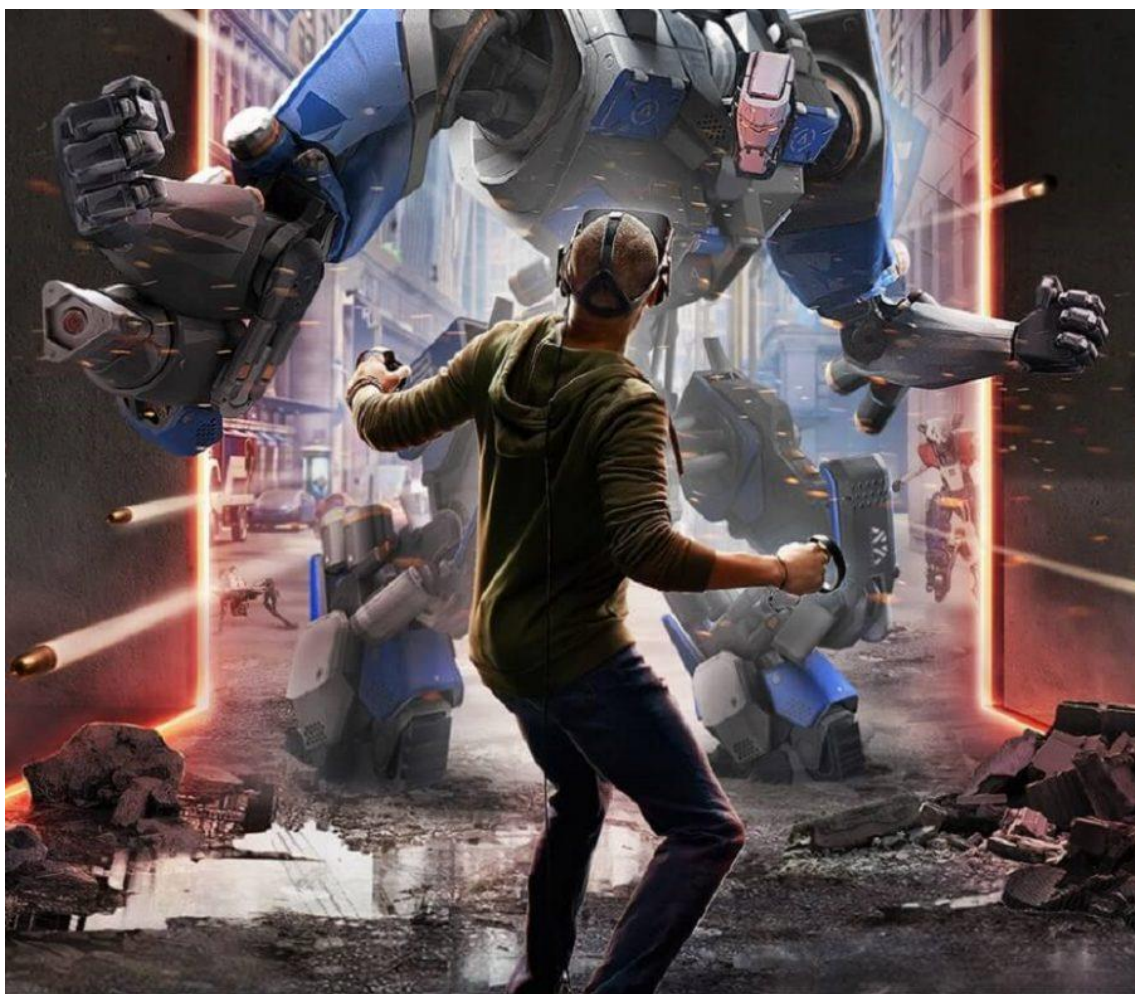


Figure 89: Player "immersed" in the video game, fighting against a robot.
(Photo credit: Kyselova, V).

On the development of VR over the years in the field of architecture, it has had a more constant evolution, compared to that of video games. From the first rendered images to the full VR experiences of the projects, all this development is thanks to the hard work of the Calibre Institute and students from the building information technology group.

In current times, practices such as Hellyar architects or Darkin architects use VR technology as one more tool in the design of all their projects, for them the use of VR is a very important part of their work, especially when it comes to communicating the project to clients, the use of VR makes this part of the process much easier and more enjoyable for both parties.



Figure 90: Architect "immersed" in the design of the project in which he is working.
(Photo credit: Virsabi).

The Lampeter University campus VR is a project created by the INSPIRE team, to attract more students to the Lampeter Campus using VR, but also this is a clear example of how VR can be used in architecture to advertise a university, by creating the campus in the virtual world. Showing that VR is not only used for the creation of new buildings but also for the recreation and study of existing buildings.

Since its beginnings, the use of VR technology in the field of architecture has become an important part of the firms that have chosen to use it, and even a fundamental part of them.

Although the technology in the use of VR in the field of architecture is advanced, many improvements are still needed, to fully "depend" on its use and can replace the use of more traditional architectural methods.

Changes such as the increase in the quality of the graphics, the speed of navigation through the programs, or the option of being able to allow the user to make the necessary modifications in real-time, would make VR the new future of architectural expression (Buildner, 2016).

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Interview with David Darkin RIBA, Business Owner & Architect, Darkin Architects on 20 December 2022

Appendix A: Interview questions

The following questions were asked, during a series of MS Teams conversations, to Dennis Hellyar RIBA, Principal Architect at Dennis Hellyar Architects; and David Darkin RIBA, Business Owner & Architect, Darkin Architects.

The questions were devised by the author of this dissertation.

1. What is your understanding of Virtual Reality?
2. Why did you start using Virtual Reality technology in your firm?
3. How long have you been using Virtual Reality technology?
4. What part of the Virtual Reality technology do you find most helpful and why?
5. What Virtual Reality program or programmes are you using now?
6. What Virtual Reality program or programmes do you want to use in the future and why?
7. How important is the use of Virtual Reality in your practice?
8. At what stage of your design do you use Virtual Reality technology?
9. In your experience, what are the benefits of using virtual reality for architectural purposes?
10. Do you use Virtual Reality with your clients, and how?
11. What kind of feedback do you normally receive from the clients that used Virtual Reality technology?
12. Would you recommend the use of Virtual reality to an architectural firm that is not using it now?

Responses were received during MS Teams conversations with Dennis Hellyar RIBA on 14 December 2022, and David Darkin RIBA on 20 December 2022.