DIPLOMA
THESIS

Uplatnění technologie virtuální reality v marketingu firem

Application of Virtual Reality Technology in the Marketing of Companies

STUDY PROGRAM

Innovation Project Management

THESIS ADVISOR

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ZADÁNÍ DIPLOMOVÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

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II. ÚDAJE K DIPLOMOVÉ PRÁCI

Název diplomové práce:

Uplatnění technologie virtuální reality v marketingu firem

Název diplomové práce anglicky:

Application of Virtual Reality Technology in the Marketing of Companies

Pokyny pro vypracování:

Cílem práce je vysvětlit technologii virtuální reality, její využití v marketingu a prezentovat užití virtuální reality na praktickém příkladu z praxe. Práce bude rozdělena do tří částí. Teoretická část vysvětlí pojmy umělá inteligence a virtuální realita, technologii virtuální reality, použití této technologie v různých oblastech reálné praxe, specificky pak v oblasti marketingu. Zaměří se na přínosy a rizika užití této technologie. Metodická část představí specifickou úlohu uplatnění nástrojů virtuální reality na konkrétním příkladu, popíše konkrétní postupy tvorby virtuálního modelu. Praktická část se bude sestávat z vytvoření virtuálního modelu konkrétního praktického zadání.

Seznam doporučené literatury:

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Martina Mátlová: Virtuaální realita, Yuli, 2022: ISBN: 978-80-242-8263-3Zeynep Tacgin: Virtual and Augmented Reality, Cambridge Scholars Publishing, Newcastle upon Tyne, 2020, ISBN: (13) 978-1-5275-4813-8
William R Sherman, Alan B. Craig: Understanding Virtual Reality: Interface, Application, and Design, University of California, Berkeley, Elsevier Science, 2003, ISBN: 1-55860-353-0

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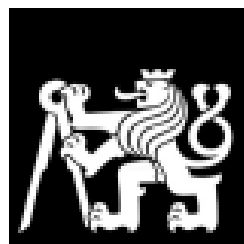|		
Ing. Oldřich Bronec, CSc.	Ing. Dagmar Skokanová, Ph.D.	prof. PhDr. Vladimíra Dvořáková, CSc.
podpis vedoucí(ho) práce	podpis vedoucí(ho) ústavu/katedry	podpis děkana(ky)

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Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v diplomové práci.

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Datum převzetí zadání	Podpis studenta

GAZETDINOV, Denis. *Application of Virtual Reality Technology in the Marketing of Companies*. Prague: CTU 2023, Master's thesis. Czech Technical University in Prague, Masaryk Institute of Higher Studies.

Statement

I declare that I have done my thesis independently. I further declare that I have used all sources correctly and completely and list them in the attached list of references used. I have no serious reason against making this thesis available in accordance with Act No. 121/2000 Coll., on Copyright, on Rights Related to Copyright and on Amendments to Certain Acts (Copyright Act), as amended.

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Abstract:

The aim of the thesis is to explain virtual reality technology, and its use in marketing and to present the use of virtual reality in a practical example from practice. The thesis will be divided into three parts. The theoretical part will explain the concepts of artificial intelligence and virtual reality, virtual reality technology, and the use of this technology in various areas of real practice, specifically in the marketing field. It will focus on the benefits and risks of using this technology. The methodological part will introduce the specific role of applying virtual reality tools on a specific example, describing specific procedures for creating a virtual model. The practical part will consist of creating a virtual model of a specific practical assignment.

Keywords:

Virtual reality, innovative marketing, unreal engine, project management.

Abstrakt:

Cílem práce je vysvětlit technologii virtuální reality, její využití v marketingu a prezentovat užití virtuální reality na praktickém příkladu z praxe. Práce bude rozdělena do tří částí. Teoretická část vysvětlí pojmy umělá inteligence a virtuální realita, technologii virtuální reality, použití této technologie v různých oblastech reálné praxe, specificky pak v oblasti marketingu. Zaměří se na přínosy a rizika užití této technologie. Metodická část představuje specifickou úlohu uplatnění nástrojů virtuální reality na konkrétním příkladu, popíše konkrétní postupy tvorby virtuálního modelu. Praktická část se bude sestávat z vytvoření virtuálního modelu konkrétního praktického zadání.

Klíčová slova:

Virtuální realita, inovativní marketing, unreal engine, řízení projektů.

Content

1. Introduction

Today, the number of touch points between consumers and brands in the purchase decision process is increasing due to the growing number of opportunities in the online environment, including online shopping sites, forums, brand communities on social media, online marketplaces, and mobile applications. Virtual reality (VR) is a new way of life in the professional world.

Virtual reality (VR) is rapidly gaining presence in diverse aspects of human existence, including professional life, interaction with friends and acquaintances, and daily activities such as online shopping, where demand is rapidly increasing. As a result, companies must recognize that today's consumers are inundated with a large amount of advertising content and seek new ways to attract attention and promote their products. In this context, virtual reality is emerging as a key component of innovative marketing techniques that companies are adopting to achieve their objectives.

Virtual reality is a contemporary challenge to existing conventions and has been little studied in academia. Interest in the field has been steadily growing over the past few decades, and the COVID-19 craze that began in 2020 has triggered a surge of interest in virtual reality and its incorporation into personal lives and its use in business and marketing.

Currently, virtual and augmented reality technologies have not yet reached a mature and productive stage. As a result, advertising and marketing communications professionals do not always know which areas and problems these tools can most effectively address. In many cases, the problem is that virtual and augmented reality technologies are only used to create a superficial WOW effect, despite their greater and more diverse potential in communicating with the target audience.

On the one hand, many advertising professionals are eager to keep up with the times, to study and incorporate the fruits of new developments into their toolkit, because effective communication requires speaking the same language as the audience, to surprise and anticipate their expectations. On the other hand, new technologies tend to become obsolete, public reaction can be slow, and the concept or idea development stage can be long. As a result, many promising tools are perceived with skepticism and disappear from the sight of experts, while the public has long been ready to accept them. This combination of factors has created a situation where companies are in no hurry to implement new formats in their communications, and advertising experts do not insist on or offer them.

The relevance of this study is due to the ambiguous attitude of the professional community to the possibilities of applying virtual reality technologies in their work, particularly in marketing and advertising.

The object of the study is virtual reality technology.

The subject of the study - the possibility of using virtual reality technology as one of the technological tools to solve the communication tasks of advertising.

Purpose of the study – development of VR applications to demonstrate products of the automotive sector.

The aim of the study is to accomplish the following objectives:

1. Review the relevant literature on the research topic;
2. Evaluate and choose appropriate development tools;
3. Analyze the hardware's technical specifications;
4. Investigate software environments suitable for application development;
5. Identify application themes and select appropriate graphic resources for implementation;
6. Create scene using graphical objects and enable interactive engagement.

THEORETICAL PART

2. General overview of the subject area

The rapid advancement of technology has transformed various industries and practices, with marketing being no exception. The use of virtual reality technology has recently emerged as a novel and innovative approach to enhance marketing efforts, offering unique opportunities to engage with consumers in immersive, interactive, and personalized ways. This research paper aims to explore the applications and implications of VR technology in the field of marketing, addressing its benefits and risks, while providing a comprehensive understanding of the underlying concepts and technologies.

The theoretical part of this research paper will begin by elucidating the concepts of artificial intelligence (AI) and virtual reality, as well as the technology that enables the creation of immersive virtual environments. This foundation will then enable the exploration of how VR technology is currently being employed in various real-world applications, with a particular emphasis on marketing.

2.1. VR, AR, MX, AI and XR concept

The digital revolution has given rise to several technological advancements, namely Virtual Reality, Augmented Reality (AR), Mixed Reality (MX), Artificial Intelligence, and Extended Reality (XR). These innovations are revolutionizing the way we interact with the digital world and have significant implications for various industries, including entertainment, education, healthcare, and manufacturing.

Virtual Reality

Virtual Reality refers to immersive, computer-generated environments that simulate the physical world, allowing users to interact with digital objects and environments using specialized hardware such as headsets and gloves (Milgram & Kishino, 1994). VR has been widely used for training, gaming, and therapy purposes, providing realistic simulations of real-world scenarios (Cipresso et al., 2018).

Augmented Reality

Augmented Reality is the integration of digital information into the user's perception of the physical world, overlaying computer-generated graphics onto the user's environment in real-time (Azuma, 1997). AR applications include navigation systems, medical visualization, and interactive marketing, allowing for enhanced user experiences and improved task performance (Billinghurst & Duenser, 2012).

Mixed Reality (MX)

Mixed Reality (MX) is a fusion of VR and AR, combining elements of both technologies to produce new environments where physical and digital objects coexist and interact in real-time (Milgram & Kishino, 1994). MX has applications in design, training, and collaborative work, enabling users to manipulate both physical and digital objects within the same space (Lindeman et al., 2019).

Artificial Intelligence

Artificial Intelligence refers to the development of computer systems capable of performing tasks that typically require human intelligence, such as learning, problem-solving, and understanding natural language (Russell & Norvig, 2016). AI has been integrated into various applications, including speech recognition, computer vision, and robotics, and has the potential to transform industries and redefine human-computer interaction (Goodfellow et al., 2016).

Extended Reality

Extended Reality is an umbrella term encompassing VR, AR, and MX, emphasizing the continuous spectrum of reality-virtuality (Steuer, 1992). XR technologies are poised to revolutionize human-computer interaction, providing immersive and interactive experiences that blend the physical and digital worlds seamlessly (Bowman et al., 2018).

The rapid advancements in VR, AR, MX, AI, and XR technologies are reshaping the way we interact with the digital world, offering innovative solutions and applications across numerous industries. As these technologies continue to evolve, their convergence and synergy will create unprecedented opportunities for enhancing human experiences and transforming human-computer interaction.

2.2. History of VR

The notion of virtual reality gained recognition and popularity relatively recently, during the era of personal computers and the Internet. However, the ideas that catalyzed the rapid advancement of this field were conceived much earlier. The following discussion presents an overview of the historical evolution of this phenomenon.

Virtual reality has a longer history than many people realize, and it is now entering its second generation, which is anticipated to be more appealing to both consumers and businesses than the previous one. Over the past five years, VR technology has advanced considerably, with advancements made in both hardware and software. Despite this

progress, there have been challenges to the widespread adoption of VR, such as latency, nausea, high costs, and underdeveloped ecosystems. To overcome these obstacles, VR companies are increasingly using AI and cloud technologies to create stronger ecosystems. Additionally, the introduction of 5G technology is expected to help resolve latency and nausea issues.

The origins of virtual reality can be traced back to the 19th century. One of the earliest pioneers was Sir Charles Wheatstone, a scientist and inventor who proposed in 1838 that our ability to perceive depth was due to having two eyes, which see from slightly different perspectives. He created a device called the stereoscope, which utilized two images from different viewpoints to create a three-dimensional effect. This device, which was the first mechanical way to view a 3D image, was cumbersome and used mirrors to combine the two views. With the advent of photography in the following decade, stereograms could be created by capturing multiple images from real life, providing an immersive experience for stereoscopic viewing.

In 1929, Ed Link invented a flight simulator called the "Link Trainer." This device was designed to help pilots train and improve their skills without the risks and costs associated with actual flight. The Link Trainer simulated flight conditions using hydraulics and pneumatics to create realistic movements and sensations. It allowed pilots to practice instrument flying, which was becoming increasingly important as aviation technology advanced. The Link Trainer was used extensively during World War II to train military pilots, and it remains an important tool in aviation training to this day.

The View-Master was created by William Gruber in 1939. It is a device used for viewing stereoscopic images, which are photographs that appear three-dimensional when viewed through the device. The View-Master consists of a plastic viewer with two eyepieces, into which circular disks containing pairs of stereoscopic images are inserted. When the user looks through the viewer, the images appear as a single, 3D image.

Initially, the View-Master was marketed as an educational tool, with reels featuring images of famous landmarks, animals, and other educational content. However, it quickly became popular as a toy, with reels featuring popular characters and storylines from movies and television shows. The View-Master has remained popular over the years, with newer versions incorporating digital technology to display 3D images and videos.

Morton Heilig invented the Sensorama in 1952, which is considered to be one of the first virtual reality-like machines. The Sensorama was a large, cabinet-like device that used various technologies to create a multisensory experience for the user. It featured a stereoscopic 3D display, speakers for stereo sound, fans for wind effects, and even scent

generators to add smells to the experience. The Sensorama also included a vibrating seat to add tactile feedback, and hand-held controllers that allowed the user to interact with the virtual environment.

The Sensorama was designed to provide an immersive experience that went beyond just visual and auditory stimulation. Heilig believed that such a device could be used for a variety of purposes, such as entertainment, education, and even therapy. However, the Sensorama was never commercially successful and only a few prototypes were built. Despite this, it is recognized as an important milestone in the development of virtual reality technology.

Figure 1. The Sensorama Simulator prototype. Courtesy of M.Helig.
SOURCE: https://teslasuit.io/blog/history-of-virtual-reality-ultimate-guide/

While Morton Heilig is often credited with inventing the first head-mounted display (HMD), the exact date and details of this invention are not clear. It is believed that Heilig began working on a prototype for an HMD as early as the 1950s, but the first documented evidence of his work on the device dates to the 1960s.

Heilig's HMD, which he called the "Telesphere Mask," was a device worn on the head that included a display screen for each eye, as well as built-in headphones. The Telesphere Mask was designed to provide an immersive experience, allowing the user to feel as if they were fully surrounded by the virtual environment. It was also equipped with a tracking system that allowed the user's head movements to control the view within the virtual environment.
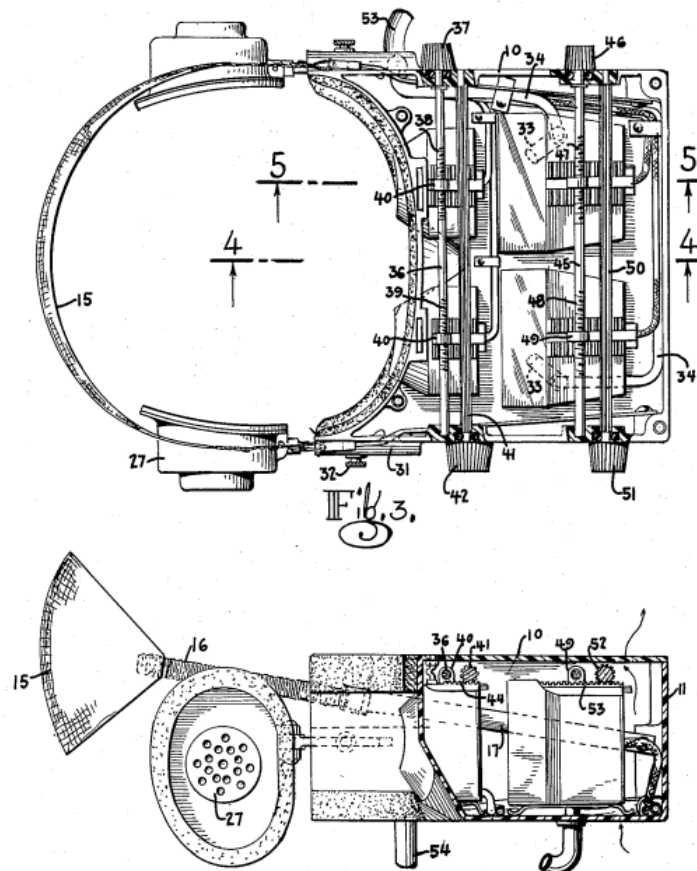
Figure 2. Helig's early head-mounted display patient.
SOURCE: https://www.packtpub.com/product/virtual-reality-blueprints/9781786462985

The Telesphere Mask was never produced on a large scale, and its use was limited to a few research and development projects. However, it is considered an important milestone in the development of virtual reality technology and paved the way for the Head-Mounted Displays (HMDs) that would become a key component of modern VR systems.

In 1961, two engineers named Comeau and Bryan developed the Headsight, which was an early version of a head-mounted display (HMD). The Headsight was a wearable device that included a display screen and optics that allowed the user to see a video image in

front of their eyes. Unlike the earlier HMD developed by Morton Heilig, the Headsight did not provide a fully immersive experience, as the user could still see their surroundings while wearing the device.

The Headsight was originally designed for military use, specifically for pilots who needed a way to see information from their instruments while looking out the cockpit window. The device was later adapted for use in other industries, such as manufacturing and engineering, where workers needed to see information or instructions while working with their hands.

While the Headsight was not as advanced as modern VR headsets, it was an important early step in the development of HMD technology. It demonstrated the potential of wearable displays to provide users with visual information in a hands-free and convenient manner.

In 1968, Ivan Sutherland, a computer scientist and pioneer in the field of computer graphics, invented a head-mounted display system that he called "The Sword of Damocles." This system is considered to be one of the earliest examples of a virtual reality system.
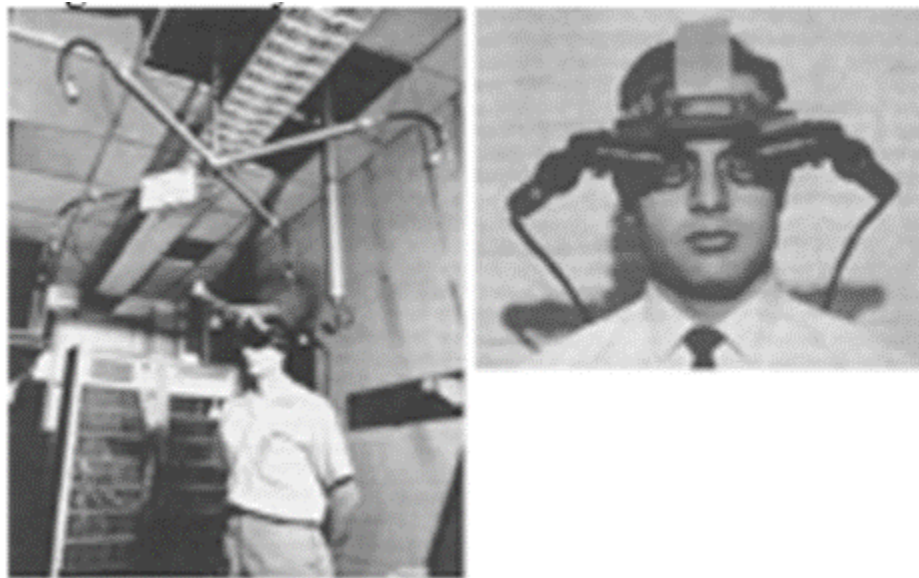
Figure 3. Ivan Sutherland and the Sword of Damocles
SOURCE: https://www.protoexpress.com/blog/augmented-reality-going-mainstream/

The Sword of Damocles was a large and heavy device that was suspended from the ceiling and held in place by a mechanical arm. The user would wear a head-mounted display that included a small display screen and optics that allowed them to see computer-generated

images in 3D. The system also included a tracking system that could sense the user's head movements and adjust the display accordingly.

While The Sword of Damocles was not a fully immersive VR system, it was a significant step forward in the development of this technology. It demonstrated the potential of head-mounted displays to create virtual environments that could be interacted with in real-time. The system was also a major influence on the development of subsequent VR technologies and paved the way for the modern VR headsets that we use today.

In 1974, Myron Krueger, an American computer artist and scientist, built an artificial reality lab called "Videoplace." Videoplace was a groundbreaking interactive environment that allowed users to create and manipulate virtual objects and interact with each other in real-time.

Videoplace used computer vision technology to track the movement of users within the lab and to detect the presence of physical objects. This allowed users to use their bodies and gestures to manipulate the virtual objects and to interact with other users within the virtual environment.

Krueger's goal with Videoplace was to create a new form of communication that combined the physical and virtual worlds. He envisioned a future where people could use these types of interactive environments to collaborate and communicate in ways that were not possible with traditional forms of communication.

Videoplace was a groundbreaking project that paved the way for the development of modern virtual reality and augmented reality technologies. Krueger's work demonstrated the potential of using technology to create immersive and interactive environments that could be used for a wide range of applications, from entertainment to education to scientific research.

The term "virtual reality" was first coined in 1987 by Jaron Lanier, an American computer scientist and pioneer in the field of virtual reality. Lanier founded a company called VPL Research, which developed some of the earliest commercial VR systems.

Lanier used the term "virtual reality" to describe the immersive digital environments that his company was creating. He believed that VR had the potential to revolutionize the way that people interacted with computers and with each other, and that it would become an important tool for a wide range of applications.

The term "virtual reality" quickly caught on and became widely used to describe a range of technologies and applications that involved immersive digital environments. Today,

virtual reality is used in fields such as entertainment, education, healthcare, and scientific research, and has become an important part of our digital landscape.

Tom Caudell is credited with coining the term "augmented reality" in 1992. Caudell was a researcher at Boeing who was exploring ways to use technology to improve the efficiency of aircraft assembly. He and his colleague David Mizell developed a system that used head-mounted displays to overlay virtual graphics onto the physical environment, allowing workers to see 3D models of parts and instructions overlaid on top of the real-world objects they were working on.

Caudell and Mizell called this system "augmented reality" because it added virtual information to the real world, enhancing the user's perception and understanding of their environment. The term has since been adopted to describe a wide range of technologies that blend virtual and real-world elements, including mobile apps, gaming, and industrial applications.

In 1995, Nintendo released the Virtual Boy, which was a 3D gaming console that used a stereoscopic display to create a sense of depth. The Virtual Boy was unique in that it was a head-mounted device that users could strap onto their head and view the game content in stereoscopic 3D.

However, the Virtual Boy was not successful due to several factors. It had a limited game library, its monochrome display was often criticized for causing discomfort and eye strain, and it was also considered too expensive for many consumers. The Virtual Boy was discontinued only a year after its release, making it one of Nintendo's least successful products.

NASA has used augmented reality technology for various purposes, including navigation and training. The X-38 was a prototype spacecraft that NASA developed in the late 1990s and early 2000s as part of its effort to design a reusable crew return vehicle for the International Space Station.

One of the challenges of designing the X-38 was ensuring that it could be maneuvered safely during atmospheric re-entry and landing. To address this challenge, NASA developed an AR-based system that allowed the pilot to visualize the spacecraft's position and orientation in real-time, overlaid on a video feed from the spacecraft's exterior cameras. The system also provided the pilot with visual cues and alerts to help them steer the spacecraft to a safe landing.

NASA has continued to use AR and other immersive technologies for various applications, including astronaut training, remote maintenance and repair, and scientific visualization.

AR and VR technologies are well-suited for space exploration and other high-risk environments, where remote guidance and enhanced situational awareness can be critical for mission success.

Steve Mann, a researcher and inventor in the field of wearable computing, developed a device called EyeTap in the late 1990s and early 2000s. EyeTap is a wearable computing device that combines a camera, a display, and a computer to create a system that can augment the user's perception of the world around them.

EyeTap uses a small camera to capture the user's visual field and then overlays computer-generated graphics onto that view, which are displayed on a screen positioned in front of the user's eye. This creates a "mediated reality" experience, where the user sees a composite view of the real world and virtual elements.

The first EyeTap prototype was developed in 1980, and subsequent versions were released in the 1990s and early 2000s. EyeTap was a significant early example of wearable computing and AR technology, and it has influenced the development of other AR and smart glasses products that have since come to market.

The first prototype of the Oculus Rift headset was designed in 2012 by Palmer Luckey, who was a young VR enthusiast and hardware tinkerer at the time. Luckey created the prototype in his garage, using off-the-shelf components and custom software to create a low-cost VR headset that offered a wide field of view and low latency.

Luckey's prototype generated significant interest among the VR community, and he teamed up with Brendan Iribe and others to found Oculus VR, a company dedicated to developing high-quality VR hardware and software. Oculus VR launched a Kickstarter campaign in 2012 to fund the development of the Rift headset, and the campaign raised over $2 million, demonstrating strong demand for VR technology.

Over the next several years, Oculus VR refined the design of the Rift headset, improving the resolution, ergonomics, and performance. In 2016, Oculus VR was acquired by Facebook, which has continued to invest in VR and AR technology and has released several versions of the Rift headset, as well as other VR and AR products.

Tundra Labs and HTC both developed full-body tracking technologies in 2021.

Tundra Labs is a startup that specializes in developing sensor systems for VR and AR applications. In early 2021, Tundra Labs released its "TL448K6D-VR" sensor, which is a high-precision, low-latency sensor designed for full-body tracking in VR. The sensor uses

a combination of infrared and visible light to track the movement of a user's body, allowing for a more immersive and realistic VR experience.

HTC, a leading manufacturer of VR headsets, also developed a full-body tracking system in 2021. The system, called "Vive Facial Tracker," is an add-on for the company's existing VR headsets that allows for accurate tracking of facial expressions and movements, as well as body movements. The Vive Facial Tracker uses a series of sensors and cameras to capture data about the user's movements, and this data is then used to animate a virtual avatar in real time.

Both of these technologies are significant advancements in the field of VR, as they allow for more realistic and immersive experiences. Full-body tracking, in particular, has been a highly sought-after feature in VR for many years, and the development of these new technologies brings us one step closer to truly lifelike virtual environments.

2.3. Hardware and software

Like most digital technologies, VR consists of three core components: hardware, software, and content. Choosing the right VR software depends on the project's requirements, hardware compatibility, the user's preferences, and the development team's expertise.

2.3.1. Hardware

Hardware - a computing device or processor, such as a computer, console, or smartphone, is required to process inputs and outputs in XR applications. The device is responsible for analyzing inputs gathered by sensors, carrying out specific tasks of the given software, and displaying the appropriate content. The amount of computing power required can vary greatly depending on the device used, ranging from smartphones and tablets to powerful desktop computers and distributed systems that can support high-quality graphics.

Head-Mounted Displays

Figure 4. Best VR headsets in 2023
SOURCE: https://www.popsci.com/story/reviews/best-vr-headsets/

HMDs are the primary devices used to experience VR, providing visual and auditory inputs to the user (LaValle, 2017). Major HMDs available in the market include:

a. Oculus Rift S

Oculus Rift S: The Oculus Rift S, developed by Oculus VR, is a PC-powered virtual reality headset that features a high-resolution display, improved optics, and a comfortable ergonomic design. The Rift S uses a built-in inside-out tracking system, called Oculus Insight, which eliminates the need for external sensors and provides precise positional tracking. Its integrated audio system delivers immersive sound without the need for headphones, and the device is compatible with the Oculus Touch motion controllers, enabling intuitive interactions within virtual environments (Oculus, 2021).

b. HTC Vive

HTC Vive: The HTC Vive is a virtual reality headset co-developed by HTC and Valve Corporation. It offers a high-quality visual experience, employing a 110-degree field of view and a 90Hz refresh rate. The Vive utilizes an external tracking system, known as the Lighthouse, which uses lasers to track the user's head and hand movements. The device is compatible with the HTC Vive Controllers, which

provide accurate motion tracking and a natural interaction experience. Additionally, the HTC Vive supports room-scale VR, allowing users to move around and interact within a predefined physical space (HTC, 2021).

c. PlayStation VR

PlayStation VR: The PlayStation VR, developed by Sony Interactive Entertainment, is a virtual reality headset designed specifically for the PlayStation gaming console. It features a 5.7-inch OLED display, providing a 100-degree field of view and a 120Hz refresh rate. The device employs the PlayStation Camera for tracking the user's head movements and the PlayStation Move motion controllers for hand interactions. Offering a plug-and-play experience, the PlayStation VR simplifies the setup process and provides seamless integration with the PlayStation ecosystem, enabling users to access a wide range of VR games and experiences (Sony, 2021).

d. Samsung Odyssey

Samsung Odyssey: The Samsung Odyssey is a Windows Mixed Reality headset developed by Samsung Electronics in collaboration with Microsoft. It features a high-resolution AMOLED display, delivering crisp visuals and vibrant colors, as well as integrated AKG headphones for immersive audio. The headset utilizes an inside-out tracking system, which simplifies the setup process and eliminates the need for external sensors. The Samsung Odyssey is compatible with the Windows Mixed Reality motion controllers, allowing users to interact with virtual objects and environments in a natural and intuitive manner (Samsung, 2021).

e. Valve Index

Valve Index: The Valve Index is a premium virtual reality headset developed by Valve Corporation. It boasts a high-resolution LCD display with a wide field of view and a refresh rate of up to 144Hz, providing a sharp and smooth visual experience. The device employs the Lighthouse tracking system for precise head and hand tracking and is compatible with the Valve Index Controllers, which feature individual finger tracking and pressure-sensitive inputs for enhanced interactivity. The headset also includes an advanced audio solution, using off-ear speakers to create an immersive and comfortable audio experience (Valve, 2021).

Motion Controllers

Motion controllers facilitate user interaction with virtual environments by capturing hand and body movements (Korn & Bideau, 2018). Examples of motion controllers include:

a. Oculus Touch

Oculus Touch: The Oculus Touch is a motion controller specifically designed for use with the Oculus Rift and Oculus Quest series of VR headsets (Abtahi et al., 2019). These controllers incorporate advanced haptic feedback, capacitive sensors, and six degrees of freedom (6DoF) tracking, providing an intuitive and immersive user experience (Gupta et al., 2020). The ergonomic design ensures comfortable and natural hand positioning, enabling precise and accurate control over in-game interactions (Guna et al., 2018). Additionally, the Oculus Touch controllers support hand presence, allowing users to perform gestures such as pointing, grasping, and throwing within the virtual environment (Mardanbegi et al., 2018).

b. HTC Vive Controllers

HTC Vive Controllers: The HTC Vive Controllers are designed for the HTC Vive VR headset, featuring a unique form factor that includes a trackpad, trigger button, and grip buttons (Gupta et al., 2020). The controllers incorporate SteamVR Tracking technology for accurate positioning and movement tracking within the virtual space (Nguyen et al., 2019). The ergonomic design and haptic feedback enable users to interact naturally and effectively with the virtual environment, ensuring a high level of immersion and presence (Guna et al., 2018).

c. PlayStation Move

PlayStation Move: The PlayStation Move is a motion-sensing controller developed by Sony Interactive Entertainment for the PlayStation VR system (Gupta et al., 2020). Utilizing a combination of inertial sensors, a gyroscope, and a magnetometer, the PlayStation Move controllers track user movements in real-time, translating them into corresponding in-game actions (Bertelson et al., 2018). The controllers also feature a unique orb-shaped light, which is tracked by the PlayStation Camera to provide accurate positioning within the virtual environment (Bideau et al., 2017). The PlayStation Move controllers offer intuitive and responsive gameplay experiences, contributing to the overall immersion of VR applications on the PlayStation platform.

d. Valve Index Controllers

Valve Index Controllers: Valve Index Controllers, also known as "Knuckles" controllers, are designed for the Valve Index VR system (Gupta et al., 2020). These controllers boast a unique feature called "finger tracking," which utilizes

capacitive sensors to detect individual finger movements, enabling natural and nuanced interactions within the virtual environment (Azmandian et al., 2019). With adjustable straps that secure the controllers to the user's hands, the Valve Index Controllers facilitate seamless object manipulation and immersive gameplay experiences (Mardanbegi et al., 2018).

Tracking Systems

Tracking systems monitor user movements, translating them into the virtual environment. Two prominent tracking methods are camera-based and sensor-based systems (Nilsson et al., 2016). Examples include:

a. Oculus Insight

Oculus Insight is a camera-based tracking system developed by Facebook Technologies for their Oculus Rift S and Oculus Quest headsets (Kreylos, 2019). The system utilizes four to five wide-angle cameras integrated into the headset to track the position and orientation of the headset and controllers in real-time. Employing computer vision algorithms and a technique known as simultaneous localization and mapping (SLAM), the cameras recognize and analyze the environment, providing precise tracking without the need for external sensors (Huang et al., 2017).

b. HTC Vive Lighthouse

The HTC Vive Lighthouse, also known as SteamVR Tracking, is a camera-based tracking system developed by Valve Corporation for the HTC Vive and Valve Index headsets. The system comprises two base stations that emit structured infrared light patterns, which are detected by photosensors on the headset and controllers. By triangulating the timing of the emitted and received light signals, the Lighthouse system calculates the position and orientation of the devices with high precision and low latency (Borrego et al., 2016).

c. PlayStation Camera

The PlayStation Camera is a camera-based tracking system developed by Sony Interactive Entertainment for the PlayStation VR headset (Yoshida, 2016). The system utilizes a dual-camera setup with wide-angle lenses to capture the headset and controllers' movements. The cameras track the position and orientation of the devices by detecting the emitted light from the headset's LEDs and the PlayStation Move controllers. The PlayStation Camera system ensures accurate

tracking, enabling users to interact with the virtual environment efficiently (Guo et al., 2017).

2.3.2. Software

Development platforms - VR development platforms are framework platforms used for creating specific VR applications and experiences. The suitability of these platforms depends on the technology and hardware involved. Advancements in these platforms have improved user comfort and accessibility in VR experiences. These platforms provide developers with tools, libraries, and APIs to create immersive virtual environments and integrate various features such as 3D models, animations, and audio. Some popular VR development platforms include Unity, Unreal Engine, and CryEngine. These platforms support various VR hardware devices and enable developers to create cross-platform VR applications. Additionally, VR development platforms offer features such as real-time rendering, physics simulation, and VR-specific scripting languages to create high-quality VR applications.

Game Engines

Game engines enable developers to create and optimize VR applications by offering pre-built tools and functionalities (Elbamby et al., 2018). Examples of popular game engines include:

a. Unity

Unity is a widely adopted, cross-platform game engine developed by Unity Technologies. This versatile engine is known for its user-friendly interface, flexibility, and extensive asset store, making it a popular choice among developers for creating VR applications (Bozorgui-Nesami et al., 2017). Unity's built-in support for multiple VR platforms, including Oculus Rift, HTC Vive, and PlayStation VR, streamlines the development process by providing a single environment for designing, building, and optimizing applications. The engine also features robust scripting capabilities through C#, allowing for the implementation of complex and interactive VR experiences. In addition to gaming, Unity has been utilized in various sectors such as architecture, automotive, and film industries, showcasing its adaptability and widespread appeal (Freina & Ott, 2015).

b. Unreal Engine

Unreal Engine, developed by Epic Games, is a powerful and comprehensive game engine that has been widely employed in the development of high-quality VR

applications (Latypov et al., 2018). It is particularly well-suited for creating visually stunning and realistic environments due to its advanced rendering capabilities and robust support for real-time ray tracing. Unreal Engine's visual scripting system, Blueprint, enables developers to create complex interactions without requiring extensive programming knowledge (Pirker et al., 2017). Additionally, the engine's compatibility with numerous VR platforms, such as Oculus Rift, HTC Vive, and PlayStation VR, facilitates the development and deployment of VR applications across multiple devices. Unreal Engine's high-performance capabilities make it a popular choice for developers in industries ranging from gaming to architecture and automotive design.

c. CryEngine

CryEngine is a game engine developed by Crytek, known for its ability to render visually stunning and highly realistic virtual environments (Kavanagh, 2016). CryEngine's advanced graphics capabilities, such as global illumination and real-time reflections, allow developers to create immersive VR applications with a strong emphasis on visual fidelity. The engine supports multiple VR platforms, including Oculus Rift and HTC Vive, allowing developers to create applications for various devices. CryEngine's robust set of development tools, including C++ and C# scripting options and an extensive suite of visual tools, enable developers to design, build, and optimize complex and interactive VR experiences. While primarily used in the gaming industry, CryEngine's impressive graphical capabilities have also attracted developers from sectors such as film, architecture, and simulation (Yilmaz & O'Connor, 2018).

Unity, Unreal Engine, and CryEngine are three prominent game engines used in the development of VR applications, each offering a unique set of features and capabilities. Unity is known for its user-friendly interface and flexibility, making it a popular choice for various industries. Unreal Engine, on the other hand, is renowned for its visually stunning environments and advanced rendering capabilities. CryEngine, with its focus on visual fidelity and realism, is also widely employed in the gaming industry and other sectors. Understanding the strengths and features of each game engine is crucial for developers looking to create immersive and interactive VR experiences tailored to their specific needs and target platforms.

VR Software Development Kits (SDKs)

SDKs provide developers with libraries, code samples, and documentation to facilitate the development of VR applications (Gutierrez et al., 2017). Examples of VR SDKs include:

a. Oculus SDK

The Oculus Software Development Kit (SDK) is a comprehensive suite of tools, libraries, and resources developed by Oculus, a subsidiary of Meta Platforms, Inc., formerly known as Facebook, Inc. (Oculus, 2021). It is designed to facilitate the development of immersive VR applications for Oculus headsets, such as the Oculus Rift and Oculus Quest series. The SDK provides developers with a robust set of APIs, including rendering, audio, input, and tracking functionalities, allowing for seamless integration with game engines like Unity and Unreal Engine. Oculus SDK also offers performance optimization tools, enabling developers to enhance the performance of their applications while ensuring a comfortable user experience (Lang, 2014).

b. SteamVR SDK

SteamVR Software Development Kit (SDK) is a comprehensive development platform created by Valve Corporation, targeting the creation of VR applications compatible with the SteamVR ecosystem, which encompasses various headsets, including the HTC Vive and Valve Index (Valve Corporation, 2021). The SDK provides a wide range of APIs and libraries, addressing rendering, input, audio, and tracking functionalities, ensuring compatibility with popular game engines like Unity and Unreal Engine. Additionally, the SteamVR SDK offers support for OpenVR, an open-source API that allows developers to create hardware-agnostic VR applications, thus promoting cross-platform compatibility and accessibility (Bailenson, 2018).

c. Google VR SDK

Google VR Software Development Kit (SDK) is a development platform provided by Google that enables developers to create immersive VR applications for a variety of platforms, such as Android, iOS, and the web (Google, 2023). The SDK supports multiple VR devices, including Google Cardboard and Google Daydream, and offers a comprehensive set of APIs and libraries for rendering, input, audio, and tracking functionalities. Google VR SDK integrates seamlessly with popular game engines like Unity and Unreal Engine, offering developers the flexibility to create cross-platform applications. Additionally, the SDK provides tools for

performance optimization and user interaction design, ensuring an engaging and comfortable experience for end-users (Milgram & Kishino, 1994).

Specific applications software

The software required to develop VR applications, such as VR, AR, or MR experiences, involves creating a virtual world or combining the real and virtual worlds through the use of framework platforms. This software includes all the necessary components to create a customized XR application for a particular use case.

Blender

Blender is a powerful open-source 3D computer graphics software suite that has gained popularity in various industries, including marketing. The software offers a broad range of functionalities, such as modeling, animation, simulation, rendering, and video editing, making it a versatile tool for marketing professionals. This article discusses the use of Blender in marketing and highlights some of its benefits and applications in the industry.

As the demand for immersive and interactive content grows, Blender has become a valuable tool for creating virtual and augmented reality experiences. Marketing professionals can use Blender to design 3D environments, simulations, and product demonstrations that can be explored through VR headsets or AR applications (Patel, 2021). This interactive content can engage users on a deeper level, increasing the likelihood of product adoption and brand loyalty.

Blender has emerged as a powerful and versatile tool for marketing professionals. With its robust features and open-source nature, it provides cost-effective solutions for creating engaging and visually appealing content, such as 3D models, animations, and interactive experiences. As the marketing landscape continues to evolve, Blender's role in the industry is expected to expand, offering new and innovative ways for businesses to connect with their target audience.

Autodesk Maya

Autodesk Maya is a 3D animation software that has become one of the most widely used tools in the world of digital design, animation, and visual effects. With its robust capabilities and flexible interface, it has found extensive application in various industries, including marketing. This article will discuss the role of Autodesk Maya in marketing, focusing on its advantages and unique features that contribute to its popularity in this field.

As virtual and augmented reality technologies continue to gain traction, Autodesk Maya has become an essential tool for creating interactive experiences in marketing (Loper, J. 2019). By designing and animating 3D models and environments in Maya, marketers can develop immersive, engaging virtual showrooms, product demos, or interactive advertisements that captivate audiences and generate buzz around their products or services.

2.3.3. Content

After developing an XR application, additional content can be added to the software to enhance the user's experience. The added content can include graphical components of a VR game, a 360° video used in a VR movie, customized avatars, 3D models, animations, images, and interactive elements. It often involves real-time rendering and integration with user input devices such as controllers and haptic feedback devices. This allows for a more immersive and interactive experience, as the user's actions can affect the graphics in real time. Real-time rendering is achieved through the use of advanced graphics processing units (GPUs) and sophisticated software algorithms that can quickly and efficiently render complex 3D environments, characters, and objects. The goal is to provide a seamless and realistic experience that immerses the user in the virtual world, with as little latency or delay as possible. Additionally, digital prototypes can be designed to demonstrate physical or non-physical objects in an AR application. The design of these digital prototypes can enable users to visualize and interact with these objects in a virtual environment, providing a valuable tool for product demonstrations and training simulations. The development of XR content involves the use of specialized software tools and development platforms, as well as a deep understanding of the unique capabilities and limitations of XR technology.

2.4. VR technology

Virtual reality experiences can be achieved through various methods, including the utilization of MotionParallax3D displays and headsets (Milgram & Kishino, 1994). MotionParallax3D displays create a realistic image on the screen by updating it in real-time based on the viewer's head movement in space (Held & Banks, 2008). This mechanism is grounded in the concept of motion parallax, which refers to the displacement of different parts of an image in relation to each other at an angular velocity proportional to the observer's distance from them, as the observer's position changes (Wexler et al., 2001). Consequently, virtual objects behave similarly to real-world objects, shifting in relation to each other and visible objects according to the same principles and laws.
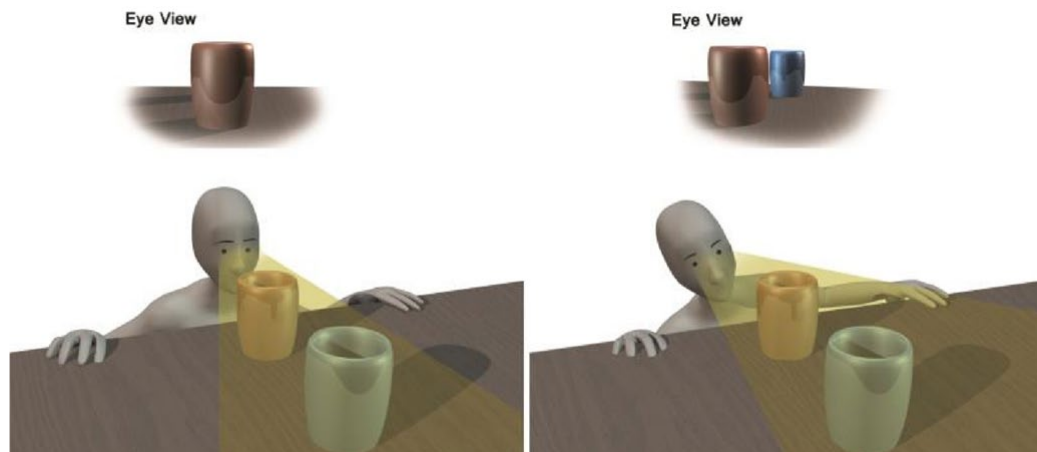
Figure 5. Parallax motion effect
SOURCE: http://lavalle.pl/vr/

Headsets, on the other hand, provide a more common variant of virtual reality experiences (Cummings & Bailenson, 2016). They consist of a device containing lenses, a screen behind the lenses, and a head position tracking system, such as a gyroscope and accelerometer (LaValle et al., 2014). The lenses and tracking system play essential roles in creating a realistic 3D experience and maintaining user comfort.

To increase the immersive effect and expand the possibilities in virtual reality, users need to interact with the virtual environment through walking, manipulating objects, and changing the visual display in response to head movements (Slater et al., 1995). Various techniques have been developed to achieve infinite movement within the virtual space, such as redirected walking (Razzaque et al., 2001), treadmills (Darken et al., 1997), and controller-based movement (Bowman et al., 1997). Additionally, manipulating objects in the virtual world can be done using hand movements with sensors or a joystick attached to them (Argelaguet & Andujar, 2013).

Figure 6. All-directional treadmill
SOURCE: https://www.seedinvest.com/virtuix/series.a.2

Perceptual distortions and simulation sickness are challenges that arise in virtual reality environments (Moss & Muth, 2011). To address these issues, headsets can be designed with adjustable lenses and interpupillary distances (Patney et al., 2016), as well as providing mechanisms to protect against accidental input errors (LaValle et al., 2014). Ensuring a high frame rate of at least 90 frames per second is also crucial for preventing motion sickness (DiZio & Lackner, 2000).

To achieve a sense of presence in another world, immersion is provided through not only high-quality images but also sound and haptic feedback (Slater & Wilbur, 1997). Multi-channel audio systems enable users to orient themselves using sound (Begault, 2000), while devices with haptic feedback provide tactile or sensory signals to solve virtual prototyping and ergonomic design tasks (Burdea & Coiffet, 2003).
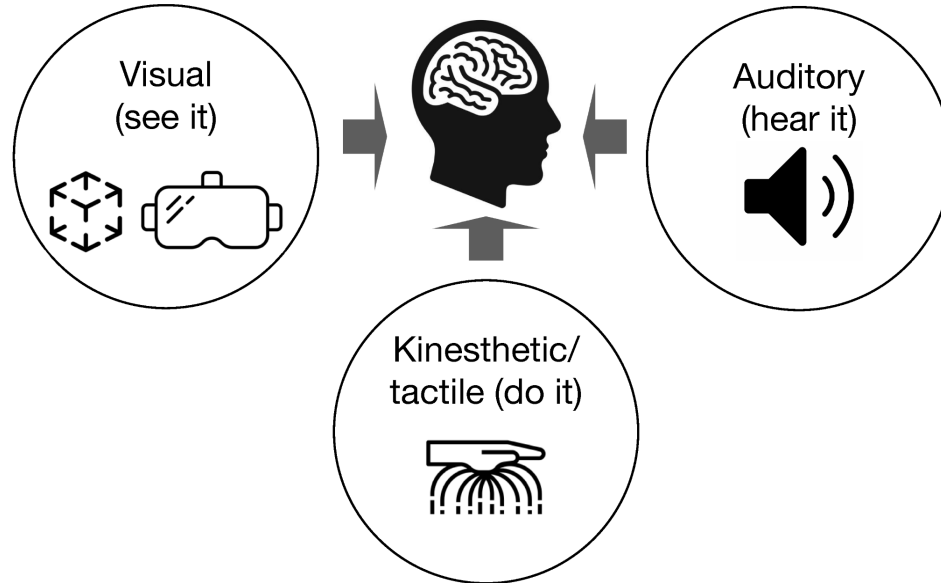
Figure 7. A Perspective Review on Integrating VR/AR with Haptics into STEM Education for Multi-Sensory Learning.

SOURCE: [A Perspective Review on Integrating VR/AR with Haptics into STEM Education for Multi-Sensory Learning](#)

2.5. Using VR technologies in practical areas

The use of VR technologies allows to create unique, interactive and multidimensional spaces, in which various forms of interaction between a person and a computer, as well as with other people, are possible. VR technologies allow the user to transport to any place and any time, creating unique conditions for learning, entertainment, medicine, architecture, engineering, design and many other areas.

2.5.1. Education

There are many studies that examine the effectiveness of immersive VR simulations in student learning compared to traditional teaching methods. Studies have shown that the group of students who received VR simulations outperformed the other groups in both short-term and long-term learning outcomes. The VR group also showed higher levels of engagement and motivation than the other groups. The study also showed that the combination of VR and non-immersive video simulations did not provide any additional benefits compared to using VR alone. The results suggest that immersive VR simulations can be an effective tool for enhancing student learning and can provide long-term benefits for students. However, more research is needed to examine the specific factors that contribute to the effectiveness of VR simulations and to determine the most effective ways to integrate them into curricula.

One example is the company Labster. It is a company that develops and provides online interactive laboratory simulations for students and educators in various fields of science. The platform was founded in 2013 by a team of scientists and educators with the aim of revolutionizing the way science is taught by providing accessible and engaging virtual lab experiences. Labster's simulations are designed to simulate real-life laboratory environments and experiments, allowing students to learn through experimentation and exploration in a safe and cost-effective manner.

Labster's simulations cover a wide range of scientific disciplines, including biology, chemistry, physics, engineering, and more. The platform offers over 200 simulations, each designed to provide students with a unique and immersive learning experience. Labster's simulations incorporate gamification elements, such as scoring and achievements, to make the learning experience more engaging and fun.

One of the key features of Labster is its accessibility. The platform can be accessed from anywhere with an internet connection, making it possible for students to access high-quality laboratory simulations regardless of their geographic location or financial situation. Labster's simulations also eliminate the need for expensive laboratory equipment and materials, making it a cost-effective solution for schools and universities.

Improving biotech education through gamified laboratory simulations:

Gamified laboratory simulations can be an effective way to improve biotech education. By creating a virtual laboratory environment that simulates real-life scenarios, students can learn and practice laboratory techniques and procedures without the need for expensive equipment and supplies.

Gamification of laboratory simulations can make the learning experience more engaging and interactive for students, as it adds an element of fun and competition to the educational process. For example, students can earn points or badges for completing tasks or mastering specific techniques, and they can compete with other students for the top score.

Another advantage of gamified laboratory simulations is that they can provide immediate feedback to students, allowing them to adjust their approach and learn from their mistakes. This can enhance the learning experience and help students develop critical thinking and problem-solving skills (Bonde, Mads & Makransky, 2014).

Furthermore, gamified laboratory simulations can help students build confidence in their laboratory skills, as they can practice and refine their techniques in a safe and controlled

virtual environment. This can prepare them for real-life laboratory settings and help them perform better when conducting experiments.

In addition, gamified laboratory simulations can be accessed remotely, which is particularly important during times when students cannot physically attend laboratory classes. This makes laboratory education more accessible and flexible, allowing students to learn at their own pace and convenience.

Overall, gamified laboratory simulations have the potential to revolutionize biotech education, making it more engaging, accessible, and effective (Pande P., 2021).

Figure 8. Screenshots from the gamified laboratory simulation tested in this study
SOURCE: https://www.labster.com/

2.5.2. Medicine

Virtual reality is a new technology with the potential to revolutionize medicine. It allows medical professionals to immerse themselves in a simulated environment, giving them a unique insight into complex medical procedures and treatments. The use of VR in medicine has grown rapidly in recent years, with applications ranging from surgical training and simulation to pain management and therapy.

VR technology offers a number of benefits in healthcare, including the ability to create a realistic and immersive environment that can be used to simulate real-life experiences. This can be particularly useful in surgical training, where VR can provide a safe and controlled environment for hands-on practice before performing procedures on live patients.

VR can also be used in pain management and rehabilitation to distract patients from pain and encourage physical activity. For example, VR can be used to create an immersive environment that simulates activities such as walking, swimming or cycling, allowing patients to engage in these activities without leaving their hospital bed.

The potential of VR in the treatment of mental disorders such as phobias and anxiety disorders. VR can be used to create a virtual environment that allows patients to confront and overcome their fears in a controlled and safe environment (Boeldt D., 2019).

The potential of VR technology to transform clinical medicine by providing new tools and approaches to teaching, pain management, rehabilitation, and treatment of mental disorders. While there are still unresolved issues such as cost and affordability, the use of VR in healthcare is an exciting and rapidly evolving field.
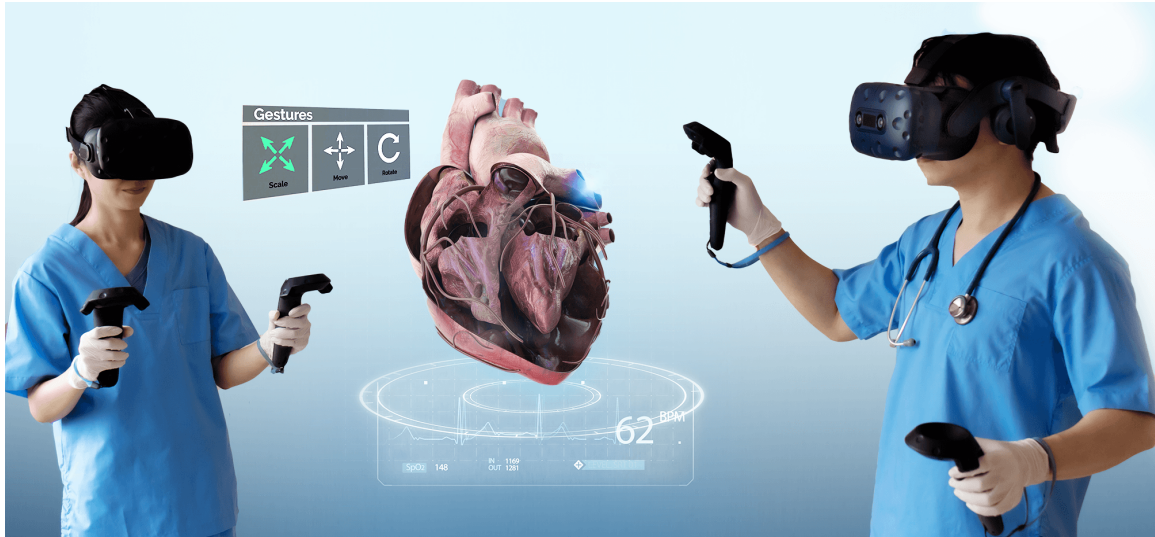

Figure 9. Medical students training using virtual reality
SOURCE: https://provenreality.com/virtual-reality/medical-education-and-vr-a-research/

2.5.3.   Entertainment

The ability to create immersive and interactive experiences has made VR a powerful tool for storytelling and entertainment. VR allows users to step into a new world, interact with objects and characters, and explore environments in ways that were previously impossible.

In the gaming industry, VR has been used to create new and exciting experiences. Gamers can now fully immerse themselves in a game, becoming a part of the story and interacting with the game world in ways that were not previously possible. VR gaming has been used to create everything from realistic simulations of popular sports like skiing and skateboarding to fantastical worlds and experiences like traveling through space or battling mythical creatures.

The VR app, Beat Saber, was released in 2019 and became one of the most popular VR games in history, selling more than 1 million copies in less than nine months. The

developer, the Czech company Beat Games, was bought by Facebook's Oculus division shortly thereafter (Alexandros Vigkos, 2021).

Beat Saber is a popular virtual reality application developed by Beat Games, a VR game studio. It is a music-based game that combines fast-paced action with rhythm-based gameplay, challenging players to use two virtual "sabers" to slash through oncoming obstacles in time with the beat of the music.

The game is played on a VR headset with motion controllers, allowing players to physically move their arms and slash through the obstacles as if they were wielding actual lightsabers. The game features a variety of music tracks, ranging from electronic dance music to rock and pop, with different difficulty levels to cater to players of all skill levels.

Beat Saber quickly gained a dedicated following among VR enthusiasts and gamers, earning critical acclaim for its innovative gameplay mechanics, immersive music experience, and stunning visual design. It has since become one of the most popular VR games of all time, with millions of copies sold and numerous awards and accolades. The game has also spawned a community of creators who make custom tracks, further expanding its already impressive library of songs.

Figure 10. Beat Saber Video game.
SOURCE: https://beatsaber.com/

2.5.4. Manufacturing and Engineering

The use of XR technology has revolutionized the process of digital prototyping. By utilizing virtual reality environments, designers can create and modify digital prototypes without the need for physical materials, reducing costs and minimizing waste. SEAT, a leading car

manufacturer in Spain, has embraced this technology in the development of its cars, and has reaped the benefits of its use.

Traditionally, the process of designing cars involved constructing physical models, a time-consuming and costly process. If a design was rejected, the designers would have to start from scratch, wasting both time and resources. However, with the use of virtual 3D models, designers can easily visualize and modify both the exterior and interior of the product before it is physically built. This allows for a better understanding of the product and can lead to a reduction in the number of physical prototypes needed.

SEAT has taken full advantage of this technology and has implemented VR in the planning and construction of its new vehicles. By using VR to plan the production line, SEAT has been able to reduce the number of physical prototypes required before launching a new model by 50%. This has resulted in a 30% reduction in production time, and a significant cost savings for the company.

The use of XR technology has transformed the way that digital prototypes are created and modified, leading to significant benefits for companies like SEAT. The ability to create virtual environments that simulate real-world scenarios has revolutionized the design process, enabling designers to create and modify prototypes quickly and efficiently, while minimizing waste and reducing costs.

Figure 11. How is VR applied in car manufacturing at SEAT.
SOURCE: https://www.seat.com/company/news/cars/virtual-reality-car-manufacturing

2.5.5.   Marketing and Advertising

The popularity of virtual reality technology in marketing has grown significantly over the years due to its ability to offer a distinct and unforgettable way to present products and services. The objective of VR marketing campaigns is to capture the attention of customers by providing a distinctive experience that enables them to interact with a product or service in an exceptional way. This experience tends to have a long-lasting impact on the customer, increasing the chances of them either making a purchase or developing a strong attachment to the brand.

Traditional marketing strategies, such as storytelling, are no longer sufficient to attract and retain customers in a highly competitive market. Instead, companies need to provide immersive experiences that allow customers to "do" rather than just listen or watch.

VR technology can offer a unique solution to this problem, allowing companies to create immersive experiences that allow customers to interact with products or services in a simulated environment. These experiences can be highly engaging and help create a deeper emotional connection between customers and brands.

The potential of VR technology to transform the customer experience by allowing customers to share their experiences with others interactively. This can help create a network of brand advocates who are highly engaged and motivated to promote the brand to others. Benefits of using VR technology for advertising, such as increased engagement and interactivity with users. The use of VR technology can create a more memorable and impactful advertising experience, as users are more likely to remember and engage with immersive and interactive content. The advantages of VR technology are the creation of an immersive and engaging experience for consumers and the ability to showcase products in a more interactive and realistic way.

There are still many challenges to overcome, such as the cost and complexity of creating a VR experience, as well as the need to make the experience accessible to a wide range of consumers. Integrating advertising into a VR environment can be challenging, as traditional advertising methods can blend poorly with the immersive and interactive nature of VR. A scene-based approach to integrating advertising content is proposed, in which ads are seamlessly integrated into the VR environment as part of the overall scene.

The use of VR technology in advertising has significant potential, especially with a scene-based integration approach. By creating immersive and seamless ad experiences,

advertisers can better engage and connect with users, creating more impactful and memorable campaigns.

Comparing the effectiveness of VR video with traditional 2D video, the use of VR technology in marketing can have a significant impact on consumers' desire to buy a product. Participants who watched a VR marketing video had a significantly higher desire to buy a product compared to those who watched a 2D video. VR videos are more memorable and engaging for participants compared to 2D videos.

VR technology can be a valuable tool in marketing, providing consumers with an immersive and engaging experience that can increase their desire to buy a product. As VR technology continues to evolve and become more accessible, it will likely become an increasingly important tool for marketers looking to create impactful and memorable campaigns.

In addition, 80% ofrespondentssaidtheylikedVRadvertisingproducts.Thismeans that people are interested in the way VR technology is present to them and are interested in trying and feeling new things.Overall,respondents agree that VRadsinformthem well about the product (Wijayanto, Sigit & Putra, 2021).

2.5.5.1.   The IKEA

Place app is an example of how augmented reality can be used to innovate a company's service offerings. The app allows customers to virtually place furniture in their homes to see how it would look and fit before making a purchase. This AR technology improves the shopping experience for customers by providing them with a more accurate representation of how the product would look in their home.

By using AR, IKEA has improved their service offerings by reducing the likelihood of product returns due to incorrect sizing or aesthetics. Customers can now make more informed decisions about their purchases, which can lead to higher customer satisfaction rates and repeat business.

Additionally, the use of AR in the IKEA Place app provides the company with a competitive advantage by differentiating them from other furniture retailers. This innovative technology sets IKEA apart by providing a unique and engaging shopping experience that customers cannot get from their competitors.

Furthermore, the IKEA Place app has the potential to increase the company's efficiency by reducing the need for physical product displays. With AR, IKEA can showcase their

entire product line without the need for large physical showrooms. This can lead to cost savings for the company, as well as a more environmentally sustainable business model.

The use of AR technology in the IKEA Place app is a prime example of how service innovation can be achieved through the use of emerging technologies. By providing customers with a more immersive and personalized shopping experience, IKEA has improved their service offerings and created a competitive advantage in the furniture retail industry.

Figure 12. Courtesy Inter IKEA Systems.
SOURCE: https://www.architectmagazine.com/technology/ikea-launches-augmented-reality-application

2.5.5.2. Volvo Cars

Volvo Cars has collaborated with Epic Games to incorporate real-time photorealistic visualization into its next-generation cars using the Unreal Engine. The Unreal Engine is a real-time 3D creation tool used in various industries, such as games, films, television, architecture, and automotive. The aim of the partnership is to provide customers with immersive experiences that enable them to interact with and personalize their vehicles in real-time. The integration of the Unreal Engine into Volvo's next-gen vehicles will allow for real-time visualization and interactivity. With this platform, customers will have the ability to customize the exterior and interior of their cars, including color, materials, and lighting, in real-time, along with interactive features like opening doors and changing the car's position in a virtual environment. The use of the Unreal Engine in the automotive industry is expected to revolutionize the car-buying experience by providing a more immersive and realistic way to interact with desired vehicles. It also has the potential to reduce the need for physical showrooms, allowing customers to

experience and customize their cars remotely. The partnership between Volvo Cars and Epic Games serves as an example of how technology can transform industries and create new opportunities for customer experiences.

Figure 13. Volvo Cars and Epic Games.
SOURCE: https://www.media.volvocars.com/global/en-gb/media/pressreleases/301605/volvo-cars-and-epic-games-bring-real-time-photorealistic-visualisation-inside-next-generation-volvo

Upon considering the various applications of virtual reality in marketing, it can be inferred that the world is constantly evolving and dynamic. The use of VR technology has become increasingly popular in various fields, including education, healthcare, engineering, and marketing. This technology provides an innovative and immersive way to engage users, offering unique experiences that are memorable and effective in achieving specific goals. As we move forward, we can expect to see VR technology being adopted in new and exciting ways, as its potential for improving and enhancing user experiences continues to be realized. The ever-increasing volume of advertising messages and content inundating the information field has resulted in heightened competition for individuals' attention. As such, companies must seize every available opportunity to enhance their commercial success. The emerging utilization of virtual reality technology in marketing constitutes a novel opportunity that is gaining momentum. It is anticipated that VR will continue to proliferate across diverse facets of human existence in the future, thereby augmenting the areas in which it is already proving profitable for companies.

2.6.   Project implementation

Project implementation is a systematic process that allows organizations to convert their objectives into tangible outcomes. It encompasses various stages, each of which serves a specific purpose and contributes to the overall success of the project. A well-structured algorithm for project implementation can enhance efficiency, reduce risk, and increase the likelihood of achieving desired results (Kerzner, 2017).

Figure 14. Project Management Process
SOURCE: https://www.apogaeis.com/blog/project-management-process-all-you-need-to-know/

Project Initiation: The project initiation phase commences with the identification of a project's purpose, scope, and objectives. Stakeholders, including sponsors, clients, and project teams, collaborate to define the project's feasibility and potential benefits. The outcome of this phase is a project charter, which serves as a formal document outlining the project's goals, constraints, and initial requirements (PMBOK Guide, 2017).

Project Planning: During the planning phase, project managers develop a detailed project management plan, which consists of various subsidiary plans, including scope, schedule, cost, quality, human resources, communication, risk, procurement, and stakeholder management. These plans provide a comprehensive framework for project execution, ensuring that all aspects are meticulously considered and addressed (PMBOK Guide, 2017).

Project Execution: The execution phase involves the mobilization of resources and the implementation of project plans. Tasks are assigned to project team members, who are responsible for completing their assignments according to the specified schedule, budget, and quality requirements. Project managers must maintain open lines of communication with stakeholders to ensure that expectations are met and that any issues are addressed promptly (Kerzner, 2017).

Project Monitoring and Control: Monitoring and control are ongoing processes that occur concurrently with project execution. The purpose of these processes is to track, review, and regulate the progress of the project to ensure alignment with the project management plan. This phase may involve making adjustments to the project's scope, schedule, or resources to address potential risks or discrepancies (PMBOK Guide, 2017).

Project Closure: Upon completion of the project, the closure phase commences. This phase entails the formal acceptance of project deliverables, the evaluation of project performance, and the documentation of lessons learned. The project is then officially closed, and resources are released (Kerzner, 2017).

Understanding the general algorithm for project implementation is essential for project managers to achieve successful outcomes. By carefully navigating the initiation, planning, execution, monitoring, and closure phases, project managers can enhance efficiency, reduce risk, and ultimately deliver successful projects that align with organizational objectives.

2.7. Methods of situational analysis

Situational analysis is a systematic approach that helps organizations comprehend the factors and dynamics affecting their performance within a specific context. This analytical process is crucial in enabling businesses to make well-informed decisions and develop strategies that address their particular needs and objectives. Various methods have been developed for conducting situational analysis, each with its unique strengths and weaknesses. This essay will discuss four commonly used methods: SWOT Analysis, PESTLE Analysis, and Porter's Five Forces analysis. To determine the benefits and risks of using VR technology, use the following analyses. Situational analysis is essential for organizations to understand the factors that affect their performance and inform strategic decision-making. Methods such as SWOT analysis, PESTLE analysis, and Five Forces analysis provide different approaches for examining internal and external factors, enabling businesses to develop comprehensive and adaptable strategies.

2.7.1. SWOT

SWOT analysis is a strategic planning tool that helps organizations identify their internal strengths and weaknesses, as well as external opportunities and threats.

Table 1. SWOT analysis

Strengths	Weaknesses
The internal factors that give an organization an advantage over its competitors, such as its unique skills, resources, or capabilities.	The internal factors that put an organization at a disadvantage compared to its competitors, such as a lack of resources, skills, or experience
Opportunities	**Threats**
The external factors that present opportunities for growth or improvement, such as changes in the market or technology, or new customer needs.	The external factors that could negatively impact an organization, such as competition, economic conditions, or regulatory changes.

SOURCE: Own elaboration

SWOT analysis is typically used as part of a larger strategic planning process and can be used to identify the key factors that will impact an organization's future success. By understanding its strengths, weaknesses, opportunities, and threats, an organization can develop strategies to take advantage of its strengths, address its weaknesses, capitalize on its opportunities, and mitigate its threats.

2.7.2.   PESTEL analysis

PESTEL analysis is a framework for analyzing the macro-environmental factors that can impact an organization or industry. PESTEL stands for:

1. Political: The political factors that can impact an organization or industry, such as government policies, regulations, and political stability.
2. Economic: The economic factors that can impact an organization or industry, such as inflation, interest rates, and economic growth.
3. Sociocultural: The social and cultural factors that can impact an organization or industry, such as demographics, lifestyle trends, and values.
4. Technological: The technological factors that can impact an organization or industry, such as advancements in technology, the adoption of new technologies, and the rate of technological change.
5. Environmental: The environmental factors that can impact an organization or industry, such as climate change, resource availability, and environmental regulations.

6. Legal: The legal factors that can impact an organization or industry, such as labor laws, intellectual property laws, and consumer protection laws.

PESTEL analysis is typically used as part of a larger strategic planning process and can help organizations understand the broader macro-environmental factors that may impact their operations, and make informed decisions about their future direction.

2.7.3.   Porter's Five Forces analysis

Porter's Five Forces analysis is a seminal framework in strategic management that examines the competitive dynamics within an industry. This analytical tool was initially proposed by Michael E. Porter, a distinguished professor at Harvard Business School, in his influential 1980 book, "Competitive Strategy: Techniques for Analyzing Industries and Competitors" (Porter, 1980). Porter's Five Forces framework elucidates the interplay of five competitive forces which shape industry structure, profitability, and strategic positioning: threat of new entrants, bargaining power of suppliers, bargaining power of buyers, threat of substitute products or services, and rivalry among existing competitors.

- Threat of New Entrants: This force assesses the likelihood and potential impact of new market entrants in a given industry. Barriers to entry, such as capital requirements, economies of scale, product differentiation, and access to distribution channels, can deter new competitors and protect incumbent firms' market position (Grant, 2016).
- Bargaining Power of Suppliers: This force examines the extent to which suppliers can influence an industry's competitive landscape by dictating terms, conditions, and prices. Factors such as supplier concentration, availability of substitute inputs, and the importance of suppliers' goods or services to buyers determine the relative power of suppliers (Dobbs, 2014).
- Bargaining Power of Buyers: This force evaluates the ability of buyers to exert pressure on industry participants through price negotiation, product preferences, and other demands. Buyer concentration, product differentiation, and availability of alternative suppliers can influence the relative power of buyers (Dobbs, 2014).
- Threat of Substitute Products or Services: This force appraises the potential for substitute products or services to disrupt the industry's competitive equilibrium. The availability of functionally similar or superior alternatives, relative price-performance trade-offs, and buyer propensity to switch can affect the threat posed by substitutes (Grant, 2016).
- Rivalry among Existing Competitors: This force investigates the intensity of competition among current industry players. Factors such as the number of

competitors, industry growth rate, fixed or storage costs, and product differentiation can contribute to the degree of rivalry in a given industry (Porter, 2008).

Porter's Five Forces analysis is a valuable tool for understanding the competitive forces that shape an industry's structure and dynamics, thereby informing strategic decision-making. By considering each of the five forces, firms can identify opportunities and threats, and develop strategies to enhance their competitive advantage.

2.8. Stakeholders

Stakeholders are essential constituents in various domains, including business, politics, and social systems. Their roles, interests, and influence on decision-making processes are paramount in determining the success or failure of projects, policies, and initiatives. This paper delineates the concept of stakeholders, explicates their significance, and identifies key categories in diverse contexts. Additionally, it emphasizes the necessity of engaging stakeholders in decision-making endeavors.

The term "stakeholder" is derived from the concept of an individual or group having a "stake" or interest in a particular issue or outcome (Freeman, 1984). Stakeholders comprise a wide array of actors, encompassing individuals, organizations, and communities that are either directly or indirectly affected by decisions or actions (Mitchell, Agle, & Wood, 1997). These entities possess varying degrees of power, legitimacy, and urgency, which impact their influence on decision-making processes (Mitchell et al., 1997).

Stakeholders are integral components of decision-making processes, with their engagement proving indispensable for the attainment of democratic ideals, legitimacy, and effective outcomes. A comprehensive understanding of stakeholder dynamics, including their diverse roles and interests, is crucial for navigating complex organizational and societal challenges.

2.9. Development team

The development team for project management is a crucial component in the successful execution of projects, as they are responsible for translating strategic objectives into tangible deliverables. This team typically comprises a multidisciplinary group of professionals with diverse skills and expertise, encompassing areas such as project

management, software development, quality assurance, design, and business analysis (Kerzner, 2017).

The formation of an efficient development team necessitates a comprehensive understanding of team dynamics and the requisite expertise. A vital aspect of this process is the selection and allocation of human resources, which should be based on their respective competencies, experience, and communication abilities (Pinto, 2019). Moreover, it is imperative to foster a culture of collaboration, information sharing, and mutual trust among team members to facilitate synergistic outcomes (Belbin, 2012).

Leadership plays a crucial role in directing the development team towards successful project completion. An effective project manager should exhibit strong communication and interpersonal skills, enabling them to align team members' efforts towards a unified goal (Turner, 2016). Furthermore, the project manager should promote a solution-oriented mindset, encouraging the team to actively identify and address potential obstacles (Müller & Turner, 2010).

Equally important is the implementation of well-defined project management methodologies that delineate the project's scope, schedule, and budget, in addition to monitoring progress and managing risks (PMBOK Guide, 2017). The integration of agile practices, such as Scrum, can promote adaptability and enhance the responsiveness of the development team to changing project requirements (Sutherland, 2014).

In conclusion, the development team for project management is instrumental in achieving project success. By fostering a culture of collaboration, effective leadership, and adherence to established project management methodologies, organizations can optimize the efficiency of their development teams and attain desired project outcomes.

2.10. Communication Plan

A communication plan serves as a roadmap for information dissemination, fostering collaboration and transparency among project stakeholders (PMBOK, 2017). It outlines the communication needs, channels, frequency, and responsible parties, ensuring that pertinent information is shared in a timely and efficient manner (Kerzner, 2017). The effective execution of a communication plan bolsters stakeholder engagement, mitigates risks, and facilitates decision-making processes (Müller & Turner, 2010). A robust communication plan is essential for successful project management, as it guides the flow of information, supports collaboration, and ensures stakeholder engagement. By carefully analyzing stakeholder needs, setting clear objectives, and selecting appropriate

communication channels and frequency, project managers can create an effective communication plan that fosters transparency and drives project success.

Key Components of Communication Plans:

1. Stakeholder Analysis: Identifying and categorizing stakeholders based on their level of interest, influence, and communication requirements (Bourne, 2016).
2. Communication Objectives: Establishing clear goals for each communication activity, such as informing, persuading, or soliciting feedback (Pinto & Kharbanda, 1995).
3. Communication Channels: Determining the most appropriate communication medium (e.g., email, meetings, reports) for each stakeholder group, considering factors like urgency, formality, and confidentiality (Dainty et al., 2006).
4. Communication Frequency: Specifying the regularity and timing of communication activities, while remaining flexible to accommodate project changes (Larson & Gray, 2017).
5. Roles and Responsibilities: Defining the roles of individuals and teams in the communication process, ensuring accountability and consistency (Heagney, 2016).

Effective communication plans are integral to the success of project management. By incorporating key components in the design and implementation of communication plans, project managers can create a foundation for collaborative, transparent, and engaged project environments that ultimately drive project success. Regular monitoring and adjustments ensure that the communication plan remains relevant and efficient throughout the project lifecycle, thereby promoting stakeholder satisfaction and project excellence.

2.11. Project risk management

Project risk management is a crucial aspect of successful project execution, as it helps to identify, assess, and mitigate potential risks that could impact a project's timeline, budget, or deliverables. The process encompasses several key stages, which include risk identification, risk assessment, risk response planning, and risk monitoring and control.

Risk Identification:

The first step in project risk management involves identifying potential risks that could impact the project. This can be achieved through various techniques, such as

brainstorming sessions, expert interviews, historical data analysis, and checklists. The goal is to create a comprehensive list of risks that can be further analyzed and prioritized.

Risk Assessment:

Once the risks have been identified, they need to be assessed in terms of their probability of occurrence and the potential impact they may have on the project. This is typically done using qualitative and quantitative methods. Qualitative assessment involves categorizing risks based on their likelihood and impact, whereas quantitative assessment involves assigning numerical values to these factors. The outcome is a prioritized list of risks, which can then be addressed through risk response planning.

Risk Response Planning:

After assessing the risks, project managers need to develop strategies to address them. There are four primary risk response strategies:

a. Avoidance: This involves altering the project plan to eliminate the risk or protect the project objectives from its impact.

b. Mitigation: This strategy aims to reduce the likelihood or impact of a risk by implementing proactive measures.

c. Transfer: This involves shifting the responsibility for the risk to a third party, such as through insurance or contracts.

d. Acceptance: This strategy is employed when the cost of mitigating a risk outweighs the potential benefits, or when the risk cannot be managed by other means. In this case, project managers must be prepared to deal with the risk's consequences.

Risk Monitoring and Control:

Risk monitoring and control is an ongoing process that involves tracking identified risks, monitoring residual risks, and identifying new risks throughout the project's lifecycle. This ensures that risk management plans remain effective and that any necessary adjustments can be made in a timely manner. Monitoring and control techniques include risk audits, risk reviews, and key performance indicators (KPIs).

In conclusion, project risk management is a vital component of successful project execution. By identifying, assessing, and addressing potential risks, project managers can minimize their impact on project objectives and ensure that the project stays on track. Implementing a proactive risk management strategy enables organizations to better navigate uncertainties and achieve their goals.

METHODOLOGY PART

3. Methodology

The subject of research and objectives in the research work is to study the possibility of VR technologies and their application for marketing purposes in the automotive industry. In the following chapters, which will already deal with the project as such, the information will be based on a modeling method, the principle of which is based on simplifying reality, but which relies on established key parameters that must be observed in the modeling. This methodology will be used mainly in the planning phase of the project.

3.1. The role of applying virtual reality tools

Virtual Reality technology has become increasingly popular in various industries, and the automotive sector is no exception. KIA, a renowned automaker, has been leveraging the potential of VR technology to create virtual car showrooms that offer a unique and immersive experience to potential customers. This new approach to marketing not only showcases KIA's innovative spirit, but also provides a variety of benefits to both the brand and its customers.

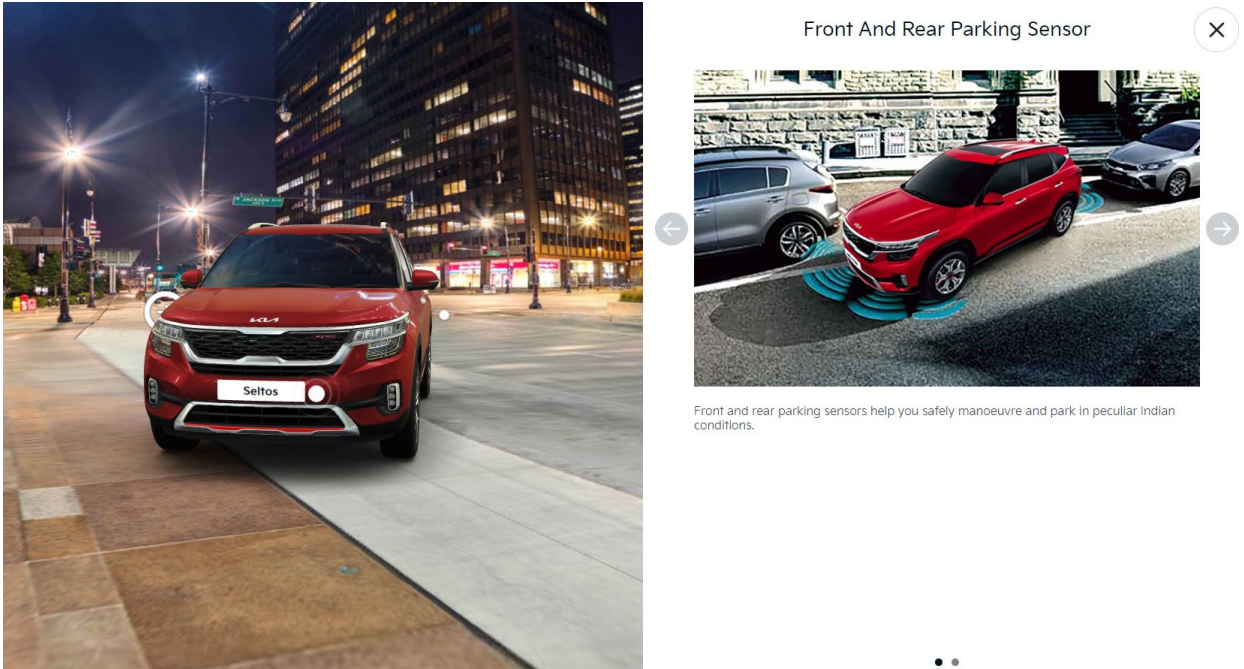*Figure 15. Kia Virtual Experience*
SOURCE: Own elaboration

Figure 16. Kia Virtual Experience and Tip
SOURCE: Own elaboration

Enhanced Customer Experience

KIA's virtual reality car showroom significantly improves the customer experience by offering an interactive, immersive, and personalized environment. Customers can virtually walk around the showroom and inspect the vehicles from different angles. They can open doors, view the interiors, and even interact with various features such as lights, entertainment systems, and more.

Moreover, the virtual showroom enables customers to customize their desired vehicles by choosing colors, trims, and other options. This level of personalization allows customers to visualize their dream car and better understand the available features, facilitating informed decision-making. Additionally, the virtual test drive feature simulates real-life driving conditions, providing customers with a more accurate representation of the vehicle's performance and handling.

Cost-Effective Marketing

By implementing a virtual reality car showroom, KIA can significantly reduce the costs associated with traditional marketing efforts. The virtual showroom eliminates the need for physical space, which in turn reduces rent, utility, and maintenance expenses. It also minimizes the costs related to events and exhibitions, as well as the need for sales staff.

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Moreover, a virtual showroom can be accessed by potential customers from anywhere, at any time. This allows KIA to reach a global audience without incurring the expenses related to international marketing campaigns or expansion into new territories. As a result, the company can allocate its resources more efficiently and invest in other aspects of its business, such as research and development or customer service.

Environmentally Friendly Approach

Incorporating a virtual reality car showroom into KIA's marketing strategy contributes to a more sustainable approach to business. By reducing the reliance on physical showrooms and events, the company can significantly decrease its energy consumption and waste production. This not only helps in minimizing the environmental impact but also aligns with the growing consumer demand for eco-friendly practices.

Additionally, by offering a virtual test drive feature, KIA can reduce fuel consumption and emissions that would typically result from real-life test drives. This further showcases the company's commitment to sustainability and environmental responsibility.

Data Collection and Analytics

The virtual reality car showroom provides KIA with a wealth of data on customer behavior, preferences, and interests. As users interact with the platform, their choices and actions can be recorded and analyzed. This data-driven approach enables KIA to gain insights into customer needs, preferences, and trends, which can be used to refine marketing strategies, improve product offerings, and optimize targeting.

For example, by analyzing the most popular vehicle customizations, KIA can identify which features and options resonate with customers and incorporate these preferences into future models. Additionally, understanding customer behavior within the virtual showroom can help the company identify areas of improvement and create a more engaging user experience. This, in turn, can result in higher customer satisfaction and increased sales.

KIA's virtual reality car showroom is a testament to the brand's commitment to innovation and customer-centricity. By embracing VR technology, KIA not only provides a unique and immersive experience for potential buyers but also promotes a cost-effective, environmentally friendly, and data-driven approach to marketing.

3.2.   Development plan for the VR car showroom

Virtual Reality is a rapidly evolving technology, offering immersive and interactive experiences in various domains, including automotive design and sales. A VR Car showroom developed using the powerful Unreal Engine, can revolutionize the way consumers explore and customize vehicles before purchase. This paper outlines the key considerations and implementation steps for developing a VR Car showroom using Unreal Engine, addressing aspects such as user experience, 3D modeling, materials, lighting, and optimization. Developing a VR car showroom is a fairly complex and multitasking project that requires consideration of many factors and steps. Here is my proposed plan for developing a VR car showroom for 172 days:

Table 2. Development plan

Project Initiation	Define project goals	3 days	Project Manager
	Define functional requirements	5 days	UX/UI Designer
	Define non-functional requirements	3 days	Project Manager
	Analyze existing solutions	5 days	Data Analyst
	Analyze potential users	4 days	Data Analyst
Project Planning	Develop project schedule	5 days	Project Manager
	Allocate resources	3 days	Project Manager
	Develop risk management plan	4 days	Project Manager
	Develop communication plan	3 days	Project Manager
	Design VR showroom concept	7 days	UX/UI Designer
	Create user interface prototype	5 days	UX/UI Designer
	Select technologies and tools	5 days	VR Developers
	Develop detailed 3D modeling plan	4 days	3D Modelers
	Develop functional development plan	5 days	VR Developers
	Develop testing and debugging plan	4 days	Testers

	Develop launch and support plan	4 days	Project Manager
Project Execution	Create 3D car models	10 days	3D Modelers
	Develop VR space	15 days	VR Developers
	Develop showroom functionality	20 days	VR Developers
	Adjust 3D car models for VR environment	5 days	3D Modelers
	Develop car viewing functionality in VR	10 days	VR Developers
	Integrate with VR equipment and platforms	10 days	VR Developers
Project Monitoring and Control	Monitor project progress	Ongoing	Project Manager
	Track resource utilization	Ongoing	Project Manager
	Update project schedule	Ongoing	Project Manager
	Manage risks and issues	Ongoing	Project Manager
	Perform quality control	Ongoing	Testers
	Implement changes and improvements	As needed	Project Manager, VR Developers
Project Closure	Test VR showroom on various devices	10 days	Testers
	Debug and fix bugs	5 days	VR Developers
	Optimize VR showroom performance	5 days	VR Developers
	Final project review	3 days	Project Manager
	Obtain project sign-off	1 day	Project Manager
	Launch VR showroom	1 day	Project Manager
	Develop support and update plan	5 days	Project Manager
	Transition to support team	3 days	Project Manager

SOURCE: Own elaboration

3.3. Methods of situational analysis

3.3.1. SWOT

Virtual reality car showrooms (VRCS) enable consumers to customize and visualize their desired vehicle in a three-dimensional, immersive environment. As a novel technological application in the automotive industry, it is crucial to understand the potential implications of adopting VRCS to facilitate decision-making processes and optimize user experiences.

Table 3. SWOT part 1

Strengths	Weaknesses
Enhanced customer experience: VRCSs allow customers to engage in a highly immersive and interactive configuration process, providing a more accurate representation of the final product.	High initial costs: The development and implementation of VRCSs can be expensive, particularly for small and medium-sized enterprises (SMEs).
Streamlined decision-making: By enabling customers to visualize their desired vehicle in real-time, VRCSs can reduce the time and effort required for decision-making and enhance overall satisfaction.	Limited accessibility: Not all customers may have access to VR devices, thus potentially excluding a segment of the market.
Competitive advantage: Integrating VRCSs into the sales process may differentiate automotive companies from their competitors, thus attracting more customers.	Technological challenges: VRCSs require constant updates and maintenance to ensure optimal performance and compatibility with new vehicle models and features.

SOURCE: Own elaboration

Table 4. SWOT part 2

Opportunities	Threats
Expansion to other industries: Successful implementation of VRCSs in the automotive industry may pave the way for similar applications in other sectors, such as aviation, real estate, and consumer electronics.	Rapid technological advancements: The fast-paced nature of technological advancements may render existing VRCSs obsolete, necessitating constant investment in updates and improvements.
Collaboration with VR hardware manufacturers: Partnerships with VR device manufacturers could facilitate the widespread adoption of VRCSs and enhance the overall user experience.	Data privacy and security concerns: VRCSs collect and store sensitive customer data, raising concerns about data privacy and security.
Increased market share: Early adopters of VRCS technology may gain a competitive edge and secure a larger share of the market.	Potential backlash from traditional sales channels: The adoption of VRCSs may disrupt traditional sales channels, leading to resistance from industry stakeholders

SOURCE: Own elaboration

3.3.2.   PESTLE

The analysis examines the external factors influencing the industry, highlights key trends, and uncovers potential opportunities and challenges for businesses operating in this sector.

- Political Factors: The VR car showroom industry is influenced by various political factors such as government policies, regulations, and initiatives promoting the adoption of virtual reality technologies. Government support for research and development (R&D) in VR and augmented reality technologies is crucial in accelerating innovation and fostering industry growth.
- Economic Factors: The economic climate significantly impacts the VR car showroom industry. Economic growth, disposable income, and consumer confidence affect the demand for automobiles and, consequently, the adoption of VR car showrooms as a sales and marketing tool. Additionally, the cost of VR technologies influences the affordability and accessibility of VR car showrooms for businesses and consumers.

- Social Factors: The increasing acceptance and adoption of VR and AR technologies by consumers and businesses shape the VR car showroom industry. As user experiences improve, customers are more likely to embrace VR car showrooms for their purchasing decisions. Furthermore, demographic changes, such as the preferences of younger generations for technologically advanced solutions, contribute to the industry's growth.
- Technological Factors: Advancements in VR technology, such as higher resolution displays, improved motion tracking, and reduced latency, enhance the quality and realism of VR car showrooms. Additionally, developments in artificial intelligence, machine learning, and data analytics enable more personalized and immersive experiences for users.
- Legal Factors: Legal aspects such as data privacy, intellectual property rights, and consumer protection regulations can impact the VR car showroom industry. Compliance with these regulations is crucial to maintain consumer trust and avoid legal disputes.
- Environmental Factors: Environmental concerns, such as energy consumption and electronic waste associated with VR technologies, can influence the industry's growth. Adherence to sustainable practices and the development of eco-friendly solutions are essential for businesses to meet increasing consumer demand for environmentally responsible products and services.

3.3.3. Porter's Five Forces

In analyzing the competitive landscape of the virtual reality car showroom industry, I can apply Michael E. Porter's Five Forces framework to discern the key factors shaping the industry dynamics. Porter's Five Forces consist of five distinct elements: competitive rivalry, the threat of new entrants, the bargaining power of suppliers, the bargaining power of buyers, and the threat of substitute products or services. In the context of the VR car showroom market, these forces are as follows:

- Competitive Rivalry: The intensity of competitive rivalry within the VR car showroom industry is contingent upon the number of market participants, product differentiation, and the rate of industry growth. With numerous technological advancements and increasing demand for immersive experiences in automotive retail, competition in this domain is likely to escalate. As companies strive to offer unique and innovative solutions, competitive rivalry may engender rapid technological progress and price competition.
- Threat of New Entrants: The barriers to entry for the VR car showroom market are relatively high, owing to the requirement of substantial financial and technological

investments. Furthermore, established incumbents possess a competitive advantage due to their strong brand recognition, economies of scale, and expertise in the field. However, the lucrative nature of the industry may still attract new entrants, particularly those with a strong background in VR technology or automotive retail.

● Bargaining Power of Suppliers: Suppliers in the VR car showroom industry primarily consist of VR hardware manufacturers and software developers. As the industry relies heavily on cutting-edge technology and high-quality components, the bargaining power of suppliers can be significant. However, the emergence of multiple suppliers for VR components could potentially mitigate this power, resulting in more balanced negotiations between suppliers and VR car showroom developers.

● Bargaining Power of Buyers: The buyers in the VR car showroom market include automotive manufacturers, dealerships, and potentially individual consumers. With a wide array of VR car showroom solutions available, buyers may enjoy substantial bargaining power, as they can choose from different providers to find the most suitable and cost-effective solution. This may compel VR car showroom developers to offer competitive pricing and enhanced features to attract and retain customers.

● Threat of Substitute Products or Services: The primary substitutes for VR car showrooms are traditional car showroom platforms and other digital means of vehicle customization, such as augmented reality showrooms. While these alternatives may pose a threat to the VR car showroom industry, the immersive and engaging nature of VR technology is likely to sustain its appeal to customers. Consequently, the threat of substitutes could be moderate, as long as VR car showrooms continue to offer unique and superior user experiences.

3.4. Stakeholders

In the development and implementation of a virtual reality car showroom, several stakeholders play crucial roles in ensuring the project's success. These stakeholders can be broadly classified into internal and external categories, each with varying degrees of involvement and influence on the showroom's outcome.

● Automotive manufacturers: As the primary clients for a VR car showroom, automotive manufacturers have a vested interest in the project's success. They require an immersive and efficient system that effectively showcases their product offerings and facilitates consumer engagement.

- VR technology developers: These stakeholders are responsible for developing and maintaining the cutting-edge technology that underpins the car showroom. They continuously innovate and refine the software and hardware components to ensure seamless and realistic user experiences.
- Marketing and sales teams: Tasked with promoting the showroom and driving customer engagement, these stakeholders collaborate closely with other internal teams to tailor the VR experience to specific customer segments and deliver targeted marketing campaigns.
- Automotive designers and engineers: As the creators of the car models, designers and engineers work closely with VR developers to ensure the showroom accurately and authentically represents the vehicles, allowing users to explore and customize various aspects of the car in real-time.
- Dealerships and retail partners: These external stakeholders serve as the primary distribution channel for the showroom, integrating it within their sales process to enhance the customer journey and ultimately drive sales.
- End-users (consumers): The consumers, as the ultimate end-users of the VR car showroom, hold significant influence over its success. Their preferences, feedback, and overall satisfaction with the experience are crucial in shaping the showroom's development and future iterations.

The successful development, implementation, and continuous improvement of a VR car showroom relies upon the effective collaboration and alignment of various stakeholders, each contributing their unique expertise and resources to the project. This harmonious synergy is critical in ensuring that the showroom delivers a truly immersive and satisfying experience for its end-users.

3.5. Development team

The number of people in a VR car showroom development team may depend on various factors, such as the size of the project, the complexity of the showroom, the level of experience of the team members, and others. Typically, the VR showroom development team consists of the following specialists:

- Project manager;
- VR developers;
- 3D modelers;
- UX/UI designers;
- Data Analyst (optional) ;
- Testers (optional).

Thus, the minimum number of team members to develop a VR car showroom is about 4 people. However, for larger and more complex projects, the number of team members can be increased in order to ensure higher quality development and meeting project deadlines.

Tasks for each member of the VR car showroom development team:

Project manager:

- Creation of a work plan and control of deadlines;
- Communication with the customer;
- Development of the project budget and cost control;
- Development team management.

VR Developers:

- Development of software for interaction with a VR helmet;
- Creation of an interactive vehicle control system;
- Work with graphics and sound;
- Animation development.

3D Modelers:

- Creation of 3D models of cars and parts;
- Optimization of models for work in VR;
- Creation of textures and materials.

UX/UI designers:

- Development of user interface design;
- Development of icons and buttons for management;
- Development of navigation schemes;
- Creation of interface prototypes.

Data Analyst:

- Analysis of data collected during the use of the showroom;
- Development of reports for the customer;
- Optimizing the car selection process with data.

Testers:

- Testing the showroom on different devices;
- Testing the functionality of the showroom;
- Identification and tracking of errors and bugs;
- Development of test scenarios.

However, it should be taken into account that the specific tasks of each team member may be additional and vary depending on the specific conditions of the project.

3.6. Communication plan

Approximate communication plan for car VR showroom and responsible:

Daily project status update:

- Development team meeting every day at the beginning of the working day;
- Answer: Project Manager.

Regular progress reports:

- Project progress reports once a week;
- Regular expense reports;
- Answer: Project Manager.

Communication with the customer:

- Regular communication with the customer to discuss issues and clarifications;
- Monthly presentations of the team's work for the customer;
- Answer: Project Manager.

Organization of communication within the team:

- Regular meetings and discussions of problems among developers;
- Weekly rallies with designers and analysts;
- Answer: Project Manager.

Prompt response to problems:

- Establishing a communication channel between developers and testers for the rapid detection and elimination of errors;
- Regular error checking and correction requests;
- Answer: Testers and developers.

Communication within different departments:

- Coordination of the model assembly process between developers and 3D modelers;
- Communication between UX/UI designers and VR developers;
- Answer: Developers, 3D modelers and UX/UI designers.

Communication with the user:

- Conducting user testing and collecting feedback from users;
- Development of surveys and questionnaires for collecting feedback;
- Answer: Data Analyst.

The specific communication plan may be modified depending on the requirements and specifics of the project. It is important that every member of the team is informed about the communication plan and their role in it in order to ensure effective work and achievement of the project goals.

3.7. Risks and benefits

The integration of Virtual Reality technology in marketing strategies, particularly in the automotive industry, has witnessed rapid growth in recent years. VR car showrooms serve as interactive tools that enable potential customers to virtually explore and customize automobiles to their preferences. While these VR showrooms have brought about numerous advantages, they also pose certain risks that require careful consideration. This part looks at the potential pitfalls of using VR car showrooms in marketing and highlights the positives of VR for effective marketing efforts.

Risks:

- Privacy and Security Concerns. The integration of VR car showrooms necessitates the collection, storage, and analysis of user data. This raises concerns regarding data privacy and security, as the mishandling of sensitive information may result in breaches that could tarnish a company's reputation and incur legal ramifications. It is, therefore, imperative to establish robust data protection protocols to prevent unauthorized access, ensuring the confidentiality and integrity of user data.
- Technological Limitations. The efficacy of VR car showrooms hinges on the accuracy and realism of the virtual environment. However, rendering high-quality graphics and ensuring seamless interactivity may pose significant technological

challenges. Additionally, any discrepancies between the virtual and real-life automobiles may engender customer dissatisfaction and undermine trust in the brand. To circumvent these issues, it is crucial to invest in advanced hardware and software solutions and maintain rigorous quality control procedures.

- Accessibility and Digital Divide. Despite the proliferation of VR technology, not all potential customers have access to the requisite devices and internet connectivity to utilize VR car showrooms. This digital divide may exacerbate existing inequalities and inadvertently alienate segments of the target audience. To address this, marketers must adopt a multifaceted approach by complementing VR initiatives with traditional marketing channels, ensuring equitable access to information and engagement opportunities.

- Health and Safety Risks. The utilization of VR technology may induce adverse physiological and psychological effects, such as motion sickness, disorientation, and eyestrain, among users. These health and safety risks may deter potential customers from engaging with VR car showrooms and negatively impact the overall user experience. To mitigate these risks, it is essential to adhere to industry best practices and consider implementing features that allow users to customize their VR experience according to individual comfort levels.

Benefits:

- Enhanced Customer Engagement: The immersive nature of VR technology facilitates an interactive and engaging experience, enabling potential customers to explore and personalize vehicles in a virtual environment. This heightened level of engagement fosters a deeper emotional connection with the brand, ultimately increasing the likelihood of customer conversion.

- Comprehensive Product Visualization: VR Car showrooms provide users with the ability to customize and visualize vehicles with unparalleled detail, enabling a more accurate representation of the final product. This affords customers greater confidence in their decision-making process, as they can thoroughly explore different configurations before making a purchase.

- Streamlined Sales Process: The utilization of VR Car showrooms can significantly expedite the sales process by allowing customers to examine various configurations and options in a virtual setting. This diminishes the need for physical showrooms and inventory, subsequently reducing overhead costs and improving the overall efficiency of the sales process.

- Real-time Data Collection and Analysis: The integration of VR Car showrooms with data analytics tools can offer invaluable insights into customer preferences and behavior. This real-time data collection enables marketers to ascertain trends,

optimize product offerings, and tailor marketing strategies based on consumer demand.

- Expanded Market Reach: The digital nature of VR Car showrooms permits the transcendence of geographical boundaries, providing automotive manufacturers with the ability to reach a global audience. This increased market exposure can lead to greater brand recognition and a broader customer base.
- Sustainable Practices: The transition from physical showrooms to virtual environments not only reduces overhead costs but also promotes environmentally-friendly practices. VR Car showrooms minimize the need for printed marketing materials, the production of which entails significant resource consumption and waste generation.

Virtual Reality technology has revolutionized the automotive marketing landscape by providing immersive and interactive experiences for potential customers. VR car showrooms have become increasingly popular as they facilitate personalization, foster emotional connections, and enhance brand engagement. However, despite these apparent benefits, the implementation of VR car showrooms is not without risks. By addressing privacy and security concerns, overcoming technological limitations, bridging the digital divide, and ensuring user health and safety, marketers can harness the full potential of VR car showrooms and increase customer engagement in a responsible and effective manner.

PRACTICAL PART

4. Developing the VR Car showroom

The main objective of the project is to create a virtual reality application with the ability to view a model of the cars. The functionality of the project is the ability to move around the designed playground and the opportunity to view the car from all sides.

A VR Car showroom empowers users to explore, customize, and visualize vehicles in a highly immersive and interactive virtual environment. Utilizing the capabilities of the Unreal Engine, a leading game engine known for its photorealistic rendering and robust support for VR, developers can create a cutting-edge showroom that enhances the customer journey and fosters deeper engagement. The equipment will be the VR-Headset HTC Vive. Development takes place on a Lenovo Lenovo ThinkBook 16p G2 ACH laptop.

Developing a VR car showroom in Unreal Engine will require a team with a variety of skills and experience. In my work, I will use the ready-made car model, which is available in the epic games marketplace for general access, and incorporate VR space into it. The VR space will allow the user to experience the experience of interacting with the VR car showroom. The development of a VR application will consist of 4 key considerations:

1. 3D Modeling: High-quality 3D models of vehicles and their components are required for an immersive VR experience. These models should be detailed, accurate, and optimized for real-time rendering in the Unreal Engine. Importing CAD data, retopology, and level of detail techniques can be employed to achieve the desired balance between visual fidelity and performance.
2. Materials and Textures: Realistic materials and textures enhance the visual appeal of the VR Car showroom. Physically-based rendering (PBR) materials, supported by the Unreal Engine, can be utilized to create realistic representations of car paint, upholstery, and other components. Additionally, texture maps such as albedo, normal, roughness, and metallic should be generated and imported for a convincing appearance.
3. Lighting and environment: Accurate and aesthetically pleasing lighting is paramount for achieving photorealistic visualization in the VR Car showroom. Unreal Engine's powerful real-time ray tracing capabilities can be harnessed to create realistic reflections, shadows, and global illumination, providing users with a lifelike and immersive experience.
4. Developing VR functionality: Implementing locomotion methods in a VR car showroom is essential for user navigation and maintaining a comfortable experience. There are various locomotion techniques, each with its pros and cons. In this paper the method of teleportation will be implemented.
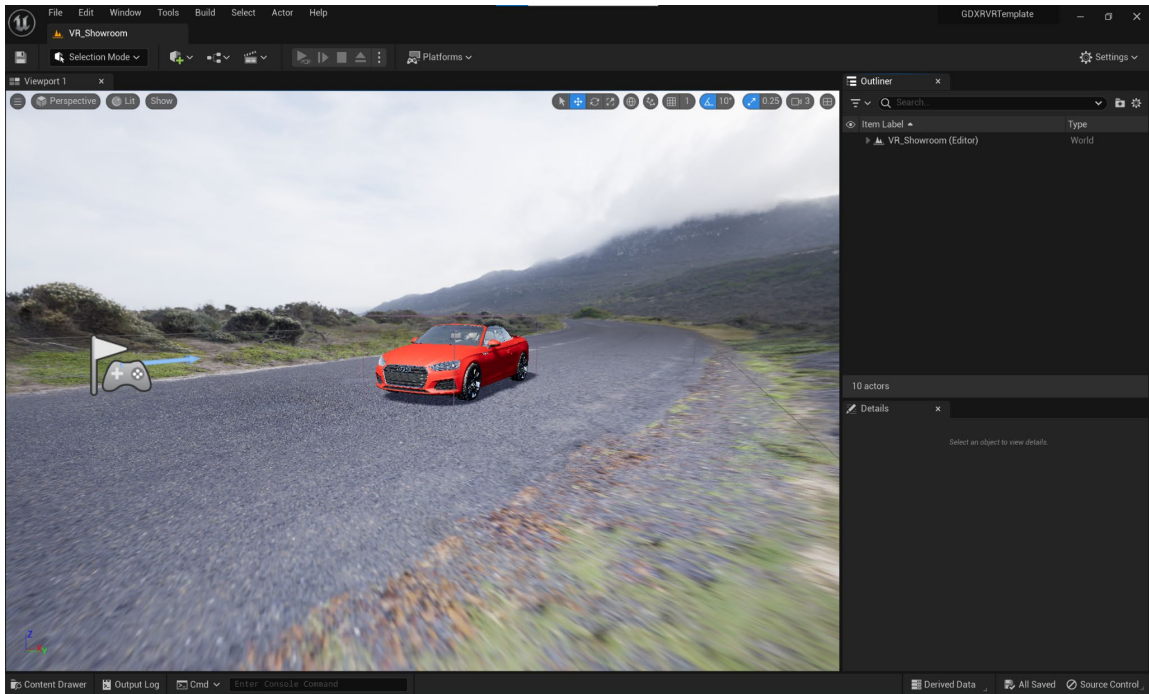
Figure 17. VR Showroom Unreal Engine viewport
SOURCE: Own elaboration

4.1. 3D Modeling

The project uses a 3D model of the car Audi a5. It is a high-resolution multi-component model. The first step to using a 3D model in Unreal Engine's Car showroom is to import the model into the engine. The model can be acquired from a variety of sources, such as official manufacturer's assets or a 3D artist. The model should be in a format compatible with Unreal Engine, such as FBX (Filmbox), OBJ (Object file), or glTF (GL Transmission Format).

Acquiring the Model

Before importing the 3D model of the car into Unreal Engine, I will need to obtain the model from a reliable source. There are a few options to consider:

- Official manufacturer's assets: Reach out to Audi directly to request access to their 3D model assets for the car. This approach ensures the highest quality and accuracy of the model.
- Third-party marketplaces: Platforms such as TurboSquid, CGTrader, or Sketchfab offer high-quality 3D models for purchase. Make sure to select a model that has been optimized for real-time rendering and game engines.

- Custom creation: If we have the necessary skills or resources, we can create a custom 3D model of the car using 3D modeling software like Autodesk Maya, 3ds Max, or Blender.

As said before, we use a 3D model of the car from a free resource.

Figure 18. 3D model of car
SOURCE: Own elaboration

Preparing the Model

Before importing the model into Unreal Engine, I need to make some adjustments to ensure it is optimized for real-time rendering:

- Optimize the mesh: Reduce the polygon count of the model to improve performance, while maintaining the overall quality and detail. This can be done using retopology tools in my 3D modeling software.
- UV mapping: Ensure the model has proper UV maps to avoid texture stretching and allow for the accurate application of materials.
- Rigging: If we plan on animating parts of the car, such as doors, wheels, or suspension, we will need to rig the model with bones or other deformers.
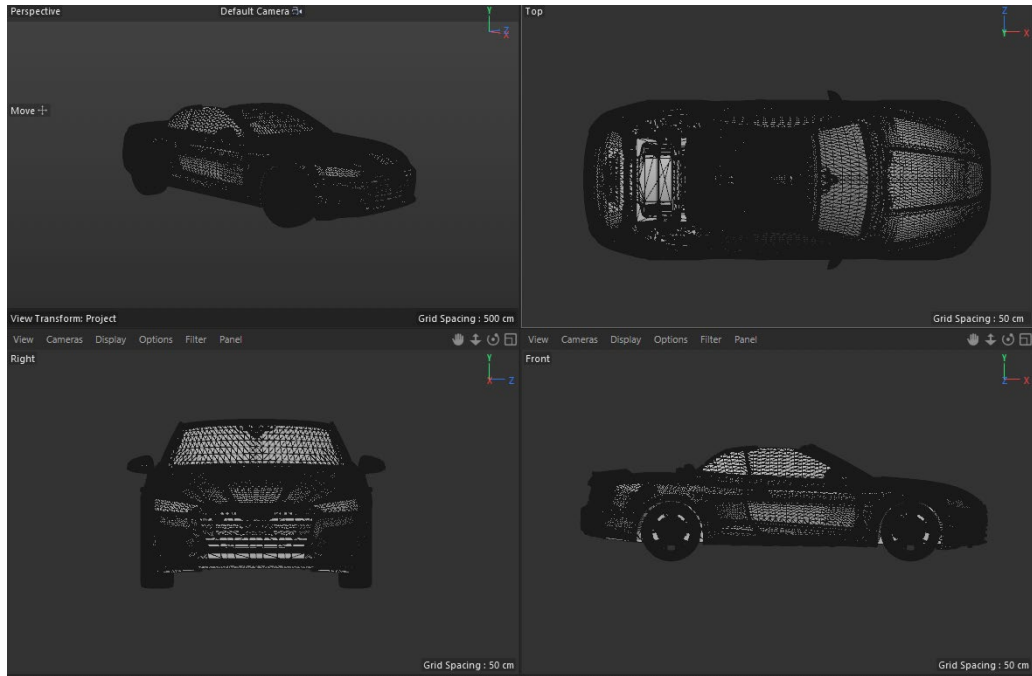
Figure 19. High-polygonal 3D model of car
SOURCE: Own elaboration

Importing the Model into Unreal Engine

Once the 3D model of the car is ready, we can import it into Unreal Engine. Ensure the model is in a compatible format: Unreal Engine primarily supports FBX, OBJ, and glTF file formats. If my model is not in one of these formats, we will need to convert it using my 3D modeling software or a dedicated conversion tool.

In Unreal Engine, open the Content Browser and click the "Import" button. Navigate to the location of my 3D model file, select it, and click "Open." A dialog box will appear with import options, such as mesh, materials, and textures. Adjust these settings as needed and click "Import."

After importing, the car model will appear in the Content Browser. Double-click the model to open it in the Static Mesh Editor. Check for any issues with the model, such as incorrect scale, missing parts, or flipped normals. If we find any problems, correct them in my 3D modeling software and re-import the model.

By carefully following these steps, we can successfully import a high-quality 3D model of the car into Unreal Engine, setting the foundation for my Car showroom project.

Figure 20. 3D model of car in Unreal Engine
SOURCE: Own elaboration

4.2. Materials and Textures

After importing the 3D model, we'll need to set up the materials for the car. In Unreal Engine, materials are created using a node-based system called the Material Editor. We'll need to create and assign materials for different parts of the car, such as the body, glass, tires, and interior. For a more realistic appearance, use PBR materials, which take into account the properties of the surfaces being rendered, such as roughness, metallic, and normal maps.

Creating realistic and visually appealing materials is a crucial aspect of setting up a 3D model of the car in Unreal Engine. It is essential to ensure that the materials properly simulate the appearance of real-world materials, such as car paint, metals, leather, and rubber. The process of setting up the materials involves several important steps:

To begin, we'll need to analyze the 3D model and identify the different parts that require unique materials. Common components of a car model include the body, glass, interior surfaces, wheels, and lights. It is helpful to create a list or schematic of these components and their corresponding materials to guide my work.

For each material ,we'll need to gather or create texture maps that define various properties of the surface, such as its color (albedo), roughness, metallicity, and normal

(bumpiness). High-quality texture maps are vital for achieving a realistic appearance, so it's essential to use detailed, high-resolution images or procedural textures. We may need to create these textures using dedicated software like Substance Painter or Photoshop, or source them from online resources.
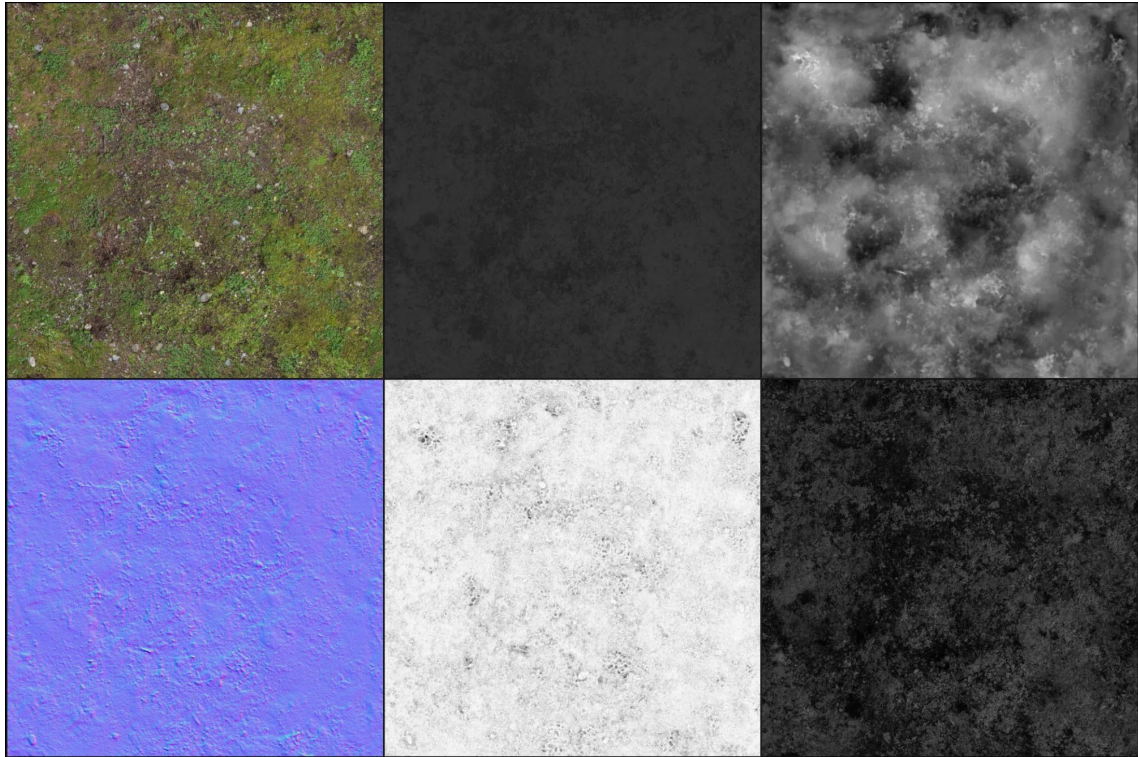
Figure 21. The texture maps
SOURCE: https://www.cgdirector.com/normal-vs-displacement-vs-bump-maps/

With my texture maps prepared, we can create materials in Unreal Engine using the Material Editor. The Material Editor is a node-based system that enables and creates complex materials by combining and modifying various properties and maps. For each material,we'll need to import my texture maps and create appropriate connections between nodes to define the material's appearance. We should consider using PBR materials, which provide a more realistic rendering by accounting for the physical properties of the surfaces being rendered.
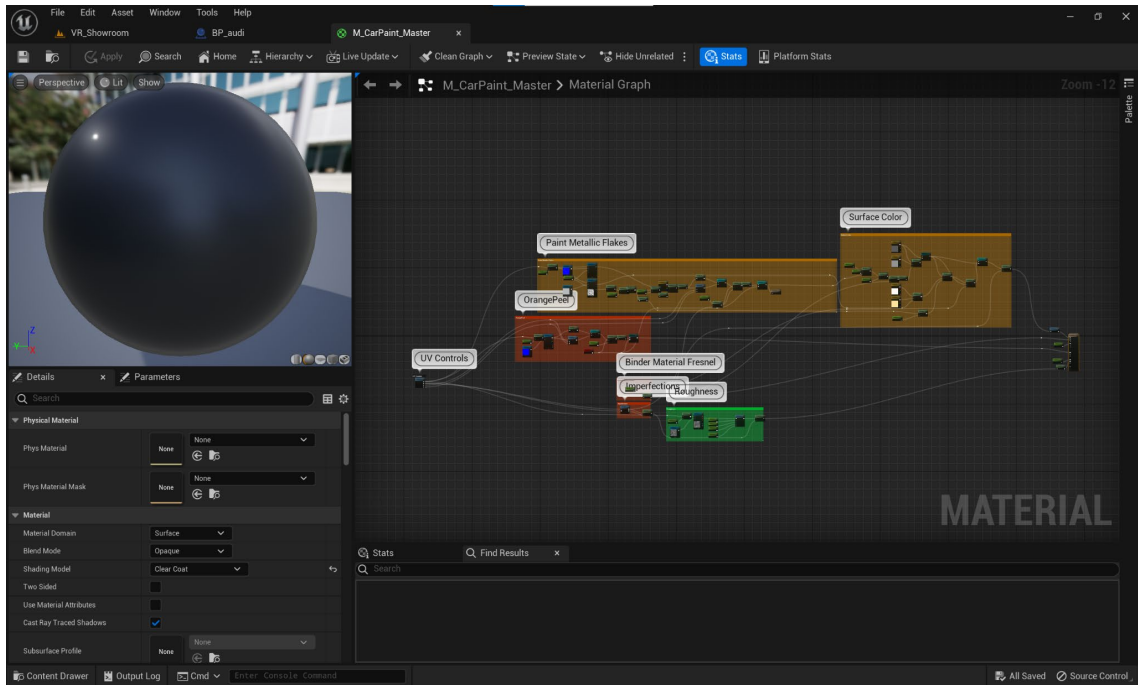
Figure 22. The Material Editor
SOURCE: Own elaboration

To create a flexible and easily customizable system for the car materials, we can use Material Instances and Parameterization. Material Instances are derived from a parent material and can have their parameters adjusted independently, allowing for quick and efficient changes to the appearance of the car. For example, we could create a parent material for the car paint, and then generate Material Instances with different colors or finishes (e.g., metallic, matte, or pearlescent). By parameterizing certain properties of the materials, such as color or roughness, we can expose these values to the Car showroom interface, enabling users to make customizations.
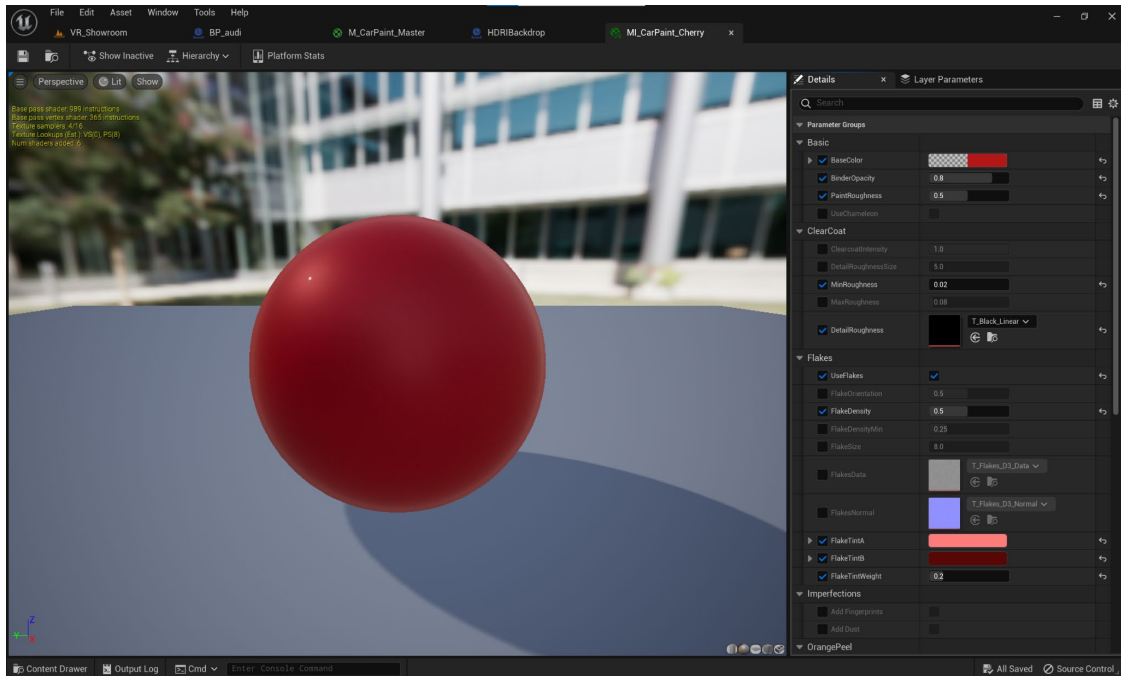
Figure 23. The Material Instance
SOURCE: Own elaboration

Once we have created the materials for the car, we'll need to assign them to the appropriate parts of the 3D model. This can be done in Unreal Engine's Static Mesh Editor or by selecting the individual components of the car in the main editor viewport. Ensuring that each material is correctly assigned will result in a more accurate and visually appealing representation of the car.

By setting up high-quality materials for the car and organizing them in a flexible and easily customizable manner, we can create a Car showroom experience that is both visually impressive and engaging for users.

Figure 24. The materials are configured
SOURCE: Own elaboration

4.3.   Lighting and environment

Setting up proper lighting and environment are crucial to accurately showcase the car model and enhance the overall experience of the Car showroom. Here are some more in-depth considerations for creating the ideal lighting and environment scenario:

When setting up lighting in Unreal Engine, we have the option to choose between dynamic and static lighting. Dynamic lighting allows for real-time changes in light sources and shadows, while static lighting is precomputed and baked into the environment. Although dynamic lighting offers more flexibility and interactivity, it can be more resource-intensive. Static lighting, on the other hand, provides better performance but lacks real-time adaptability. Depending on my project requirements, we may choose one or a combination of both.

Unreal Engine offers various light types, such as Directional, Point, Spot, and Rectangular lights. Each light type has its characteristics and uses. For instance, Directional lights can be used to simulate sunlight, while Point lights can represent small light sources like lamps. Experiment with different light types and their placement to create a well-lit environment that highlights the car's design features.

High Dynamic Range Imaging (HDRI) is a technique that captures a wider range of brightness values than traditional photography, allowing for more realistic lighting and reflections. Unreal Engine supports the use of HDRIs for image-based lighting (IBL), which can create accurate and natural lighting conditions. By using an HDRI, we can create a convincing environment that complements the car and provides context for the user, such as a virtual showroom or an outdoor scene.

Figure 25. The HDRI light is set up
SOURCE: Own elaboration

Unreal Engine supports ray tracing, a rendering technique that simulates the behavior of light to create realistic reflections, shadows, and global illumination. By enabling ray tracing, we can enhance the Car showroom's visual fidelity and make the car model look more lifelike. However, ray tracing can be resource-intensive and may require more powerful hardware to run smoothly. Carefully consider the trade-offs between visual quality and performance when using ray tracing in my project.

Post-processing effects are visual enhancements applied to the final rendered image, such as color grading, bloom, ambient occlusion, and depth of field. By using post-processing effects in Unreal Engine, we can fine-tune the look of the Car showroom to match my artistic vision and create a more cinematic or stylized presentation. Experiment with different post-processing settings to achieve the desired atmosphere and visual style for my Car showroom.

By focusing on these aspects of lighting and environment, we can create a visually engaging and realistic Car showroom that showcases the car in its best light and provides users with an immersive and enjoyable experience.
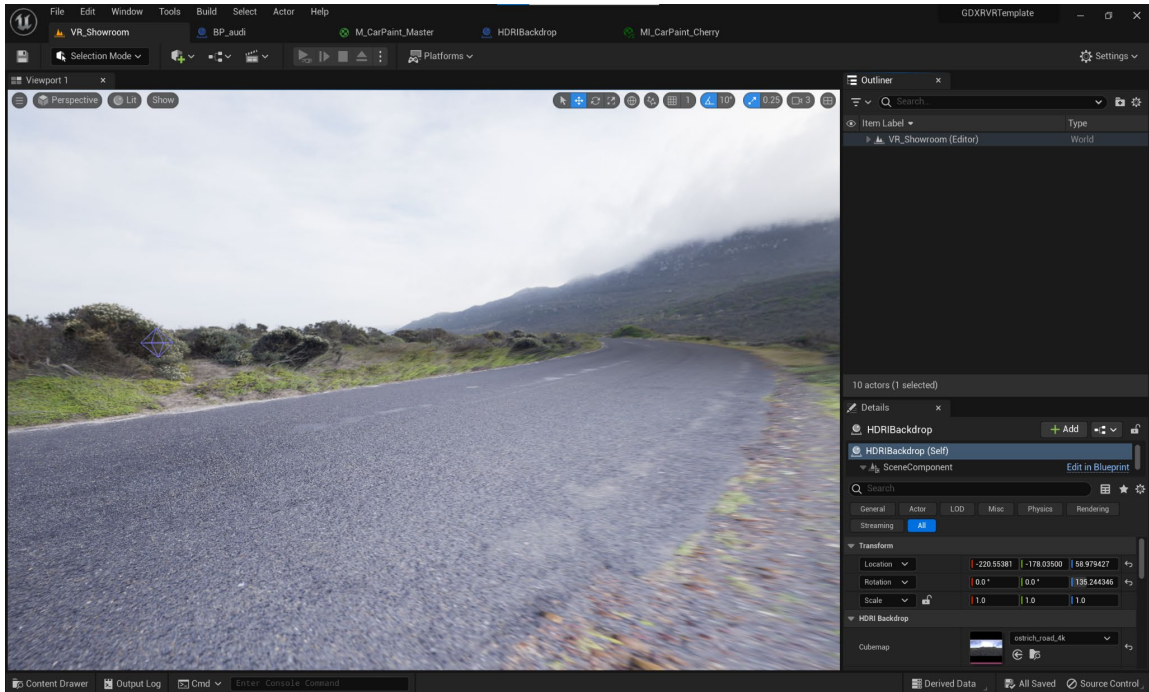

Figure 26. The environment is set up
SOURCE: Own elaboration

4.4. Implementing VR Character

Implementing VR characters in an Unreal Engine VR car showroom can greatly enhance the user experience, provide personalized assistance, offer educational opportunities, and enable businesses to gather valuable feedback. By doing so, businesses can improve customer satisfaction, increase sales, and reduce costs, making it a wise investment for the future of the automotive industry.This project already includes a basic car showroom setup, which can be customized according to my needs. Make sure it has the necessary plugins enabled, such as the "Oculus VR" or "SteamVR" plugins, depending on my target VR platform.

To create a VR character, we can use the built-in VR template provided by Unreal Engine. In the content browser, navigate to the "VirtualRealityBP" folder, and add the "MotionControllerPawn" blueprint to its scene. This blueprint already includes a simple VR character with motion controller support. We may need to adjust the scale, position, and rotation of the character to fit my car showroom scene.
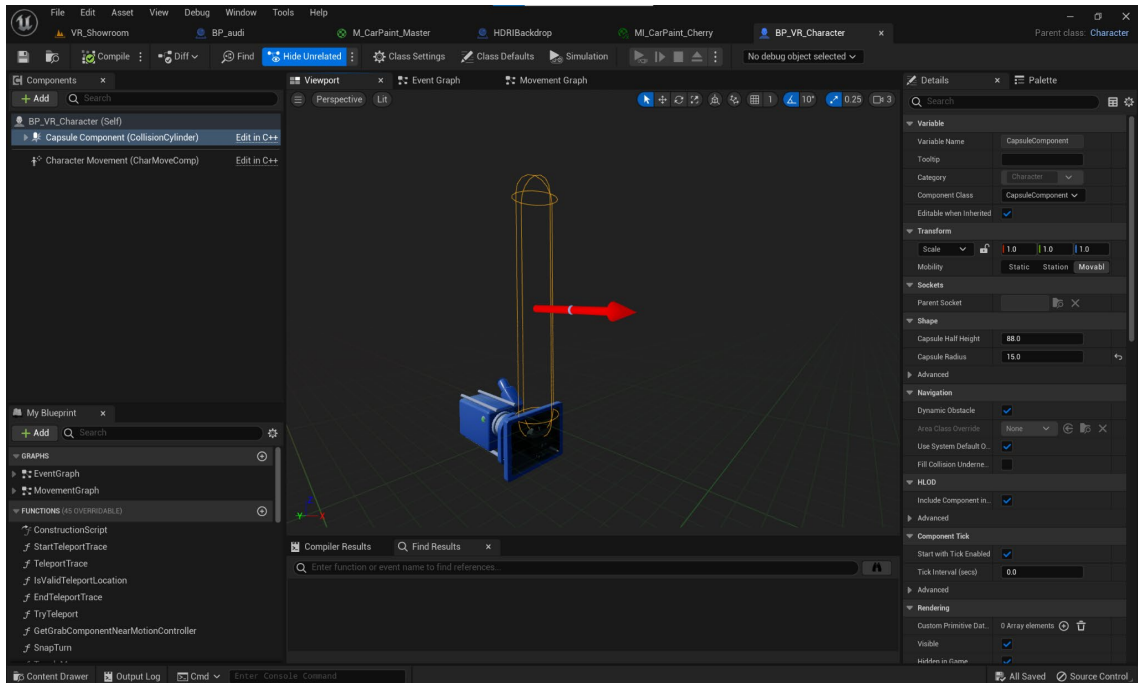
Figure 27. VR Character
SOURCE: Own elaboration

Inside the "MotionControllerPawn" blueprint, we'll find a "MotionController" component for each hand. To customize the appearance of the motion controllers, we can replace the default mesh with a custom model or use the provided "BP_MotionController" blueprint for more advanced functionality, such as haptic feedback or button inputs. Make sure to set up input mappings in the project settings to handle the button inputs from my VR platform.
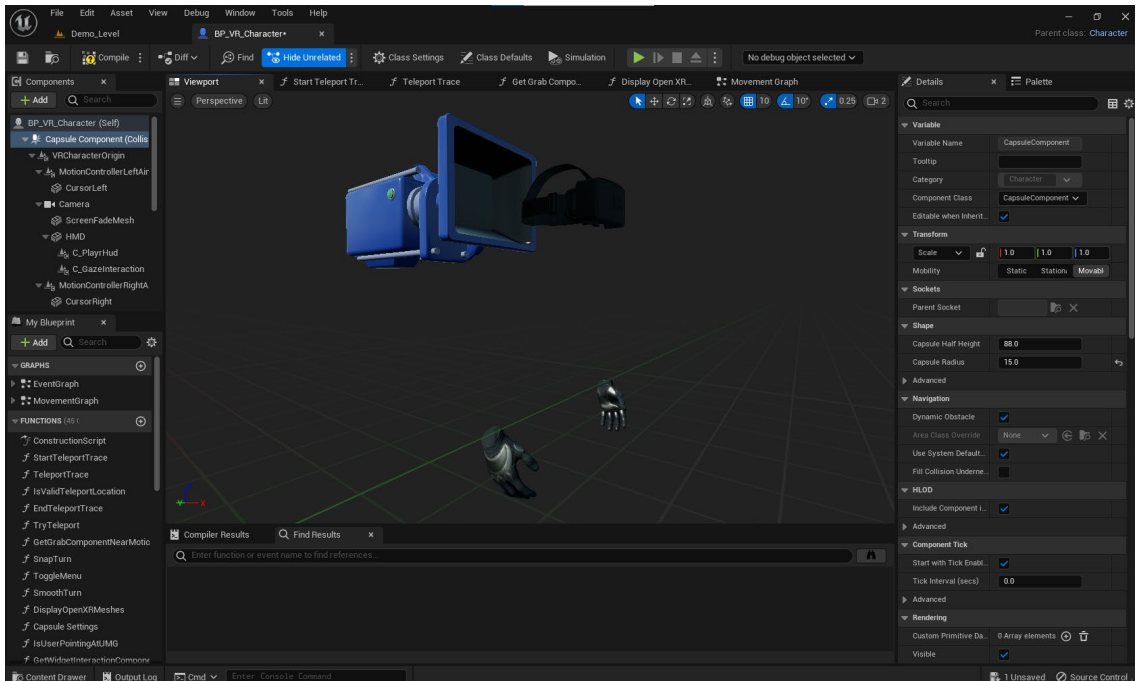
Figure 28. VR Character with Motion Controllers
SOURCE: Own elaboration

By following these steps, we will be able to implement a VR character in a car showroom using Unreal Engine. This immersive experience allows users to explore and customize their dream car in a virtual environment, providing a unique and engaging way to showcase automotive products.

4.5. Developing VR functionality

In this work we are aiming to introduce the VR space and add the ability for the user to move around the space. At this point we have introduced a VR character. Next, we need to implement locomotion methods, such as teleportation or free movement, for user navigation. Teleportation is a widely used locomotion method in VR applications due to its comfort and ease of use. It allows users to instantly move to a selected location in the virtual environment. Free movement, also known as smooth locomotion, replicates real-life walking or gliding through the environment. Users control their movement using the VR controller's joystick or touchpad. In the practical part, teleportation will be implemented.

To do this, we must perform the following steps: implement the teleportation logic, enable teleportation input, create a teleportation visualization, update teleportation visualization during gameplay.

The logic of teleportation consists of several functions: StartTeleportTrace, TeleportTrace, IsValidTeleportLocation, EndTeleportTrace.

StartTeleportTrace is a function in Unreal Engine used to initiate a line trace to determine the destination of a teleportation or movement event. It involves setting up input events, implementing the function, performing a line trace, determining the teleportation destination, providing visual feedback, and executing the teleportation. Using this function, developers can create an engaging and immersive VR experience for players.
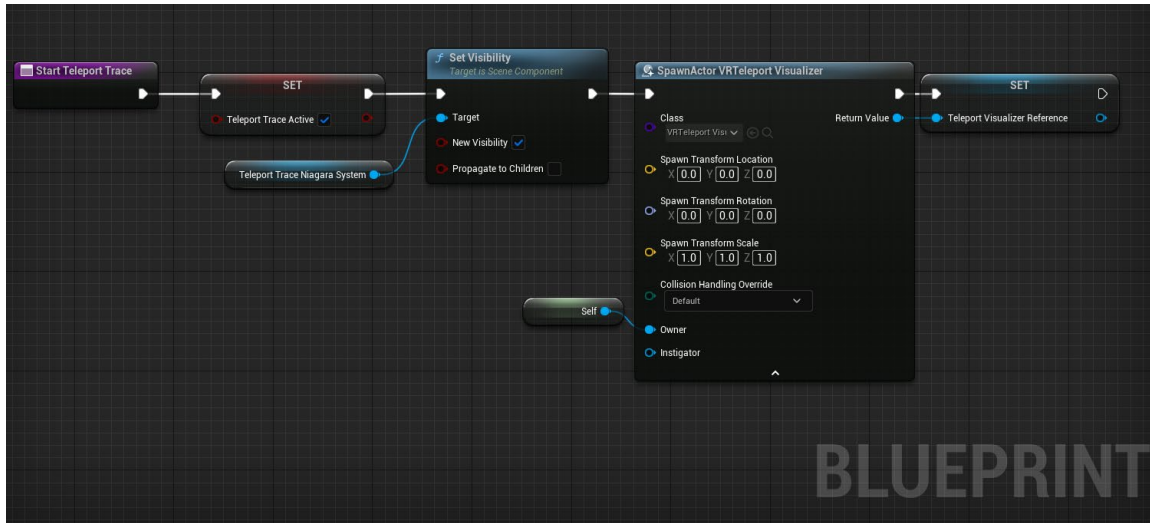
Figure 29. Blueprint of StartTeleportTrace
SOURCE: Own elaboration

TeleportTrace utilizes Unreal Engine's line tracing and collision system to identify a suitable target location for teleportation. This is accomplished by casting a trace from the starting point to the desired endpoint, detecting any potential obstacles or collisions along the way. The primary components involved in this process include:

A. Line Tracing: A technique that involves drawing an invisible line in the game world between two points to detect intersections with game objects.
B. Collision Channels: Define how different objects interact with each other in terms of collisions and overlaps.
C. Hit Result: Contains information about the detected intersection, such as the location, normal, and the hit object.

The IsValidTeleportLocation function checks various factors to determine if a specific location is safe and suitable for teleportation. The primary factors considered are:

A. Collision: The function checks if the desired teleport location is free from any physical collisions with other objects, such as walls, floors, or other game objects.

This ensures that the character or object being teleported does not end up inside another object or in an otherwise inaccessible location.

B. Navigation: IsValidTeleportLocation also checks if the destination is reachable through the game's navigation system. This is important to prevent characters or objects from being teleported to unreachable locations that would break the game's logic or flow.

C. Custom conditions: Developers can implement their own set of rules and conditions to further refine the IsValidTeleportLocation function. These custom conditions could involve game-specific logic or requirements that are important to the overall gameplay experience.

Add NavMeshBoundsVolume to indicate the teleportation area (green rectangle). Limit the teleportation area with NavModifierVolume (empty space inside the green rectangle. In this area will be the car.
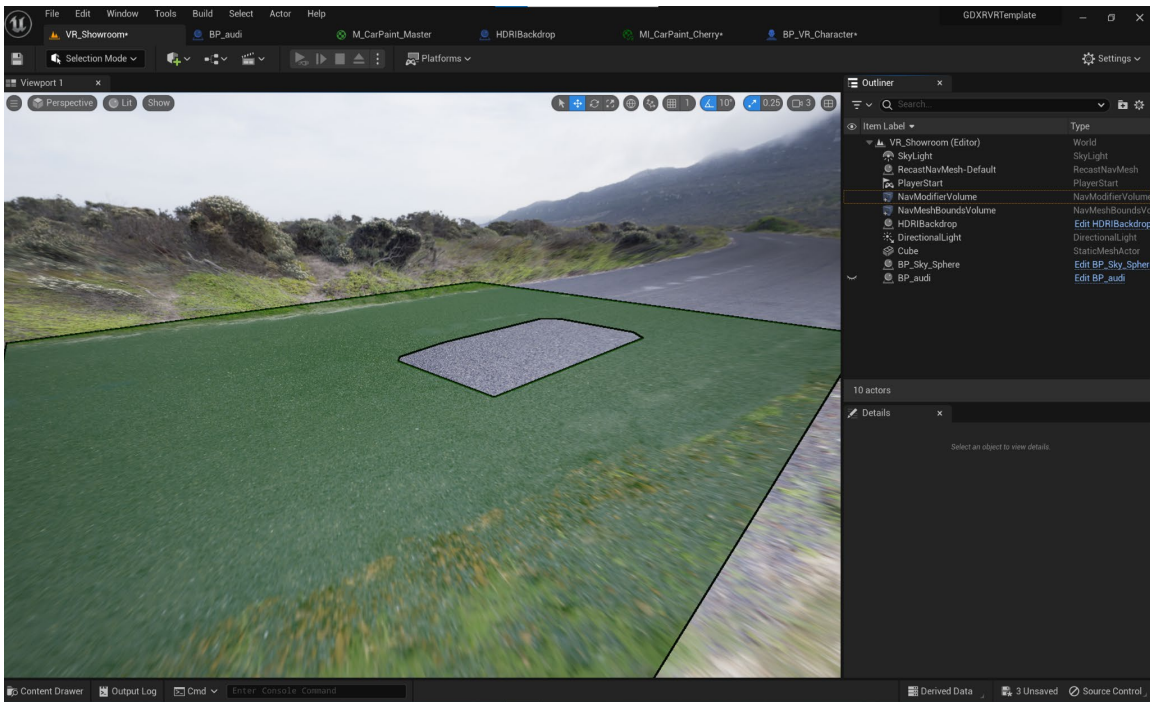
Figure 30. NavMeshBoundsVolume and NavModifierVolume
SOURCE: Own elaboration

EndTeleportTrace is the final step of the teleportation process. Once a valid target location has been determined, this function is called to finalize the teleportation. It moves the player to the target location, applying any necessary adjustments such as updating physics states and playing appropriate animations or sounds. The function would then be called after a successful teleportation trace has been performed and a valid destination has been found.

4.6.   Car showroom

In this project, we will be combining four essential steps - developing virtual reality functionality, lighting and environment, materials and texture, and 3D modeling - to create an immersive and interactive level in the Unreal Engine. The seamless integration of these components is crucial to create a visually appealing and engaging experience for the users. Connect the VR headset HTC Vive. Position the 3D model in the scene. Check the functionality of the VR character.
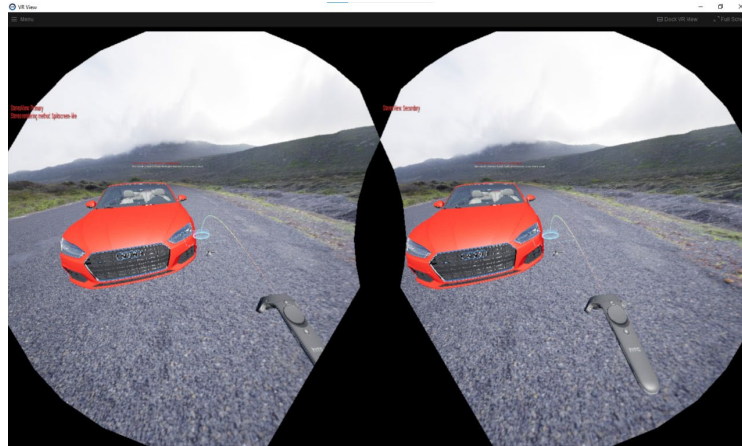
Figure 31. VR Car showroom teleportation
SOURCE: Own elaboration
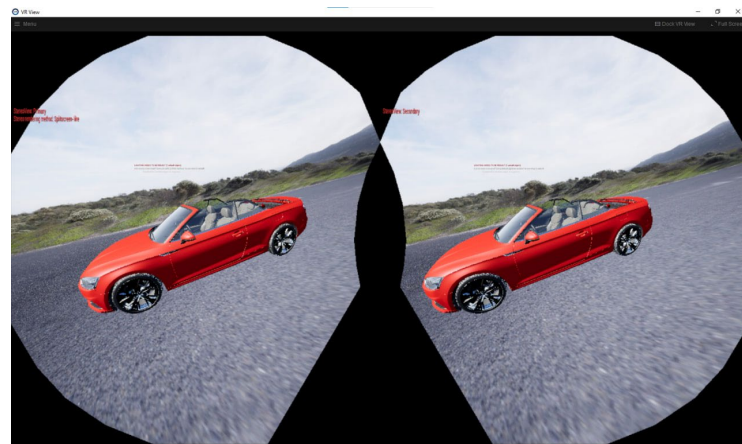
Figure 32. VR car showroom
SOURCE: Own elaboration

5. Conclusion

In the course of the master's thesis work, the object of study of which was selected was the subject of virtual reality, and the application VR Car showroom was developed.

Before the development, it was necessary to solve theoretical issues and consider the concept of virtual reality. Virtual reality evolved gradually, its growth was hampered by the small capabilities of computing devices of those years. Today, more and more new applications and helmets provide a three-dimensional view. Their varieties were analyzed, a type of helmet and the platform for which the development was produced. Virtual reality finds its application both in highly specialized professional fields and in applications designed for a wide audience. However, despite this, there are still not enough products that apply these new technologies. It is the promise of the field and the lack of its elaboration that makes the relevance of the graduate qualification work.

A plan for implementing VR development in the company was developed. The pros and risks of using the technology are listed. Stakeholders were identified as well as the development team and the communication plan. Particular attention is paid to the interaction with virtual reality: control, movement, and navigation. The mechanism of virtual reality helmets is studied. Developing virtual reality has its own subtleties, which often become apparent only when immersed in it.

To complete the project I had to study and delve not only into the chosen topic, but also into the field of application development, programming, 3D modeling, user interface, and exploring the development environment of the Unreal Engine.

In order to ensure that the project is viable with new features and objects, responds to the user in a timely manner, and does not slow down, it is worth considering aspects of optimization in VR development.

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List of Abbreviations

2D   Two-dimensional

3D   Three-dimensional

AI   Artificial intelligence

API   Application programming interface

AR   Augmented reality

AV   Augmented verticality

GPU   Graphics processing unit

FPS   Frames Per Second

OO   Object-oriented

HMD   Head-mounted display

HUD   Head-up display

IoT   Internet of Things

MR   Mixed reality

UE   Unreal Engine

UI   User Interface

UX   User Experience

VR   Virtual reality

RE   Real environment

XR   Extended Reality

CAD   Computer-aided design

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