VSB TECHNICAL UNIVERSITY OF OSTRAVA | FACULTY OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Use of Virtual Reality and/or Augmented Reality Resources to Control and Visualize Processes

Využití prostředků virtuální reality a/nebo rozšířené reality pro řízení a vizualizaci procesů

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Diploma Thesis

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2. Analysis of the specified technology, tools and possibilities for its visualization and control/management using means of virtual or augmented reality.
3. Decision and selection of a partial part of the technology for the pilot implementation of the use of virtual/augmented reality both from a technical and program point of view and verification of operation in real conditions.
4. Evaluation of the implemented design and partial solution.

References:

[1] Schmalstieg, D., Hollerer, T.: Augmented reality: Principles and practice. Addison-Wesley, Boston 2016 ISBN 9780321883575
[2] Jason, J.: The VR book. Human-centered design for virtual reality. MC, 2016 ISBN:9781970001129

Extent and terms of a thesis are specified in directions for its elaboration that are opened to the public on the web sites of the faculty.

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Abstract

This thesis investigates the use of virtual reality (VR) and/or augmented reality (AR) resources for process control and visualization. The research looks on the usefulness of these technologies in improving understanding and management of complex processes in industries such as manufacturing, construction, and healthcare. A comprehensive evaluation of the literature on VR and AR suggests that these tools provide considerable benefits, such as better safety, efficiency, and accuracy, as well as improved visibility and control of operations. The thesis also discusses the obstacles and constraints of employing virtual reality and augmented reality resources in process management and visualization, such as technological issues, cost, and user acceptability. The diploma thesis focuses on managing real-world equipment from a virtual environment using the ESP8266 Board, Unity VR platform, and Google Firebase database for online data transmission. This procedure may be used in a variety of sectors where it is impossible to get to a certain spot in the actual world but a clear vision of the location is necessary for operating certain equipment, which is provided by the virtual world with the assistance of VR googles.

Abstrakt

Tato práce zkoumá využití zdrojů virtuální reality (VR) a/nebo rozšířené reality (AR) pro řízení a vizualizaci procesů. Výzkum se zaměřuje na užitečnost těchto technologií při zlepšování porozumění a řízení složitých procesů v průmyslových odvětvích, jako je výroba, stavebnictví a zdravotnictví. Komplexní hodnocení literatury o VR a AR naznačuje, že tyto nástroje poskytují značné výhody, jako je lepší bezpečnost, účinnost a přesnost, stejně jako lepší viditelnost a kontrola operací. Práce také pojednává o překážkách a omezeních využívání virtuální reality a zdrojů rozšířené reality v procesu řízení a vizualizace, jako jsou technologické problémy, náklady a uživatelská přijatelnost. Diplomová práce se zaměřuje na správu reálného zařízení z virtuálního prostředí pomocí desky ESP8266 Board, platformy Unity VR a databáze Google Firebase pro online přenos dat. Tento postup lze použít v různých sektorech, kde není možné se dostat na určité místo ve skutečném světě, ale pro ovládání určitého zařízení je nutná jasná vize místa, kterou poskytuje virtuální svět s pomocí VR. google.

Keywords

Tracking, Markers, Registration, Sensor fusion, Virtual reality, Augmented reality, Universal Render Pipeline, Application Programming Interface, Extended Reality, User Interface.

List of Abbreviations:

1 AR - Augmented Reality

2 VR - Virtual Reality

3 3D - Three Dimensional

4 HMD - Head Mounted Display

5 PC - Personal Computer

6 LCD - Liquid Crystal Display

7 GIS - Geographic information systems

8 GPS - Global Positioning System

9 CT – Computed Tomography

10 MRI – Magnetic Resonance Imaging

11 CAD – Computer Aided Design

12 ARES - Aerospace Relay and Electronics System

13 HUD – Head Up Display

14 FPV – First Person View

15 SLAM - Simultaneous Localization and Mapping

16 LIDAR - Light Detection and Ranging

17 LED - Light Emitting Diode

18 IDE - Integrated Development Environment

19 ESP - Embedded System Processor

20 USB - Universal Serial Bus

21 API - Application Programming Interface

22 REST - Representational State Transfer

23 HTTP - Hypertext Transfer Protocol

24 XR - Extended Reality

25 UI - User Interface

26 URL - Uniform Resource Locator

27 JSON - JavaScript Object Notation

28 URP - Universal Render Pipeline

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1 Introduction

Researchers and scientists have made it their mission to understand how the world is embracing technological development. The introduction and development of augmented reality and virtual reality have made it feasible for people to find new ways to become engrossed in virtual worlds or to bring such worlds closer to reality. The actual world is enhanced via augmented reality, which combines the real world with computer-generated additions such images, texts, and three-dimensional (3-D) objects. People have a new way to experience the world thanks to augmented reality. Additionally, reputable organizations like the American Times Weekly have listed it as one of the top ten most promising technologies for the future. AR is a subset of a more general idea(MR). Mixed Reality is a term for a broad range of topics that includes AR, telepresence, virtual reality (VR), and other technologies that are related.[23] AR sits between telepresence and virtual reality. Virtual reality is a 3D computer-generated environment that people may enter and interact with via a variety of various devices, such as headsets and handhelds, that they can fully immerse themselves in. [24] The potential for augmented reality is to combine the digital and physical worlds in a direct, automatic, and usable way. It offers a straightforward and immediate user interface to a physically enhanced electronic world. Incorporating computer-generated data atop real-world imagery, augmented reality (AR) fundamentally alters how humans see and think. AR can be defined by the following four characteristics: (1) Integration of the physical and digital worlds; (2) Real-time interaction; (3) 3D registration; and (4) A portability factor.

Further these three fundamental ideas—intelligent display technology, 3D registration technology, and intelligent interaction technology—are essential to the development of AR and VR.[7]

1)Technology for intelligent displays:

Humans gather 65% of their information through their own vision, so information through display technology becomes a central idea of augmented reality (AR). Three different types of devices are being used to immerse people through their vision: handheld (portable), PC desktop display, and helmet mounted display (HMD), which is the most immersive but also the most expensive.

2)3D registration technology:

The exact overlay of virtual images in the actual world is made possible by 3D registration technology. First, ascertain how the model, the virtual picture, and the direction and position data of the camera or display device are related. Second, the rendered virtual image and model are precisely projected into the actual world, allowing them to blend with the actual environment.

3)Intelligent interaction technology:

Hardware device interactions, location interactions, tag-based interactions, and other information-based interactions are just a few examples of the several sorts of interactions that can occur in augmented reality.

This technology enables user interaction with virtual items in real-world environments, which leads to improved experiences overall.

Virtual Reality (VR) and Augmented Reality (AR) are rapidly developing technologies that have the potential to revolutionize the way we interact with and visualize processes in various industries. VR technology immerses users in a simulated environment, while AR overlays digital information onto the real world. Both VR and AR offer an unprecedented level of control and visualization that can be used to enhance processes across a wide range of applications. In my thesis, I go into great detail on VR implementation in the experiment section, where I operate a real-world device with the assistance of a virtual world and a sliding door in the virtual world with the help of a switch in the real world. We can conclude from this experiment that with the help of AR/VR, we can control various industrial equipments that are otherwise unreachable and have a clear description and view because the control is not just happening with the help of Scada systems but is also clearly explained because the virtual environment depicts the real world environment as it is.

2 History of augmented reality

In the 1960s, the first computer-generated annotations of the real world appeared. The field that eventually gave rise to both VR and AR can be credited to Ivan Sutherland. He proposed the ultimate display in an essay that contains the well-known remark below in 1965.

The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked. In 1968, Sutherland built the first VR system. Called Sword of Damocles (Figure 2.1), it employed see-through optics and head tracking but had to be hanging from the ceiling because to its weight.

Figure 2.1 Sword of Damocles (Worlds first HMD built in 1968 by Sutherland) [1]

The term "augmented reality" was first used in 1992. This term initially arose in the work of Caudell and Mizell at Boeing in 1992, who aimed to help workers in an aviation manufacturing by presenting wire bundle assembly drawings in a see-through HMD. Fitzmaurice developed the first portable spatially aware display in 1993, which was a forerunner to handheld augmented reality. Using a magnetic tracking mechanism, the LCD panel displayed the video output of an SGI graphics workstation at the time. State et al. from the University of North Carolina at Chapel Hill demonstrated a fascinating medical augmented reality (AR) application in 1994 that allowed a doctor to view a fetus inside a pregnant patient directly. This provides a broad overview of what AR can accomplish in the medical industry in the future. The first cooperative AR system, Studierstube, was created in 1996 by Schmalstieg et al. Multiple users could interact with virtual objects in the same shared space with this technique. Before 1999, there was no AR software outside of specialized research labs. When Kato and Billinghurst [1999] launched ARToolKit, the first open-source software platform for AR, the situation was altered. It included a 3D tracking library that made use of laser-printable black-and-white fiducials for tracking. The first actually practical natural feature tracking system for cellphones wasn't introduced for several years, not until 2008. This project evolved into the forerunner of the well-known Vuforia toolkit for AR developers. These discoveries serve as a stepping stone for what's to come even though we currently have a number of platforms for AR and VR to work on. [23]

3 Issues of virtual and augmented reality for the control/management and visualization of technological processes

Virtual and augmented reality have the potential to revolutionize the control, management, and visualization of technological processes. However, there are several issues that need to be addressed to fully realize this potential.

Effective user interfaces:

One of the main challenges is the development of effective user interfaces. Virtual and augmented reality systems can provide a wealth of data and information, but if the user interface is poorly designed or difficult to use, the benefits of the technology may be lost. Designing effective interfaces requires an understanding of the specific needs and requirements of the user, as well as an understanding of the technology itself. [13]

Integration with existing systems:

Another challenge is the integration of virtual and augmented reality with existing systems. Many industrial and manufacturing processes are highly complex, and integrating virtual and augmented reality technology into these systems can be challenging. This requires careful planning and coordination to ensure that the technology is integrated seamlessly and that it does not disrupt existing processes. [14]

Need for accurate and reliable data:

Virtual and augmented reality systems rely on data from sensors and other sources to provide real-time information about the process being monitored or controlled. If this data is inaccurate or unreliable, the effectiveness of the technology can be compromised. [18] As virtual and augmented reality systems rely on data from sensors and other sources to provide real-time information about the process being monitored or controlled, the referenced article discusses the significance of accurate and reliable data and how it can compromise the effectiveness of the technology.

Safety and security of virtual and augmented reality systems:

There are concerns about the safety and security of virtual and augmented reality systems. As these systems become more prevalent, there is a risk that they could be hacked or otherwise compromised. Ensuring the safety and security of these systems is essential to their widespread adoption and use and to prevent potential harm to users and organizations.[16]

3.1 Adverse health effects

Discomfort, Headaches, Eye Strain, and Fatigue:

Extended use of VR headsets can cause discomfort, headaches, eye strain, and fatigue due to the high intensity and prolonged exposure to the screens. This is known as "virtual reality syndrome" and can be caused by a variety of factors, including the weight of the headset, the brightness of the screens, the resolution of the displays, and the distance between the lenses and the eyes.

Motion Sickness and Nausea:

Some users may experience motion sickness or nausea when exposed to certain types of VR content. This is caused by a mismatch between the visual information presented to the eyes and the physical sensations of the body. For example, if the user is stationary but the VR environment is moving, or if the user is moving but the VR environment is stationary, this can cause motion sickness and nausea.

Physical Injury:

There is also a risk of physical injury if users trip or collide with objects while wearing the headset if we are using without proper guardian mode turned ON. Users may be unaware of their surroundings while immersed in the VR environment, which can increase the risk of accidents and injuries. It's important for users to clear their surroundings before using VR and to be aware of their surroundings while wearing the headset.

Decreased Social Interaction and Physical Activity:

Prolonged use of VR can also lead to decreased social interaction and physical activity, which may have negative impacts on mental health and overall well-being. VR experiences can be immersive and engaging, but they are also isolating, which can lead to a lack of social interaction. Additionally, users may become so engrossed in the VR environment that they neglect physical activity, which can lead to negative health outcomes.

Psychological Effects:

Some users may experience psychological effects from using VR, including anxiety, fear, and confusion. VR experiences can be intense and immersive, which can trigger emotional responses. Some users may also have difficulty distinguishing between the virtual environment and reality, which can lead to confusion and disorientation.

Addiction:

Finally, there is a risk of addiction associated with VR use. VR experiences can be highly engaging and immersive, which can lead to compulsive use and addiction. Users may neglect other aspects of their lives in favor of VR, which can lead to negative health and social outcomes. (2)

3.2 Overcoming the negative adverse health effects

To create VR systems that promote healthy use and mitigate the potential adverse health effects associated with VR use, designers should consider several guidelines. First, the VR headset should be ergonomically designed to reduce discomfort and fatigue, with an evenly distributed weight, adjustable straps, and proper ventilation. Second, the display quality should be optimized to reduce eye strain and motion sickness, with an adjustable resolution, brightness, and refresh rate. Third, the field of view (FOV) should be optimized to provide a natural and immersive experience without causing discomfort or nausea, with a comfortable FOV of around 100 degrees. Fourth, the method of locomotion within the virtual environment should be carefully designed to reduce motion sickness, with options for different types of locomotion and consideration of user preferences. Fifth, the VR experience should be interactive and engaging, but not overly intense or stressful, with breaks and pauses to allow for rest and recovery. Sixth, the VR environment should be designed with safety in mind to prevent physical injury, with clearly marked obstacles and warnings of potential risks. Seventh, social interaction should be encouraged within the VR environment to mitigate the negative impacts of isolation, with options for multiplayer experiences and social VR platforms. Eighth, the VR experience should be accessible to users with disabilities or special needs, with options for navigation without relying on visual cues and audio descriptions or subtitles for users with visual impairments. By following these guidelines, designers can create VR systems that promote healthy use and mitigate the potential adverse health effects associated with VR use.

4 Possibilities of visualization and control/management using AR/VR

Visualization of intricate systems and information:

VR/AR may be used to provide interactive visualizations of intricate information, such as scientific simulations or imaging simulations. This can aid in the improved comprehension and communication of the data by academics and practitioners, resulting in more sensible decisions. For instance, VR and AR may be used in scientific simulations to build interactive 3D models of complicated molecules or other structures that can aid researchers in understanding the structure and behavior of these systems. Similar to this, medical practitioners may study and comprehend complicated medical data by using VR and AR to produce 3D renderings of the human body in medical imaging. [17]

Interactive education and training:

For interactive teaching and education, VR/AR can be employed. For instance, workers may be instructed on new equipment in a secure virtual environment while medical students can perform surgical operations in a simulated setting.

Remote cooperation and communication:

VR/AR can make it possible for users to cooperate and communicate remotely. For instance, engineers can work together in real-time on a 3D model from various places, or a remote technician can use augmented reality overlays to lead an on-site worker through a repair. [18] Tasks involving maintenance and repair can be improved using VR/AR. VR simulation may be used to test and improve maintenance techniques before implementing them in the real world, or an AR overlay might give a technician real-time information on a machine's state.

Control and management of machines and systems:

In manufacturing and industrial environments, VR/AR may be utilized to control and manage machines and systems. For instance, a supervisor may use VR to watch over and oversee a convoluted supply chain, or an operator can utilize AR overlays to operate a robot on the manufacturing floor.

5 Types of VR

Desktop VR:

A desktop computer and a VR headset are required to experience this form of VR. For user input, a gamepad, keyboard, and mouse are frequently used. Desktop VR experiences are typically more accessible and less expensive than fully immersive VR experiences, although they are typically less immersive.

Fully immersive VR:

A kind of VR known as fully immersive VR gives the user a completely immersive experience. Wearing a headgear that covers the user's whole field of vision is customary for this kind of VR, which also includes extra sensory input like haptic feedback. By moving their bodies or utilizing handheld devices, the user may interact with the surroundings.

360-Degree Video:

A kind of VR called 360-Degree Video enables viewers to see video material in an immersive manner. Users are able to glance around in any direction as if they were actually there. The entertainment, tourism, and real estate sectors frequently employ this kind of VR.

Web-based VR:

VR that can be viewed through a web browser without the use of extra gear or software is known as web-based VR. Though less immersive than other forms of VR, it is more widely available and simpler to use. Virtual reality on the web has several uses, including e-commerce, education, and virtual events.

Social VR:

A particular kind of VR experience called social VR enables users to communicate with others in a virtual setting. Gaming, socializing, remote work and collaboration, and virtual events can all be done in social VR. Depending on the gear and software being utilized, social VR experiences might be totally immersive or less immersive. (Figure 5.1)

Figure 5.1 VR Chat with other human players [19]

6 Types of AR

Marker-Based AR:

Marker-based AR places virtual things in the actual environment by using a specific picture, symbol, or marker as a reference point. The marker is recognized by the camera on the mobile device or wearable gadget, which then superimposes the virtual information over it. AR with markers is frequently used in marketing, gaming, and instruction. (Figure 6.1)

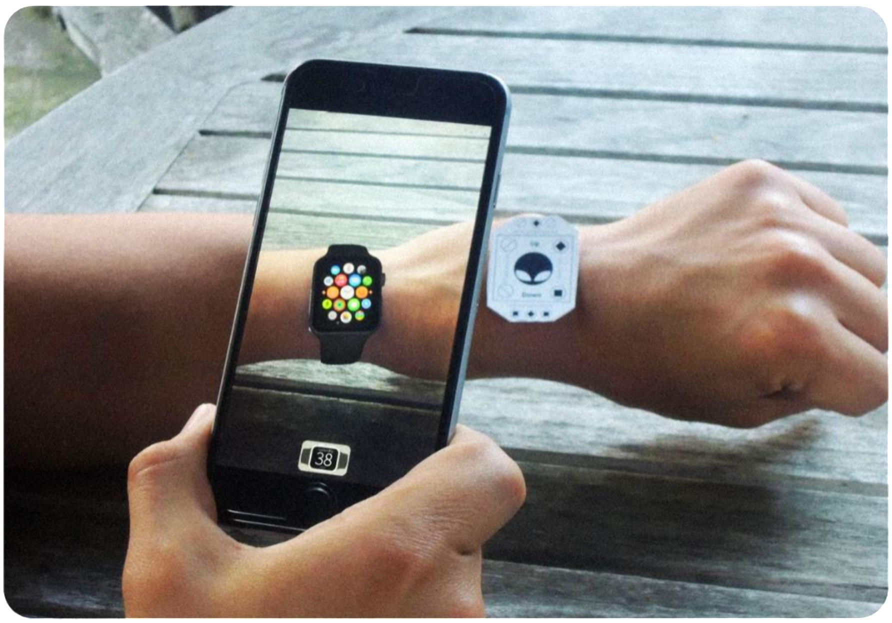

Figure 6.1 Marker based AR for watch compatibility [20]

Markerless AR:

Markerless AR detects physical items and overlays virtual material on them using computer vision and other technologies. This kind of AR can distinguish the item without a specific marking. Applications for markerless AR include industrial design, navigation, and education. (Figure 6.2)

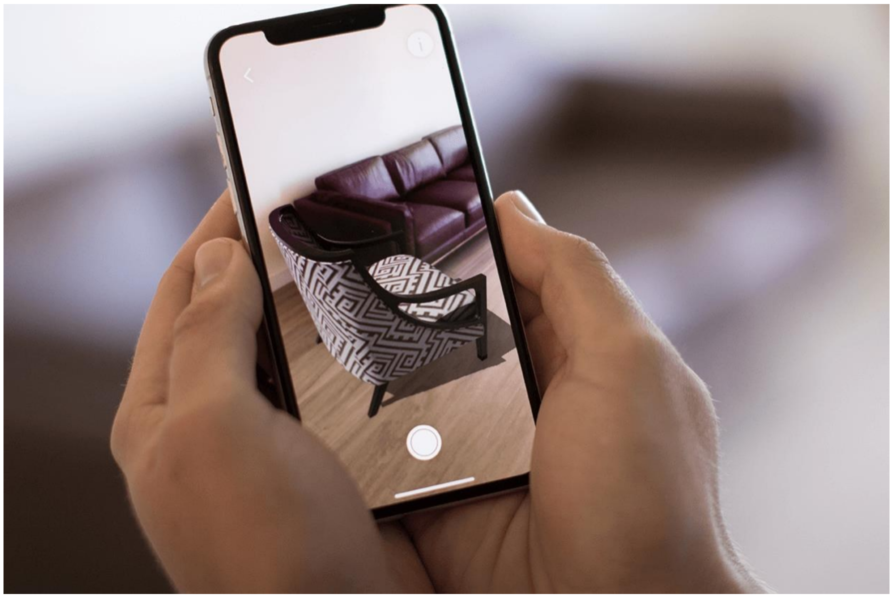

Figure 6.2 Marker less AR for furniture's position [21]

Projection-Based AR:

AR that relies on projections puts digital pictures onto physical objects like tables, walls, and floors. An augmented experience is produced by projecting the virtual material onto the surface. Advertising, live events, and entertainment all employ projection-based augmented reality.

Superimposition-Based AR:

AR that uses superimposition replaces or alters real-world things with virtual ones. With this kind of AR, a virtual object is used in place of the real-world object. Applications for superimposition-based augmented reality include fashion, education, and industrial design.

Outlining-Based AR:

AR that uses outlining surrounds actual items with virtual material. The camera recognizes the boundaries of the actual thing and draws an imaginary border around it. Applications for outlining-based AR include interior design, industrial design, and teaching.

Location-Based AR:

Location-based AR provides pertinent virtual material by using the user's location data. This kind of augmented reality (AR) tracks the user's position and offers virtual material tailored to their surroundings. Numerous industries, including tourism, education, and navigation, employ location-based AR.

Face-Based AR:

Face-based AR builds augmented realities using face recognition technologies. With this sort of AR, virtual content is superimposed over the user's face. Face-based augmented reality is employed in a variety of contexts, including entertainment, gaming, and beauty.

7 Tracking

The ability to monitor an object means that its position and orientation are continuously tracked, which is a crucial requirement if we want to apply augmented reality technology. One can track a variety of objects, including a user's head, eyes, or limbs, an AR device like a camera or display, or any object in the AR scene.

For measurement and alignment of objects in AR tracking, registration and calibration are the necessary terms which overlaps to provide the needs of AR.

1)Tracking: The dynamic sensing and monitoring of AR systems is known as tracking. We must at least be aware of the relative pose—that is, the position and orientation of the AR display with respect to the real objects—in order to display virtual objects that are registered to real items in three-dimensional space. Pose measurements must be updated frequently because AR runs in real-time (tracked over time). The term "tracking" in the context of augmented reality is typically used to refer to the three-dimensional position or six-dimensional pose (position and orientation) of real-world objects.

2)Calibration: Comparison of measurements performed with two separate devices, a reference device and a device that has to be calibrated, is the process of calibration (also known as static sensing). For geometric measurements, the reference device can be swapped out for a known reference value or coordinate system. The goal is to establish usage guidelines for the device so that it may be calibrated to produce readings on a specified scale. The AR system's components, particularly the tracking sensors, need to be calibrated for AR.

Typically, calibration is only done at specific periods. Calibration may only be performed once over the lifespan of a device, usually during or after manufacturing, depending on the measurement system.

3)Registration: In augmented reality, registration refers to the alignment of coordinate systems between virtual and real items; for example, computer graphics elements on see-through screens should line up with actual objects. It is necessary for this to monitor the user's head or the camera that is producing the video background (or both). When neither the user nor the camera is moving, acquiring static registration calls for calibration, but gaining dynamic registration calls for tracking. [1]

7.1 Types of tracking system

Stationary tracking system:

A system that does not need to be portable or mobile is significantly simpler to construct. In the 1990s, stationary tracking systems first gained popularity for use in virtual reality applications. Because of their stationary nature, stationary tracking technologies like mechanical, electromagnetic, and ultrasonic tracking systems are not particularly used in AR today. However, these systems are helpful to comprehend some fundamental tracking concepts.

Mobile Sensors:

While stationary tracking systems work well for some VR applications where the user doesn't need to walk around much, tracking systems for AR should be portable. Unfortunately, AR users cannot expect to have control over the actual infrastructure while exploring an unrestricted environment, particularly outdoors. As a result, both sensing and calculation for tracking must be carried out locally on the mobile device, typically without the assistance of external infrastructure. This restricts the approaches that can be used to those that can function with portable sensors and low computing power. A variety of nonvisual sensors, including the Global Positioning System, wireless networking, magnetometers, gyroscopes, linear accelerometers, and odometers, are present in modern mobile devices. Although the performance of these sensors is severely constrained by external factors, they still offer a substantial opportunity because they are built into low-cost products and are always available.

Optical tracking:

With literally millions of independent pixels being collected at once, digital cameras are compact, affordable, and offer incredibly rich sensory input. Cameras are already a key component of the AR system in a video see-through display, but optical tracking is also unquestionably one of the most fundamental physical tracking techniques used in AR today.

Utilizing camera-generated images necessitates comparing them to a reference model. We refer to the method as model-based tracking if a model of this kind is obtained before the tracking system is activated. Model-free tracking is an option in which a temporary model is actually acquired while being tracked. Flexibility is increased by not requiring a predefined model. Additionally, real-time methods like simultaneous localization and mapping (SLAM) can integrate 3D scanning and tracking. Model-free tracking, which functions like an odometer, can only detect the pose in relation to the starting position. Virtual objects in AR cannot be pre-registered to the actual environment using model-free tracking Commercially available solutions that combine the benefits of model-based and model-free tracking are now accessible, for instance in the Vuforia library. [1]

7.2 Markers

Markers are used in both Augmented Reality (AR) and Virtual Reality (VR) to track the position and orientation of real-world objects and place virtual content in a realistic way. However, the use of markers in AR and VR differs in some ways.

In AR, markers are used to recognize and track real-world objects and their movements. This enables AR software to superimpose virtual content on top of real-world objects, creating an augmented reality experience. AR markers are usually visual patterns, such as black and white squares or circles, that are designed to be easily recognized by AR software. The software uses computer vision algorithms to analyze the camera image and detect the marker pattern. By tracking the movement of the AR marker, the software can accurately place virtual objects in the same location and orientation as the real-world object.

In VR, markers are used to track the position and orientation of the user's head and body. This enables VR software to create a virtual environment that responds to the user's movements, creating a realistic VR experience. VR markers are usually infrared LED sensors that are attached to the user's headset and/or controllers. These sensors emit a signal that is detected by infrared cameras placed in the VR environment. By tracking the movement of the markers, the VR software can accurately track the position and orientation of the user's head and body.

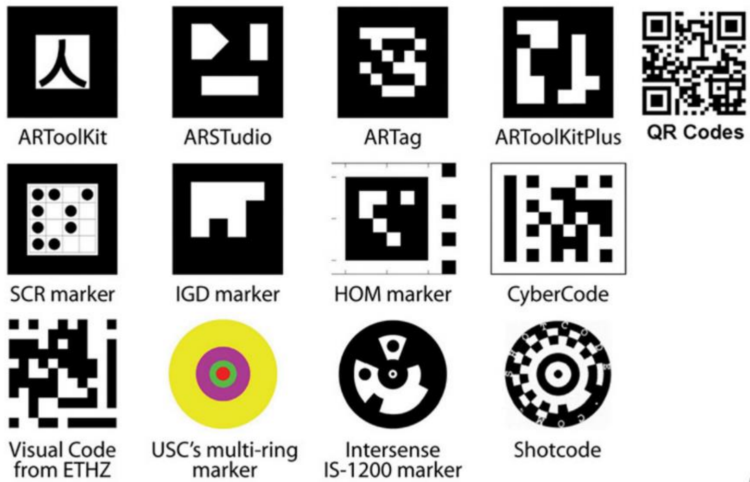

Figure 7.1 Different types of markers used in AR [1]

7.3 Sensor Fusion

Sensor fusion is an important concept in both Augmented Reality (AR) and Virtual Reality (VR), as it enables these technologies to create more accurate and realistic experiences. In AR and VR, sensor fusion refers to the process of combining data from multiple sensors, such as cameras, gyroscopes, accelerometers, and magnetometers, to obtain a more accurate understanding of the user's position and orientation in the real or virtual world.

In AR, sensor fusion is used to accurately track the position and orientation of the user's device, such as a smartphone or tablet, as well as the position and orientation of real-world objects. This enables AR software to superimpose virtual content on top of real-world objects in a way that appears realistic and seamless. For example, by combining data from the device's camera and sensors, AR software can accurately track the movement of the device and the real-world object, and adjust the position and orientation of the virtual content accordingly.

In VR, sensor fusion is used to track the position and orientation of the user's head and body in the virtual environment. This enables VR software to create a realistic virtual environment that responds to the user's movements. For example, by combining data from the headset's sensors and the controllers, VR software can accurately track the position and orientation of the user's head and hands, and adjust the virtual environment accordingly.

Sensor fusion is a complex process that requires sophisticated algorithms and hardware. In AR and VR, sensor fusion is often performed using a combination of machine learning techniques, such as deep neural networks, and specialized hardware, such as low-power processors and sensor hubs. [2]

7.4 Registration

Registration in the context of Augmented Reality (AR) and Virtual Reality (VR) refers to the process of aligning virtual content with the real world or virtual environment.

In AR, registration is the process of accurately aligning virtual content with the real-world scene. This involves detecting the position and orientation of real-world objects using sensors such as cameras or LiDAR, and then aligning virtual content to these objects. Registration is critical for creating realistic AR experiences, as it ensures that virtual content is correctly aligned with real-world objects and appears to be part of the scene.

In VR, registration refers to the process of aligning the virtual environment with the user's physical movements. This involves tracking the position and orientation of the user's head and body using sensors such as gyroscopes, accelerometers, and cameras, and then adjusting the virtual environment to match the user's movements. Registration is critical for creating a realistic VR experience, as it ensures that the virtual environment responds to the user's movements in a natural and intuitive way.

There are various techniques for registration in AR and VR, including marker-based registration, natural feature tracking, and SLAM (Simultaneous Localization and Mapping) algorithms. Marker-based registration involves using markers, such as fiducial markers or QR codes, to identify the position and orientation of real-world objects. Natural feature tracking involves detecting and tracking unique features in the real-world scene, such as corners or edges, and using these features to align virtual content. SLAM algorithms involve simultaneously mapping the environment and tracking the user's position and orientation and can be used for registration in both AR and VR. [2]

7.5 VR interaction concepts

Now similar to tracking we will look at the interaction concept of VR. VR systems rely on a range of interaction concepts that enable users to manipulate virtual objects and navigate virtual environments. we will explore the key VR interaction concepts in more detail below as it will be important to understand these concepts for implementation and execution of project.

Hand Presence:

Hand presence refers to the ability of VR systems to track and display a user's hands in the virtual environment. This enables users to interact with virtual objects and environments using their hands, creating a more immersive and natural experience. Hand presence can be achieved using a variety of hardware, including hand-held controllers, gloves, or through the use of computer vision algorithms that track a user's hand movements.

Hand Tracking:

Hand tracking is the ability of VR systems to track a user's hand movements and translate them into virtual interactions. This is achieved using a range of sensors and algorithms that detect hand movements and translate them into corresponding virtual actions. Hand tracking is an essential component of VR systems, as it enables users to interact with virtual objects in a more natural and intuitive way.

Haptic Feedback:

Haptic feedback is the use of tactile sensations to provide users with a sense of touch and physical presence in VR. Haptic feedback can include vibrations, pressure, or temperature changes that are triggered in response to virtual interactions. Haptic feedback is an important element of VR systems, as it enables users to experience a more immersive and realistic environment.

Teleportation:

Teleportation is a movement technique in VR that allows users to move through virtual environments without physically walking. This is achieved using a range of techniques, including pointing and clicking on a location in the virtual environment or using a controller to indicate a destination. Teleportation is a key component of VR systems, as it enables users to move through large virtual environments without the physical limitations of the real world.

Object Manipulation:

Object manipulation refers to the ability of users to interact with and manipulate virtual objects in a variety of ways. This can include picking up and moving objects, resizing or rotating them, and using tools or weapons within the virtual environment. Object manipulation is an essential component of VR systems, as it enables users to interact with virtual content in a more natural and intuitive way.

Gaze Interaction:

Gaze interaction is the ability to interact with virtual objects using eye movements. This can be used to select objects, activate features, or trigger events within the virtual environment. Gaze interaction is an important component of VR systems, as it enables users to interact with virtual content without the need for hand-held controllers or other hardware.

Voice Interaction:

Voice interaction is the ability to interact with a VR system using spoken commands. This can be used to navigate menus, select options, or control virtual objects. Voice interaction is an important component of VR systems, as it enables users to interact with virtual content in a hands-free and intuitive way. (2)

8 Applications

This section will cover augmented reality's technological applications as well as instances where a large audience can engage with the technology.

8.1 General applications

Education:

The goal of research is to theoretically support the use of augmented reality technology and its features at technical universities. It is suggested to use AR objects in physics lab practical practice. The following judgments are reached: The incorporation of augmented reality (AR) technologies into the learning process at technical universities boosts educational effectiveness, encourages student learning and cognitive activity, enhances educational quality, piques student interest in the subject, and supports the development of future specialists' research skills and competencies. [4]

In the study, a taxonomy of augmented reality (AR) technologies for use in education is presented, and examples of AR cards, encyclopedias, instructional books, tutorials, textbooks, and coloring books that make use of the technology are given. [5]

The usage of AR technology in higher education was the main topic of the study by Scaravetti. In higher education, virtual education is used to help students visualize and understand concepts more clearly, but because mechanical systems are difficult to comprehend with 2 dimensional designs, implementing augmented reality (AR) can aid in a deeper understanding of concepts because 3 dimensional designs can be used to visualize mechanical systems with the aid of two different interfaces, such as tablets and HoloLens glasses. [6]

Tourism:

By recreating the structure using an augmented reality (AR) app on their mobile devices and scanning the location of historical sites, tourists can utilize AR to see a historical building in its former splendor.Additionally, travellers can utilize augmented reality (AR) applications to easily find nearby ATMs, hotels, tourist attractions, stores, transit, and hospitals. World Around Me, Senditur (for seeing Spain), Smartify, AR City, Horizon Explorer (if you enjoy trekking), Wikitude World Browser, etc. are a few examples of AR applications used by visitors.

Commercial:

Interior designs: Materials can be visualized using AR technologies. With the aid of augmented reality (AR) applications, one can virtually place furniture in a specific location using handheld devices with the aid of applications like IKEA place, Decor matters, etc. One can then decide whether to purchase that particular furniture after deciding how the furniture fits their home without the hassle of measuring for size and by comparing their colors.

Virtual Tryon watches: Customers may virtually try on watches while shopping online with AR-Watches, a firm that has received a design rush certification. In essence, AR- Watched is an Android and iOS mobile application that enables users to virtually try on timepieces from various manufacturers.

It starts with a paper wristband that serves as a marker for AR to overlay a 3D image of watches onto the wrist of a user.

AR Menu: A virtual preview of food orders. When using the Jar it app, customers can visually examine their food orders in a 3D image before placing their orders. This allows customers to order food depending on their preferences and interests in the meal's aesthetics, as opposed to ordering food after viewing it through a 2D model.

Entertainment:

AR plays major role in the business and entertainment industries. For instance, when providing weather forecasts on news stations, meteorologists generally stand in front of a blue screen, which uses augmented reality to display shifting 3D weather conditions. This process is known as chroma keying.

On 20 January 2018 a future-forward merger was introduced for the 2017–18 Bundesliga season: Pregame activities for the Borussia Mönchengladbach vs. Hamburger SV matches in conjunction with Spidercam imagery, DFL successfully integrated specially created augmented reality graphics into the world stream. With the help of the implemented fully UHD-capable technology, it is possible to incorporate visuals like club crests, tables, and player profiles into the live broadcast so that they appear to be present within the stadium.(Figure 8.1)

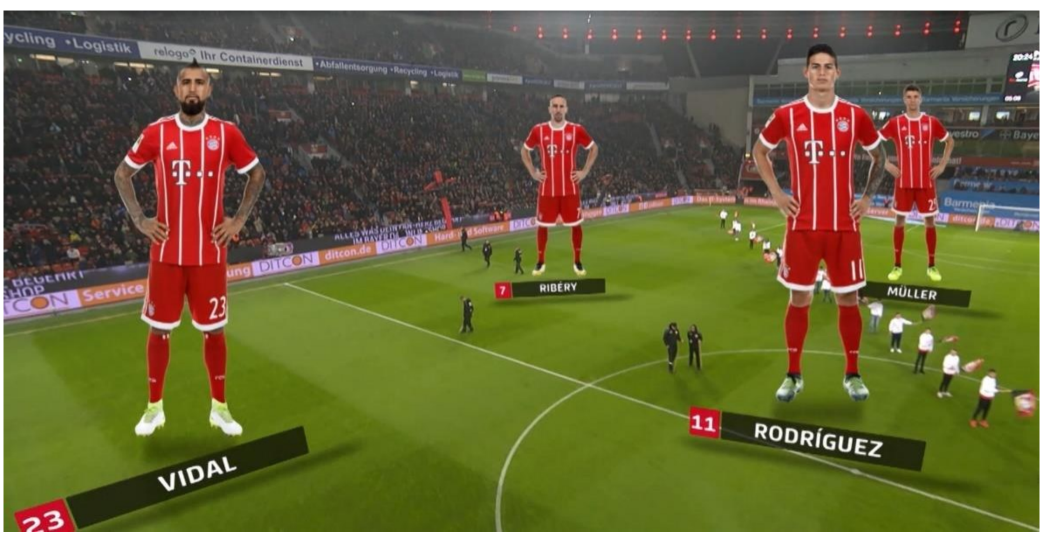

Figure 8.1 AR implemented in football field for the first time by DFL [22]

The app "We are TV" employs augmented reality to make watching TV fun. The app allows users to choose live or streaming programming, after which different cartoon characters will appear all around the display. The players can gather these cartoon characters by hurling balls at them. We are TV was founded by Martin Rogard. The social aspect of watching TV on the app is another nice feature. You can react to the plot twists and narrative developments by throwing virtual hearts, bombs, or tomatoes at the screen, much like you would to a social media post! Your friends will be able to view your reactions to the various parts of the event since you require a Facebook authentication to access the app.

Pokemon go application was released in the year 2016 developed and published by Niantic in collaboration with Nintendo and The Pokémon Company and have over 500 million downloads and it uses location-based AR technology, as it brings the imaginary pokemons into the real world through your handheld screens.

Training in military/navy:

The main goal of AR in the military is to train the troops with the help of Helmet mounted visor devices because it is difficult to train soldiers in a real-world setting because it can be risky and expensive if ships or aircraft are damaged. Before being sent to a real-world setting or a combat, military and navy personnel can practice to the utmost extent with the aid of AR.

Drones are flown without a human pilot on board and are controlled remotely. Drones have recently shown to be a crucial instrument for military operations. Drone technology can be an excellent weapon for surveillance, giving the military access to real-time data with the help of AR software like Vuforia Studio.

The job of a bridge officer on a navy ship is to monitor the ship's course and ensure its safety. Traditionally, officers would request the information they needed over the radio from the operations room to confirm what they could physically see, but today, with the aid of AR-enabled devices, they are able to do so, reducing their workload and improving ship safety. [10]

8.2 Technology applications

Construction:

Geographic information systems (GIS) are used by utility firms to manage subsurface infrastructure, such as gas pipelines and telecommunications wires. Construction managers are required by law to learn about subsurface infrastructure so they can protect it from harm during excavations. Likewise, on-site inspection is frequently necessary to determine the cause of outages or update out-of-date GIS data. The accuracy and efficiency of outdoor work can be greatly increased in all of these situations by displaying an AR view that is derived from the GIS and directly registered on the target site [Schall et al. 2008]

Figure 8.2 Tablet computer with GPS for outdoor AR(left) Georegistered view of virtual excavation revealing gas pipeline. [1]

Drones with cameras are more frequently employed for aerial construction site observation and reconstruction. Although these drones may be capable of some autonomous flight control, a human operator is still necessary. According to Zollmann et al. (2014), augmented reality (AR) can be very helpful in detecting the drone (Figure 8.3), monitoring its flying parameters (such as position over ground, height, or speed), and warning the operator of potential collisions.

Figure 8.3 A spherical AR overlay can be used to visualize the drone's position even when it is far away and scarcely visible. [1]

Maintenance and Training:

In many occupations, especially for maintenance engineers, learning how things function and how to put them together, take them apart, or fix them is a significant difficulty. Since it is frequently impossible to memorize every step in detail, they frequently spend a lot of time reviewing manuals and paperwork. However, augmented reality (AR) can directly superimpose instructions in the worker's field of vision. This can result in more efficient training, but more crucially, it enables employees with less training to complete the job in the right way. (Figure 8.4) illustrates how AR can help while removing the brewing unit from an automatic coffee maker.

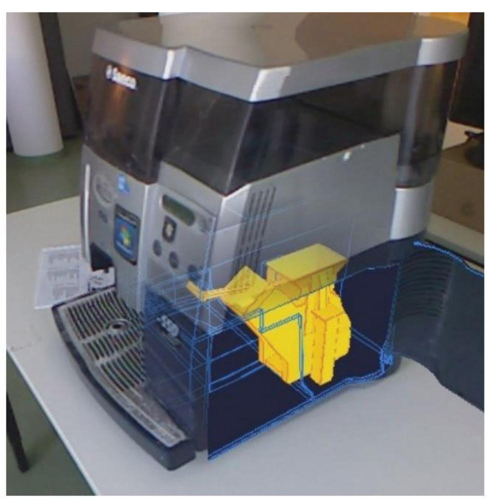

Figure 8.4 AR revealing the interior of a coffee machine to guide end-user maintenance [1]

Telepresence:

To extend an operator's sensory-motor capabilities and problem-solving skills to a distant environment is the primary goal of telepresence. The term "telepresence" refers to a human/machine system in which the human operator receives enough information about the teleoperator and the task environment, portrayed in a natural enough manner, that the operator feels physically present at the remote site. Telepresence seeks to create the illusion of presence at a distance, much to virtual reality, which strives to create the sense of presence within a computer simulation. [3] (Figure 8.5)

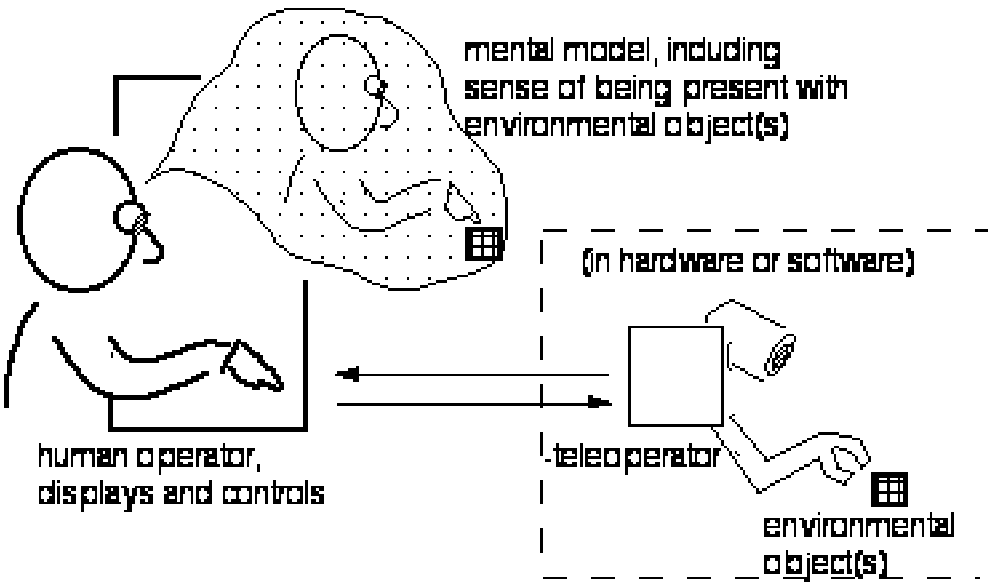

Figure 8.5 TELEPRESENCE The sensation of being there with real environmental things is created via telepresence displays and operator actions. [1]

For live mobile remote collaboration on physical tasks, if human assistance is required, augmented reality (AR) can offer a shared visual world [Gauglitz et al. 2014a]. (Figure 8.6) This method allows a remote expert to examine the area without relying on the local user's current camera location and to communicate using spatial annotations that are immediately visible to the local user in the AR view. Real-time visual tracking and reconstruction can accomplish this without the requirement for environmental preparation or instrumentation. AR telepresence blends the advantages of remote scene exploration and live video conferencing into a comfortable collaboration experience.

Figure 8.6 Using augmented reality telepresence on a tablet, a distant expert assists in an automobile maintenance scenario. [1]

Medical:

In the medical industry, augmented reality (AR) is used to visualize a complex human body component, such as the brain, with the aid of Image Guided Surgery, which makes use of preoperative scans like CT (Computed Tomography) or MRI (Magnetic Resonance Imaging) to produce a 3D model of the brain, which will further assist the surgeons in operating on the brain to remove the tumor without penetrating into superfluous regions of the brain and harming the sensitive tissues there(Figure 8.7).[8] Additionally, ultrasonic imaging employs AR. The ultrasound technician can examine a rendered image of the fetus on the pregnant woman's abdomen using an optical see-through display. It seems as though the image is inside the abdomen. [9]

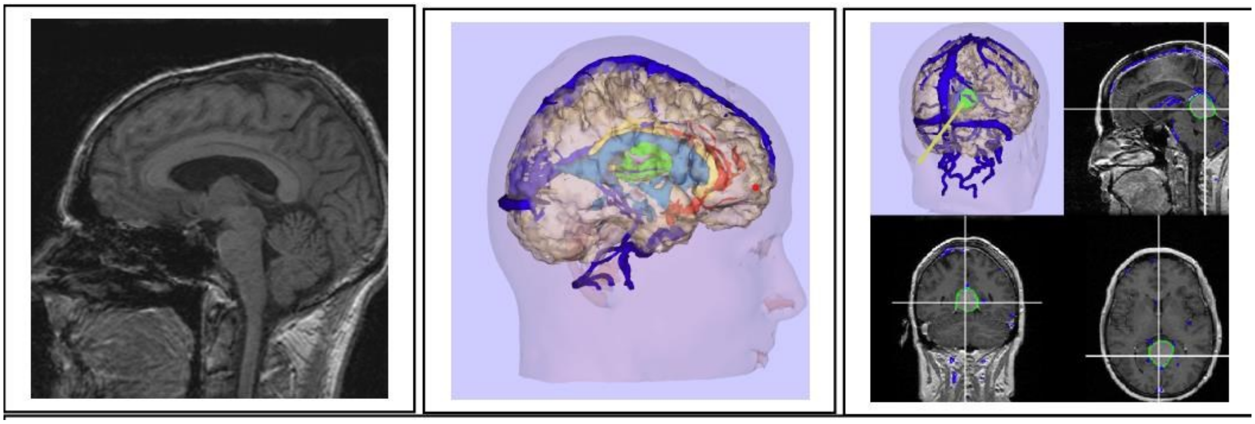

Figure 8.7 Image guided surgery using MRI to obtain a 3d model [1]

Engineering and industrial design:

Future engineering and industrial design projects will heavily rely on augmented reality. Progressively, industrial companies are using augmented reality into their technical processes. Engineers may visualize, change, and collaborate on 3D CAD data in a real world using tools like the Augmented Reality Engineering Space (ARES) from the AR firm Holo-Light. The goal of the AR software is to give engineers a new tool to improve planning, development, and production workflows.

At its headquarters in Munich, the automaker BMW now employs the augmented reality engineering space with integrated remote rendering technology ISAR. BMW use the AR software ARES Pro to save up to a year of time. The engineers can quickly comprehend the accessibility, installation options, and visibility of relevant assembly points in complex systems with the concept of superimposition of real geometry with holographic 3D models within minutes, which typically takes much longer. This is done by using true-to-scale visualization and interaction with concepts and prototypes previously created in CAD programs.

In the early stages of a design project for a client, the client can view a 3d model created with the aid of an augmented reality display and finalize the model according to their requirements, leading to satisfaction on both ends and preventing issues with the design later on that would cause unnecessary complications for the designers. Later, the client can access and learn about the progress of the model without physically being there. As a result, clients no longer have to move around as much and may access the data from anywhere.

9 VR goggles market overview

VR Googles –A heads-up display (HUD) for virtual reality allows users to interact with simulated settings and get a first-person view (FPV). VR headsets allow users to experience virtual reality content instead of their actual surroundings, such as a 360-degree VR environment, a video game, or a 360-degree movie that allows users to spin and gaze about just like they would in the real world. Despite the fact that virtual reality has been around for a while, the attached hardware required to experience it has typically been expensive, large, and power-hungry. Mobile VR headsets, which are essentially goggles today, have made it possible for VR apps to become more widely available. Each form of VR headset aims to provide the user an experience that is so genuine they forget they are wearing a headset at all.

VR headset categories:

1)A computer-based device called the Oculus Rift helped revive interest in virtual reality after the Oculus VR firm ran a successful Kickstarter campaign. With the use of Touch controllers and positioning technology, the Rift allows users to physically navigate across 3D space.

2)Hololens, a stand-alone VR headset from Microsoft. The system includes a fleet of gyroscopes and accelerometers, Wi-Fi, a camera similar to Kinect with a 120-degree spatial sensing system, 3D spatialized music, and a transparent screen for each eye.

3)The HTC Vive relies on a potent gaming PC to function. Users can move around a 15' X 15' space freely thanks to dual base stations. Together with video game software developer Portal, the system was created.

4)PlayStation VR - use a PlayStation 4 instead of a computer. The device reproduces the virtual reality headgear display on a TV.

5)A smartphone container that makes use of the phone's computing power is the Samsung Gear VR. The technology was created in association with Oculus VR and supports premium Samsung Galaxy devices.

6)Google Cardboard is a cheap, cardboard-based smartphone case. Numerous low-cost headsets that are based on the original open source design are available.

Future market of VR:

Sony's $550 PSVR 2, which requires a PS5, will be available starting on February 22. The $1,500 Meta Quest Pro is one of many new VR headsets that have just entered the market. The Quest 3 and Apple's anticipated headgear ought to be available in 2023. However, the current best option is still the 2-year-old Meta Quest 2 and HP Reverb G2. Currently, Facebook's own meta is leading the VR market, followed by Valve, HTC, and WMR (Windows Mixed Reality). The VR market is now booming and will keep growing as new technological heights are attained with VR devices.

BEST VR Devices 2022:

There are now a number of VR devices on the market that can be purchased, but it is up to us to choose which VR is best for us based on our wants and requirements. Whether it's only for first-time consumers to try out VR or for use in the workplace.

Best VR devices at their respective categories:

1) Meta Quest 2 - Best for a Standalone VR Experience

2) Meta Quest Pro - Best for Pros and High-End Enthusiasts

3) Sony PlayStation VR - Best for PlayStation Gamers

4) Valve Index VR Kit - Best for Excellent Controllers

5) HTC Vive Pro 2 - Best for the Highest-Resolution VR

HP Reverb G2 - Best for Simple, Tethered VR [25]

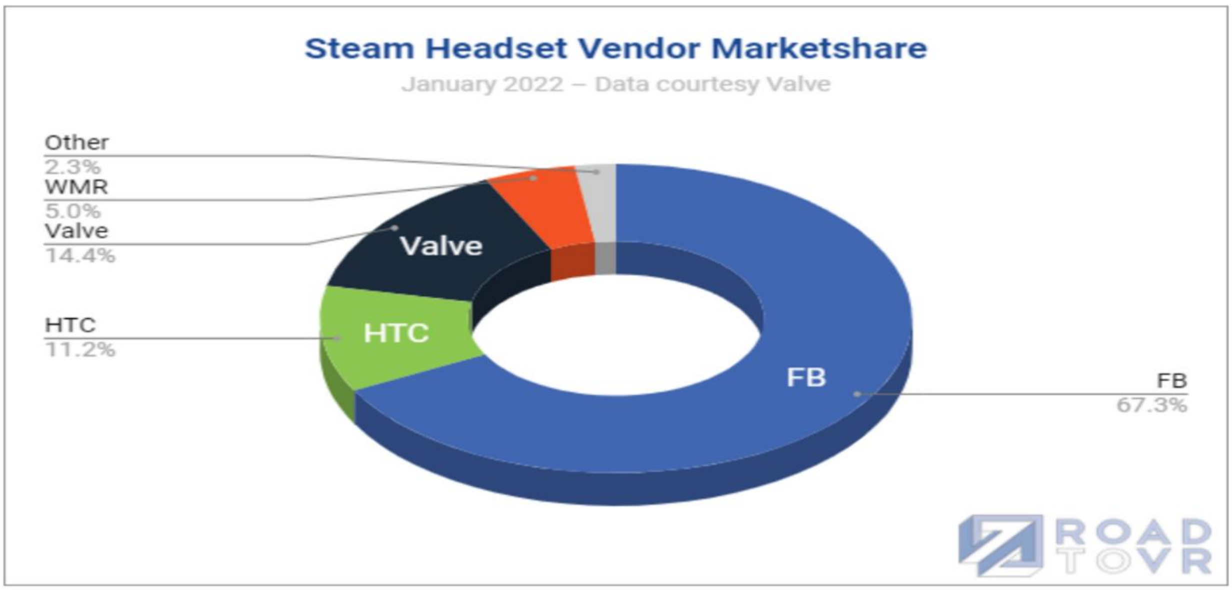

Figure 9.1 Steam headset market share 2022 [26]

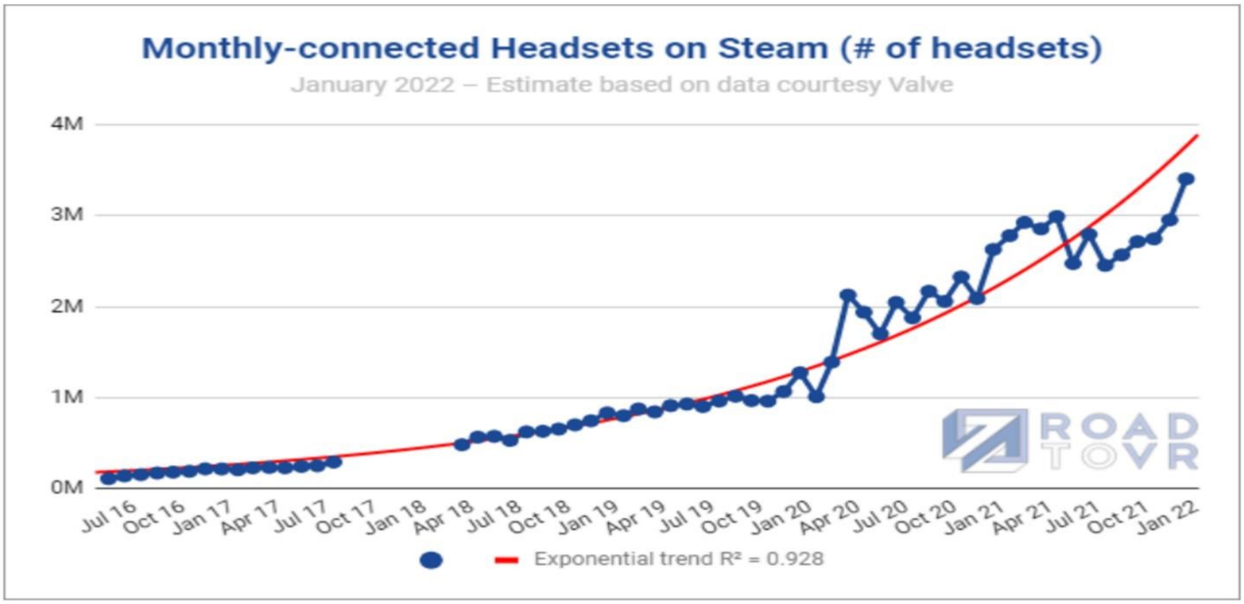

Figure 9.2 Monthly connected VR Headsets on Steam [26]

From (Figure 9.2), we can see that the number of monthly connected headsets through Steam has increased and will continue to grow in the future as the cost of VR headsets decreases and becomes more affordable to a wider audience than it was in the past. VR technology is still in its infancy and we are not yet sure how full scale VR invasion will impact our social lives. Overall this is a very exciting time to see the benefits VR will bring to the masses. Apart from gaming, we will also see the influence of VR in the education industry, healthcare, entertainment, engineering etc.

10 Visualizing and programming platforms used and comparison

In this section, I've outlined my decision-making process for picking one software platform over another and described a few more characteristics.

10.1 Raspberry pi vs Arduino

The major uses of Arduino are repetitive operations like opening the main gate, turning on and off the lights, managing the water above tank, reading data from temperature sensors, and many other similar chores.

The Raspberry Pi is regarded as the best device for carrying out a variety of tasks, including video game play, controlling intricate robotics, using interface cameras, etc.

Although both Arduino and Raspberry Pi are well-known platforms for creating electronic projects, they each offer unique advantages and are best utilized for certain tasks.

The low-level hardware programming capabilities of Arduino boards make them perfect for creating projects using sensors, motors, leds, and other tangible objects. They have a huge selection of sensors and shields, are reasonably priced, and are simple to use. The applications that need for accurate timing, real-time processing, and minimal power usage are ideally suited for Arduino.

Raspberry Pi, on the other hand, is a single-board computer with a full operating system that is intended for more difficult applications that need computational power. It is perfect for developing projects that call for high-level software development, graphics, and multimedia processing, for projects that call for complex programming languages like Python.

Therefore, I chose Arduino platform to employ based on my project needs.

10.2 Arduino IDE

The open-source Arduino IDE is an Integrated Development Environment (IDE) for creating software for the Arduino platform. For authoring, compiling, and uploading code to the Arduino board, a complete development environment is offered by the IDE, a piece of software. It is built on the Processing programming environment, which was created for building interactive and graphic applications.

With support for Windows, Mac OS X, and Linux, the Arduino IDE was created using the Java programming language. The tool offers a straightforward and understandable user interface for creating programs for the Arduino platform. Users may interface with the Arduino board and view its output thanks to the IDE's code editor, compiler, and serial monitor.

Developers may write and edit code using the IDE's built-in code editor. The editor has functions including code folding, syntax highlighting, and code completion. By employing color-coded text, syntax highlighting aids developers in identifying various sections of the code. As a developer types, code completion provides code recommendations, and code folding enables developers to compress and extend code parts.

The IDE has a compiler that turns the editor-written code into machine-readable code that the Arduino board can run. The compiler examines the code for syntactic mistakes and issues warnings if any are found. A hex file produced by the compiler can also be uploaded to the board.

A bootloader and a USB driver are among the code uploading tools provided by the IDE. The board may accept code via the serial port thanks to the bootloader, a little software that runs on it. The computer can connect with the board through the USB port thanks to the software package known as the USB driver. Developers may choose the board type, CPU, and serial port from a menu in the IDE.

Developers can interface with the board and check its output thanks to the serial monitor that is part of the IDE. Developers may give commands to the board via the serial monitor, which also shows messages provided by the board. To debug and troubleshoot code, utilize the serial monitor.

Developers may install and manage libraries using the IDE's library manager. Developers can utilize libraries, which are pre-written pieces of code, in their work. The IDE comes with a variety of libraries that offer features including reading and writing to digital and analog pins, serial connection with other devices, and servo motor control.

Based on C and C++, the Arduino programming language was created. The language comes with a selection of libraries and functions that simplify working with the board for developers. For novices and enthusiasts, the language's simplicity and ease of learning make it the best choice. [27]

Figure 10.1 Arduino logo

10.3 Unity vs Unreal engine

Usefulness: Compared to Unreal Engine, Unity features a user-friendlier interface, making it simpler for newcomers to get started. Beginners will benefit from the platform's reduced learning curve and fewer technical knowledge requirements.

Unity provides a great level of customization, enabling programmers to design unique VR experiences. The engine gives developers greater control over the experience by enabling the creation of unique shaders, physics simulations, and audio effects.

Cost: The complete edition of Unity is less expensive than the premium version of Unreal Engine and comes with the majority of the capabilities needed for VR production. Due to this, it could be an easier choice for novice developers or students working on projects.

Performance: Unity is intended for mobile devices and tiny projects, so it may run better in that area. Unreal Engine is recognized for its superior graphics rendering capabilities, but Unity may perform better overall. This might be significant for developers who want to create VR experiences for standalone headsets or mobile devices.

Support from the community: Unity offers a sizable and vibrant developer community, which is useful for receiving assistance with coding, debugging, and locating resources. Finding pre-made components to utilize in your VR project is simple because to the platform's extensive catalog of assets and plugins.

10.4 Unity

On a variety of VR devices, Unity VR is a well-liked platform for creating virtual reality experiences. Unity VR is a software engine that offers a variety of tools and technologies for building interactive, immersive virtual worlds.

Unity VR is a gaming engine that enables the creation of 3D worlds, objects, and characters at its heart. Then, using scripts and other programming components, these virtual objects are used to build interactive experiences that can be viewed and operated using a VR headset. Unity VR is a user- and developer-friendly platform that supports a variety of VR headsets, including as the Oculus Rift, HTC Vive, and PlayStation VR.

The support for 3D modeling and animation that Unity VR offers is one of its standout features. Several programs, such as Blender and Maya, are available to developers for the creation of 3D models of objects, characters, and locations. Then, to build immersive VR experiences, these models may be loaded into Unity VR and coupled with scripts and other coding components. Additionally, Unity VR supports animation, giving programmers the ability to give their virtual objects realistic motions and interactions.

Unity VR's support for physics simulations is another crucial feature. To provide believable movements and interactions between virtual objects, physics simulations are employed. For instance, accurate gravity and collision impacts may be produced using a physics simulation, enabling the creation of interactive experiences that simulate the actual world. Popular physics engines like PhysX and Havok, which may be utilized to build complex and realistic VR experiences, are supported by Unity VR.

Audio and visual effects are supported by Unity VR as well. Because of this, programmers can produce engrossing audioscapes and visual effects that improve the VR experience as a whole. The user would be able to hear sounds originating from various directions as they moved around the virtual world, for instance, if a developer made a VR experience with spatial audio. Additionally, Unity VR has support for post-processing effects that may be utilized to develop cinematic and immersive VR experiences, such depth of field and color grading.

Unity VR now provides support for mobile devices to make VR experiences available to a larger audience. As a result, a larger audience may be reached by developers who can now create VR experiences that can be enjoyed on smartphones and tablets. It is possible to construct VR experiences that can be accessible through a web browser thanks to Unity VR's support for web-based VR experiences.

Unity VR is assisting in expanding the realm of what is practical in the field of virtual reality with its strong tools and technology.

Figure 10.2 Unity VR compatiple with all types of VR googles [28]

10.5 XR Plugin

Building VR and AR apps for a variety of platforms, including as Oculus, SteamVR, and Windows Mixed Reality, is supported via the XR Plugin, a Unity package. Without having to write platform-specific code, you can create VR applications in Unity and distribute them to a variety of devices with the XR Plugin.

The XR Plugin in Unity has the following salient features:

Support for several platforms: The XR Plugin is compatible with a number of VR and AR systems, such as Oculus, SteamVR, Windows Mixed Reality, and others. Without needing to write platform-specific code, this enables developers to construct VR and AR applications that can work across a variety of devices.

Straightforward configuration: The XR Plugin's user-friendly interface makes it straightforward to set up VR and AR settings, including rendering, input, and tracking. Without having to delve into platform-specific settings, this enables developers to rapidly set up their VR and AR applications.

Cross-platform input: The XR Plugin offers a standard input API that enables developers to support a variety of input devices across different platforms, including controllers and hand-tracking.

Performance enhancements: The XR Plugin has performance enhancements that help VR and AR apps run more quickly and with less lag.

Simply add the package to your project and then modify the parameters to correspond to your target platform to utilize the XR Plugin in Unity. From there, you can build VR and AR experiences that work with a variety of devices using Unity's built-in tools and capabilities.

10.6 Rest client

Users can connect with RESTful APIs (Application Programming Interfaces) via a form of software program known as a REST client. Developers and other technical users that need to connect with web services that adhere to the Representational State Transfer (REST) design principles often utilize the REST client.

Java, Python, and JavaScript are just a few of the computer languages that may be used to create REST clients. RESTful API development is supported by a number of well-known web development frameworks, including Django, Flask, and Express.

In order to interact with resources on the web, users of REST clients often have access to HTTP (Hypertext Transfer Protocol) queries like GET, POST, PUT, and DELETE. The resource they wish to communicate with, as well as any other parameters or information needed for the request, may all be specified by users.

REST client apps come in a number of forms, including desktop programs, browser extensions, and command-line tools. Postman, Insomnia, and cURL are a few well-known REST client programs.

For developers or technical users who need to test or debug web services, automate tedious activities, or connect several software applications, using a REST client might be advantageous. Because they are straightforward, adaptable, and scalable, RESTful APIs are often used in web development, and REST clients make it simple for developers to interact with these APIs in a user-friendly manner.

10.7 Microsoft Visual studio

Microsoft Visual Studio is an integrated development environment (IDE) that allows developers to build applications for multiple platforms. It is one of the most popular IDEs in the industry, used by millions of developers around the world. Visual Studio supports several programming languages, including C++, C#, Visual Basic, F#, and JavaScript, and can be used to develop desktop, web, mobile, and cloud applications.

The primary goal of Visual Studio is to provide developers with a comprehensive set of tools and features to simplify the development process. This includes a code editor, debugging and testing tools, project management tools, and integration with various third-party tools and services. The IDE is designed to be customizable, so developers can tailor it to their specific needs.Visual Studio offers a rich code editing experience, with features such as syntax highlighting, IntelliSense (code completion), and refactoring. The editor also supports version control systems, such as Git and SVN, making it easy to manage changes to code over time. One of the key features of Visual Studio is its debugging capabilities. The IDE includes a powerful debugger that allows developers to step through code, inspect variables, and diagnose issues in real-time. Visual Studio also supports remote debugging, which allows developers to debug code running on a different machine or in the cloud. It includes a number of testing tools, including unit testing and integration testing frameworks. These tools allow developers to automate the testing process and ensure that their code is working as expected. The IDE also includes performance profiling tools that can be used to identify performance bottlenecks and optimize code. It also includes project management tools that allow developers to manage their projects from within the IDE. This includes features such as project templates, solution management, and build automation. The IDE also includes integration with various third-party tools and services, such as Azure DevOps, GitHub, and Docker, making it easy to work with these tools within the IDE.

Visual Studio is available in several different editions, each with different features and capabilities. The Community edition is a free and I have used free version as it is enough for the application I am using it for as it is ideal for individual developers or small teams. The Professional and Enterprise editions include additional features and are designed for larger teams or organizations.

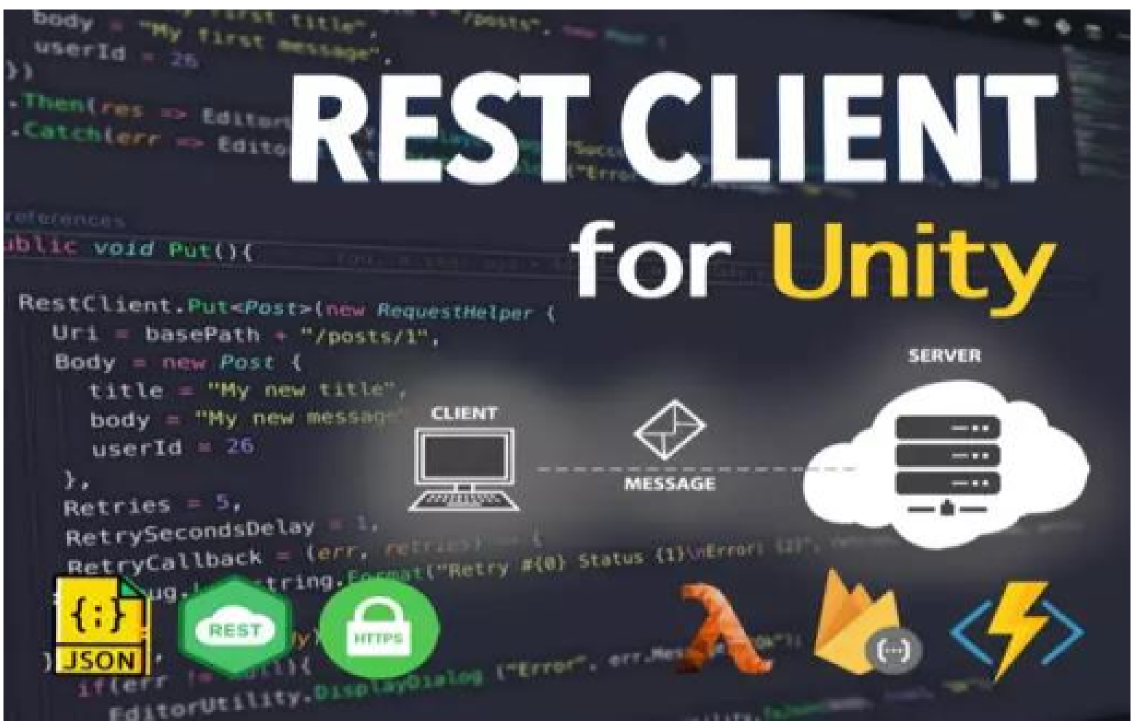

Figure 10.3 Rest client from asset store [29]

11 Experiment

In my thesis I am communicating from Virtual world(VR) to real world by sending DI from VR to led in real world connected with ESP8266 board.

11.1 Software Installation

For programming with ESP8266 board we need to install ArduinoIDE software and for working with VR googles and preparing UI we need to install Unity software. In order to transfer data between Unity VR and the Arduino IDE, the Firebase database serves as a bridge.

11.2 Hardware Connection

With the aid of an ESP8266 board,Bread board, a 220 ohm resistor, and wires, prepare the hardware connection for the led's ON/OFF.

11.3 Arduino IDE programming

Install the necessary drivers so that the Nodemcu esp8266 is recognized by the programming PC before beginning to program for the ESP8266 Board in the Arduino IDE platform and make a note of the port number where it is attached.

Install the required packages for the nodemcu esp8266 in order to program.

Choose the precise Node MCU model that will be used on the board; in my instance, it is Node MCU 1.0 (ESP-12E Module).

Through the tools section of the IDE, locate and choose the precise port where the esp8266 is attached before uploading any application. With the help of Serial monitor simulate and test whether the esp8266 board is communicating with the platform.

Once the communication is working properly connect the already hardwired ESP8266 with the PC where Arduino IDE platform is installed with the help of USB cable.

Before starting to create the firebase database, we may simulate and control the led that is attached to one of the digital inputs using the GPIO pin diagram of the ESP8266 that we can get on the official website of esp8266.

11.4 Configuration of the Google Firebase database

We can set up Google Firebase to accept data from the ESP8266 once all essential hardware connections have been done and the led is going ON/OFF correctly from the Arduino platform. Find firebase.google.com by searching for it and selecting Get Started. (Figure 15.1) Once we select Add Project, we will be sent to the terminal where we may add new projects. (Figure 15.2)

After selecting Add project, we will be prompted to give our project a name. After entering a suitable project name, clicking Continue, we leave the rest of the options as they are, and then we choose an account for our project, which is typically the Google account we use for Firebase. Continue by clicking the button, and Firebase will complete configuring your project.

After establishing the project, the Firebase functional console will be displayed to us; from here, we can configure authentications and set up the Realtime database. Before building our database, we must specify the guidelines for authenticating people who transmit data to it. To do this, we first click on

Authentication in the sidebar and then select Get Started. After selecting Email/Password as your sign-in method and turning on both Email/Password and Email Link, click Save. (Figure15.3) The user email and password we want the user to use to access the database must be entered. We must return to Users and click on Add User. We must make a note of these information someplace since we will need them in the code for programming in both the Arduino IDE and Unity VR. We have finished the authentication process with this. We must once more select Realtime Database from the sidebar and then select Create Database. Start the project in test mode after choosing an area. Our database has now been set up.(Figure 15.4) With that step configuration of the Google Firebase database is completed.

11.5 Programming on Arduino IDE for PUT and GET data from Firebase

Once the Google Firebase database setup is completed, we can move on towards programming in Arduino IDE for the transfer of led ON/OFF data from ESP8266 to Firebase database.

First, we must include all of the essential libraries into the program. (Figure 11.1)

```
#if defined(ESP32)
#include <WiFi.h>
#include <FirebaseESP32.h>
#elif defined(ESP8266)
#include <ESP8266WiFi.h>
#include <FirebaseESP8266.h>
#endif

#include <addons/TokenHelper.h>


#include <addons/RTDBHelper.h>
```

Figure 11.1 Required packages in Arduino IDE platform

For data transfer to operate, the ESP8266 must be linked to wifi at all times. To do so, we must specify and configure the Wifi connection to which the ESP must be connected using its WIFI_SSID and Password. (Figure 11.2)

```

/* 1. Define the WiFi credentials */
#define WIFI_SSID "            "
#define WIFI_PASSWORD "          "



// For the following credentials, see examples/Authentications/SignInAsUser/EmailPassword/EmailPassword.ino

/* 2. Define the API Key */
#define API_KEY "                                        "

/* 3. Define the RTDB URL */
#define DATABASE_URL "vr-library-default-rtdb.firebaseio.com" //<databaseName>.firebaseio.com or <databaseName>.<region>.firebasedatabase.app

/* 4. Define the user Email and password that alreadey registerd or added in your project */
#define USER_EMAIL "                     "
#define USER_PASSWORD "             "
```

Figure 11.2 Provide API key and RTDB URL

Now we have to provide API key and RTDB URL in program from our Firebase database.

11.5.1 API Key

A unique identifier used to authenticate and authorize access to an application programming interface (API) is known as an API key. It's a code that identifies a particular application or service and grants access to its features and capabilities.

API keys are a security tool that aids in controlling API access and preventing illegal access. They are frequently used to monitor how an API is utilized and to guarantee that only authorized users have access to it.

An API key is connected with certain rights or constraints, such as the amount of requests that may be performed or the data that can be accessed, when it is produced. API keys are commonly used in web development to allow third-party access to a web service or application, such as gaining access to Google Maps or Twitter APIs.

API keys are often incorporated in application code or supplied as arguments in API queries. They are useful for authenticating users, tracking use, and enabling rate limitation. An API key, for example, can be used to limit access to certain individuals, to limit the number of requests per minute or hour, or to limit the data that can be accessed.

API keys must be kept safe since they may be used to access sensitive information or modify data if they fall into the wrong hands. To prevent unwanted access to API keys, developers frequently utilize encryption or hashing. Furthermore, many APIs utilize rate limitation or throttling algorithms to avoid overuse of API keys or to prohibit fraudulent queries.

In conclusion, API keys are a crucial component of modern web development since they enable developers to give safe and regulated access to their apps and services.

11.5.2 RTDB

Realtime Database (RTDB) URL is a Uniform Resource Locator (URL) that provides a unique address to access a specific Firebase Realtime Database. The Firebase Realtime Database is a cloud-hosted NoSQL database that allows developers to build real-time applications, where data can be synchronized across clients in real-time.

The Realtime Database URL is composed of two parts: the Firebase project ID and the database instance name. The Firebase project ID is a unique identifier assigned to a specific Firebase project, while the database instance name is the name assigned to a specific instance of the Realtime Database within that project.

The format of the Realtime Database URL is as follows:

https://<project-id>.firebaseio.com/<database-instance-name>

For example, if the project ID is my-project and the database instance name is my-database, the URL to access that specific Realtime Database would be: https://vr-library-default-rtdb.firebaseio.com/ (Figure 11.4)

The Realtime Database URL provides developers with a simple way to access the data stored in their Realtime Database from their client-side applications. Clients can use the Firebase Realtime Database SDK to connect to the database instance by passing the database URL as a parameter.

The Realtime Database URL also provides a way to secure access to the database, as developers can define rules to allow or deny access to specific parts of the database based on authentication, authorization, or other criteria. Firebase Realtime Database rules are defined using a JSON-based domain-specific language that allows developers to define read and write permissions based on user authentication and data validation rules.

In summary, Realtime Database URL is a unique address that provides a simple way to access a specific Firebase Realtime Database from client-side applications.

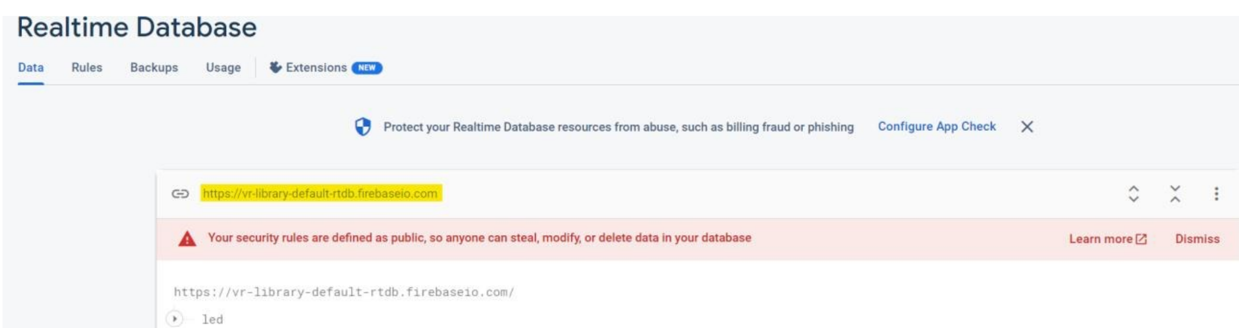

Figure 11.3 RTDB URL from firebase

We will be able to transmit and receive data from the Firebase database to the ESP8266 once all of the relevant details have been given and coded.

11.6 Creating Unity environment

Because working with Unity software takes a lot of graphics power, we must download and install Unity Hub on a PC with a powerful enough GPU to manage the job.

Install Unity Hub with Android build support module for Oculus and Windows support module for Valve and HTC Vive VR. For Interation between VR device and Unity software we install XR Interaction Toolkit package. If we want to use our software(developed UI) on all types of VR devices we have to install Universal Render Pipeline package and proceed. Further we need to Install some XR plugin management Asset from Unity Asset store for left and right hand controller in our Application. Once the setup for VR implementation is done we can edit UI environment of our VR application according to our requirement.

11.6.1 XR Interaction Toolkit

The XR Interaction Toolkit is a package for Unity that provides a set of tools to help developers create interactive experiences for virtual reality (VR) and augmented reality (AR) applications. With the XR Interaction Toolkit, developers can easily add interactions such as grabbing, throwing, and teleporting to their VR/AR applications.

To use the XR Interaction Toolkit in Unity, you will need to first download and import the package into your Unity project. You can do this by opening the Package Manager window in Unity and searching for "XR Interaction Toolkit" in the search bar. Once you have installed the package, you can start using the tools provided by the XR Interaction Toolkit.

Some of the key features of the XR Interaction Toolkit include:

Interactors and Interactables: These are the building blocks of the XR Interaction Toolkit. An Interactor is an object that can interact with other objects in the scene, while an Interactable is an object that can be interacted with.

Grabbables: Grabbables are objects that can be picked up and moved around in the scene. The XR Interaction Toolkit provides a set of scripts that can be attached to objects to make them grabbable.

Teleportation: The XR Interaction Toolkit provides a teleportation system that allows users to move around in the virtual world by pointing and clicking on a target location.

UI Interactions: The XR Interaction Toolkit includes tools for adding interactive user interfaces to your VR/AR applications.

Overall, the XR Interaction Toolkit is a powerful set of tools that can help developers create immersive and interactive experiences for VR/AR applications in Unity.

11.6.2 Universal RP

Universal RP (Universal Render Pipeline) is a lightweight rendering pipeline for Unity that provides high-quality graphics while optimizing performance for a range of platforms, including mobile devices, consoles, and PC. Universal RP is designed to be flexible and customizable, allowing developers to create their own rendering features and shaders.

Some of the key features of Universal RP include:

Lightweight rendering pipeline: Universal RP is designed to be lightweight and optimized for performance, making it ideal for use on mobile devices and other low-power platforms.

Shader Graph: Universal RP includes a Shader Graph tool that allows developers to create their own custom shaders and visual effects without needing to write any code.

Post-processing effects: Universal RP includes a range of built-in post-processing effects, including bloom, motion blur, and depth of field.

Dynamic batching: Universal RP automatically batches objects in the scene to optimize rendering performance.

Scriptable Rendering Pipeline: Universal RP is based on the Scriptable Rendering Pipeline (SRP) architecture, which allows developers to customize and extend the rendering pipeline to meet their specific needs.

Universal RP is a powerful tool for creating high-quality, optimized graphics in Unity. Its flexibility and customization options make it a popular choice for developers looking to create visually stunning games and applications across a range of platforms.

11.6.3 Virtual world room and led control

Once the setup is complete, we can move on to virtual world development, where we must program human movement using the locomotion system script and the Action based continuous move provider script, both of which will be available by default when we install the assets described above. Once the locomotion system is built, we can test it by running a simulation and moving on to the design of a room with a sliding door that functions by pushing a button and a light that is controlled by a switch that is linked to the real world led at the same time. (Figure 11.5)

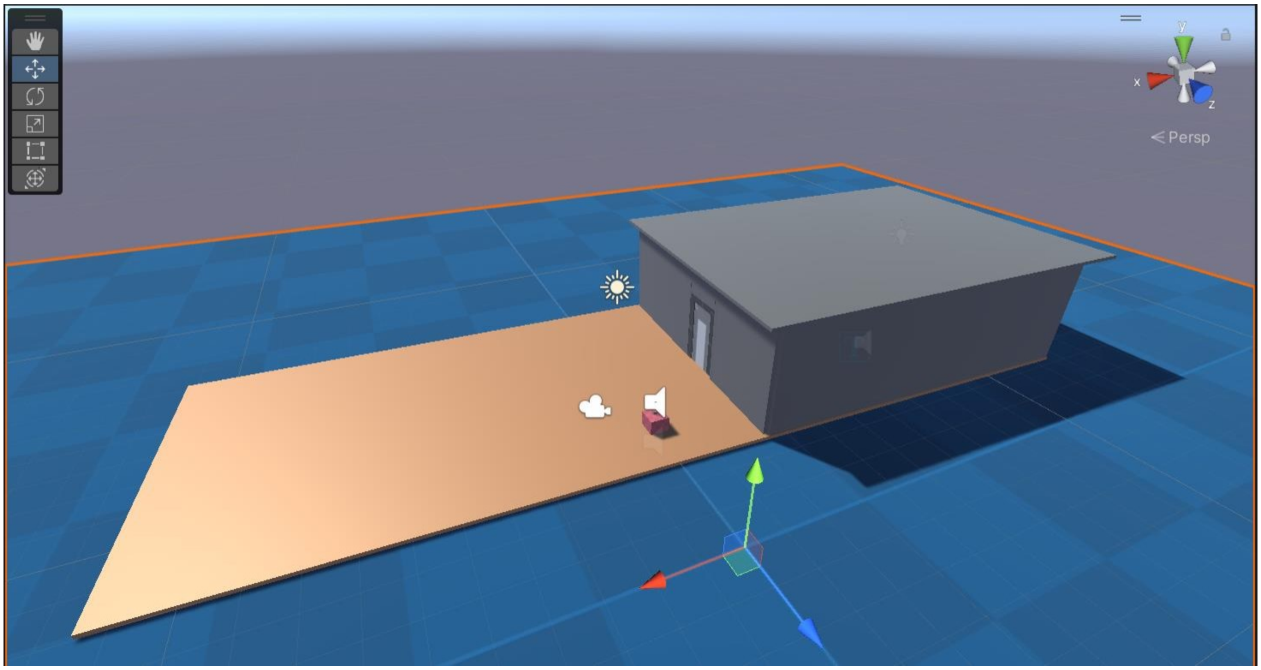

Figure 11.4 Room with sliding door and led light control linked to real world

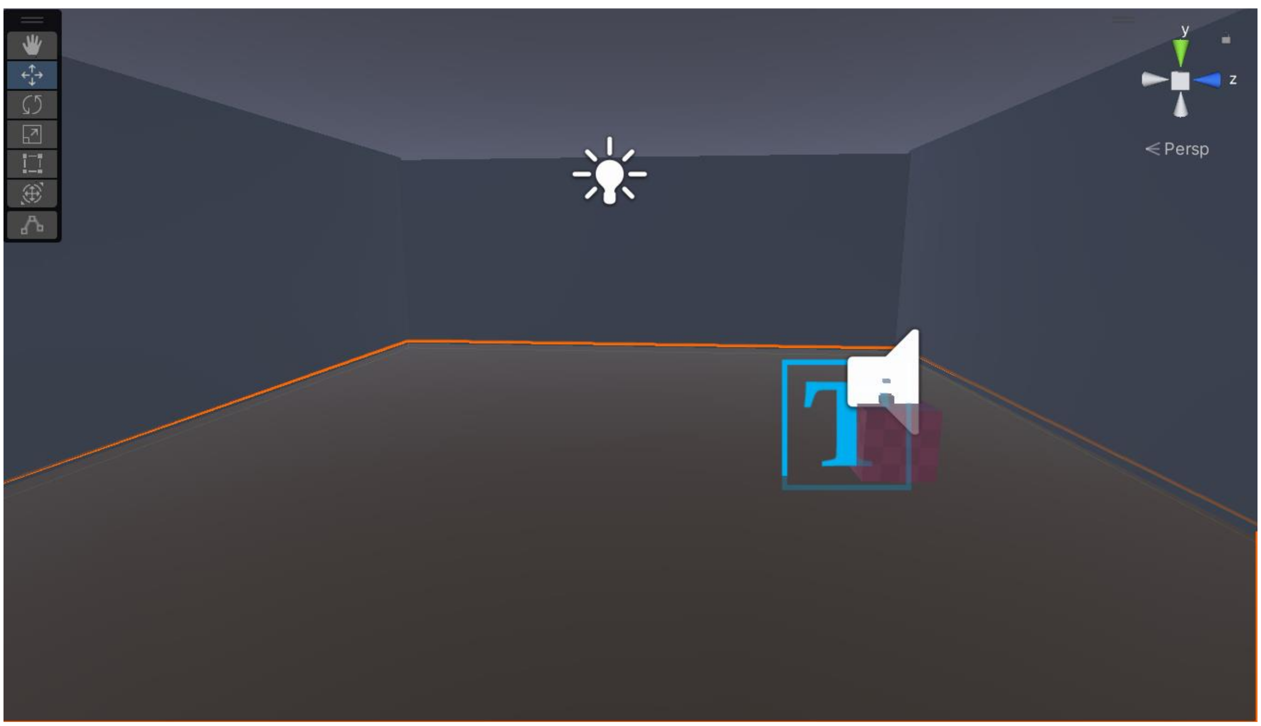

Figure 11.5 View inside the room with switch for led control in real world and light bulb control in virtual world

11.7 Preparing C# scripts for PUT and GET from Firebase database

We need to install any platform that can operate with the C# programming language in order to utilize it, and I have used Microsoft Visual Studio for programming. Create scripts to control the switch and to GET and PUT data from and to the Firebase database. To program, we must add the necessary libraries in the script. (Figure 11.7)

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.Events;
using Proyecto26;
using System;
```

Figure 11.6 Libraries that needs to be included

Once the programming part is finished and the virtual world is ready, we can use VR googles to simulate if the sliding door is opening and shutting in response to button presses and whether it is operating properly. Once the sliding door implementation is working properly, We can further proceed to implement a switch in the real world that can be used to control the sliding door in the virtual world with the help of firebase database to transfer data from real world to virtual world. As this implementation starts working we can enter the room we've created and try to control the led status data generated in the firebase database using the switch from VR world.

11.8 Control led in Real world from VR

We should be able to control the led in the real world after the data is in the Firebase database. Provide the ESP 8266 board with the appropriate power supply and connect to a wifi network so that data can be transferred from the firebase to the board and the led turns on/off based on the instruction issued by Virtual World. The whole data transfer path is given in the flowchart. (Figure 11.7) The led ON/OFF in both real world and virtual world along with how the data is shown in firebase is explained through the (Figure 11.8 to 11.15).

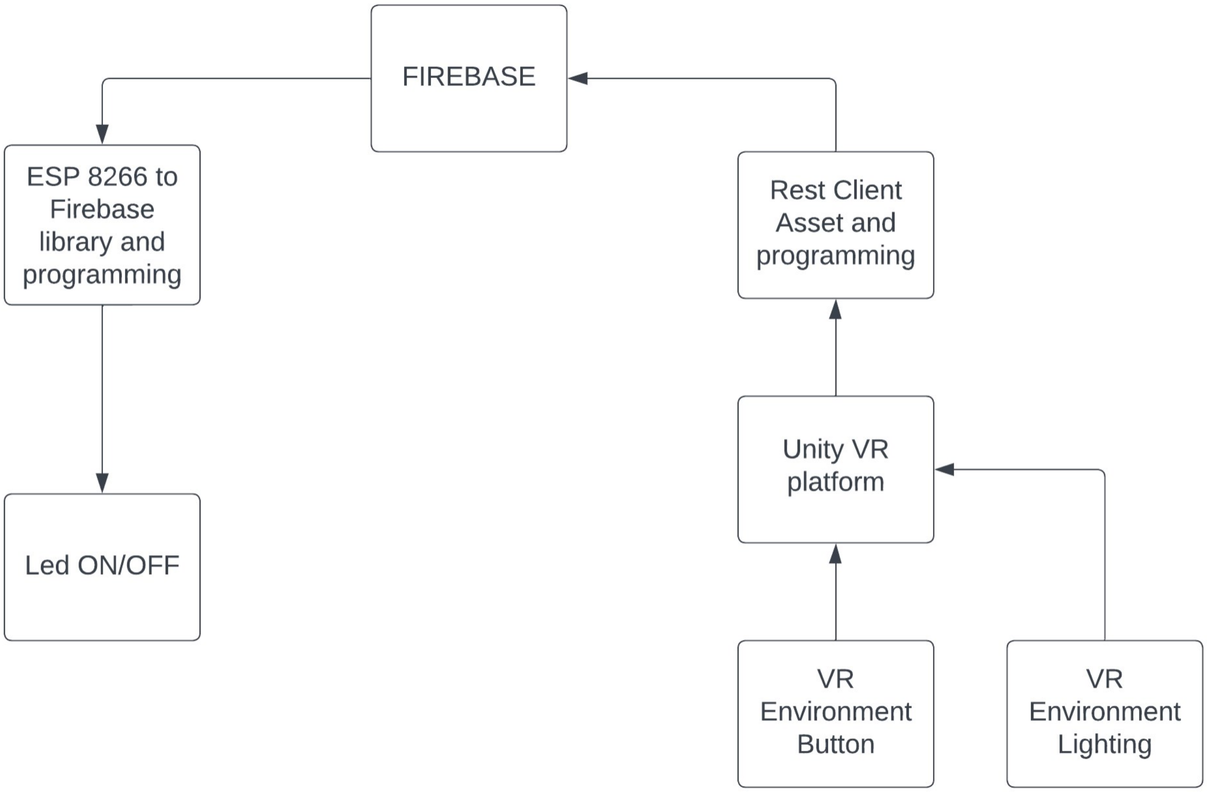

Figure 11.7 Flowchart of data transfer in Thesis

Figure 11.8 Led and room light OFF when button is pressed once

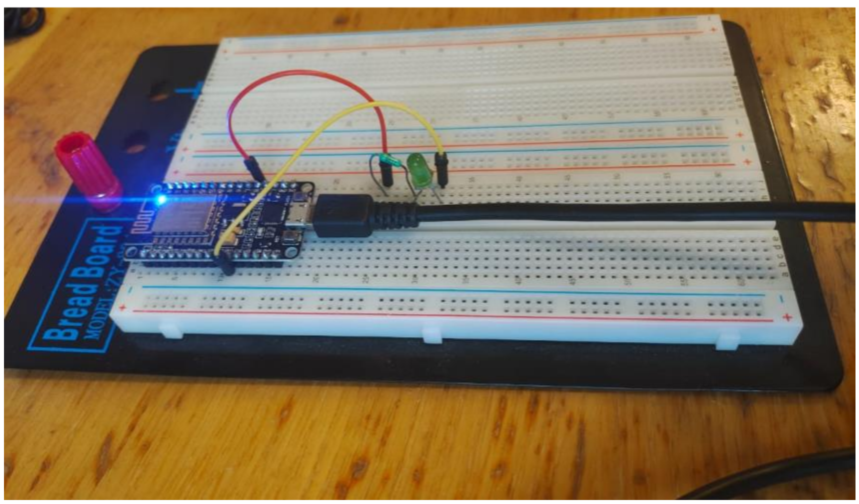

Figure 11.9 Led OFF reflecting in real world from VR

Figure 11.10 Led status in Firebase when light turned OFF in VR

Figure 11.11 Led and room light ON when button is pressed again

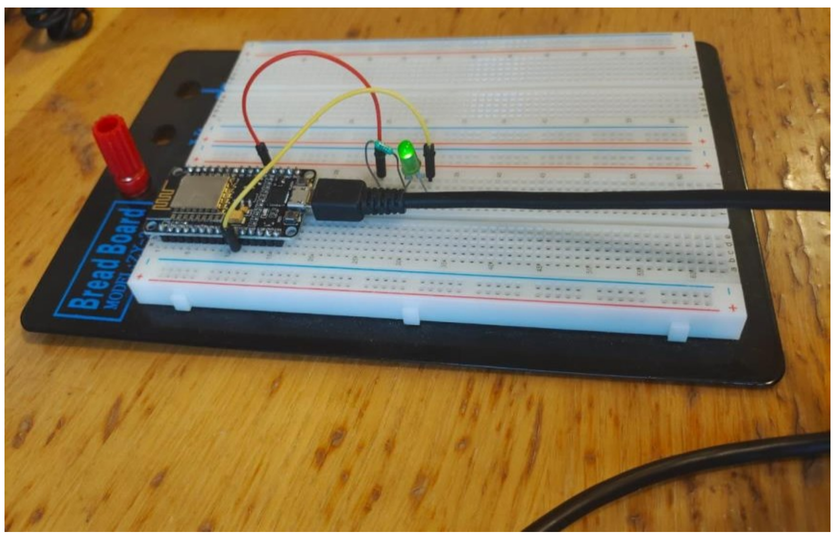

Figure 11.12 Led ON reflecting in real world from VR

Figure 11.13 Led status in Firebase when light turned ON in VR

Figure 11.14 Sliding door closed

Figure 11.15 Sliding door open when button is pressed

12 Summary

We learned about virtual and augmented reality issues for controlling/managing and visualizing technological processes, adverse health effects and the changes that needs to be implemented in order to reduce the harm to health caused by VR and Analyzed VR and AR mainly with the help of the books Augmented reality: Principles and practice by Schmalstieg, D., Hollerer, T and The VR book. Human-centered design for virtual reality by Jason, J. We learned about history of AR and VR and various general applications and technological applications of them. Then we took a look at various types of VR and AR, and understood how markers are used in both AR and VR for tracking the position of real world objects in virtual worlds, which led to understanding the concept of registration (the process of aligning virtual content with the real world or virtual environment.) and its various types: 1)marker-based registration 2)natural feature tracking, and 3)SLAM (Simultaneous Localization and Mapping) algorithms as well as the uses and types of tracking systems. We studied about several tools and platforms for implementing control and visualization through AR/VR, such as Unity, Unreal engine, Raspberry pi, Arduino IDE, Rest client, XR plugin, and Microsoft Visual studio, and then compared and chose which technologies are most suited for my project. After studying various tools and platforms, we setup and coded for the project using information obtained from literature and learning about various platforms and tools, and we demonstrated the results using the images attached.

13 Conclusion

Finally, the purpose of this thesis was to comprehend virtual and augmented reality issues for controlling/managing and visualizing technological processes, as well as various tools and possibilities for visualization and control/management using AR/VR, and to apply the knowledge gained in my project of controlling real world led ON/OFF through virtual environment VR and controlling sliding door in virtual environment from real world that is compatible with all types of VR Google, i.e. universally compatible. It is clear from this project that we can control any type of industrial equipment directly from the virtual environment without being physically present near the equipment, and this type of application is especially useful for devices that are located in inaccessible locations but require manual operation. The difference between a VR system and other SCADA systems is that if the actual world environment has to be properly understood or watched, it can be done simply with the use of VR by constructing a virtual environment that appears comparable to real world circumstances. VR and augmented reality (AR) give an immersive and interactive experience that allows users to perceive complicated systems and data in a more natural and engaging manner, improving knowledge, productivity, and decision-making. Furthermore, VR and AR resources can reduce the risk of physical injury and errors, allowing for safe and efficient process training and operation. However, it is critical to consider the potential negative health effects of VR use and to implement design guidelines to encourage healthy use. As technology advances, it is expected that VR and AR will become more integrated into numerous processes and industries, providing new opportunities for innovation and growth.

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15 Appendix

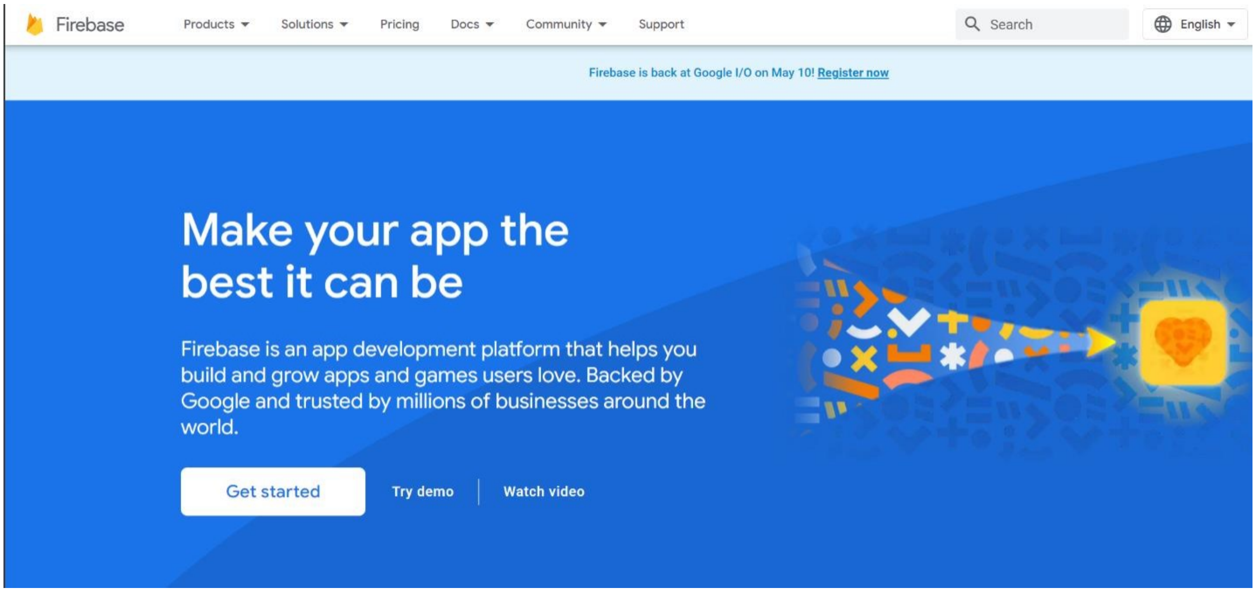

Figure 15.1 Firebase homepage

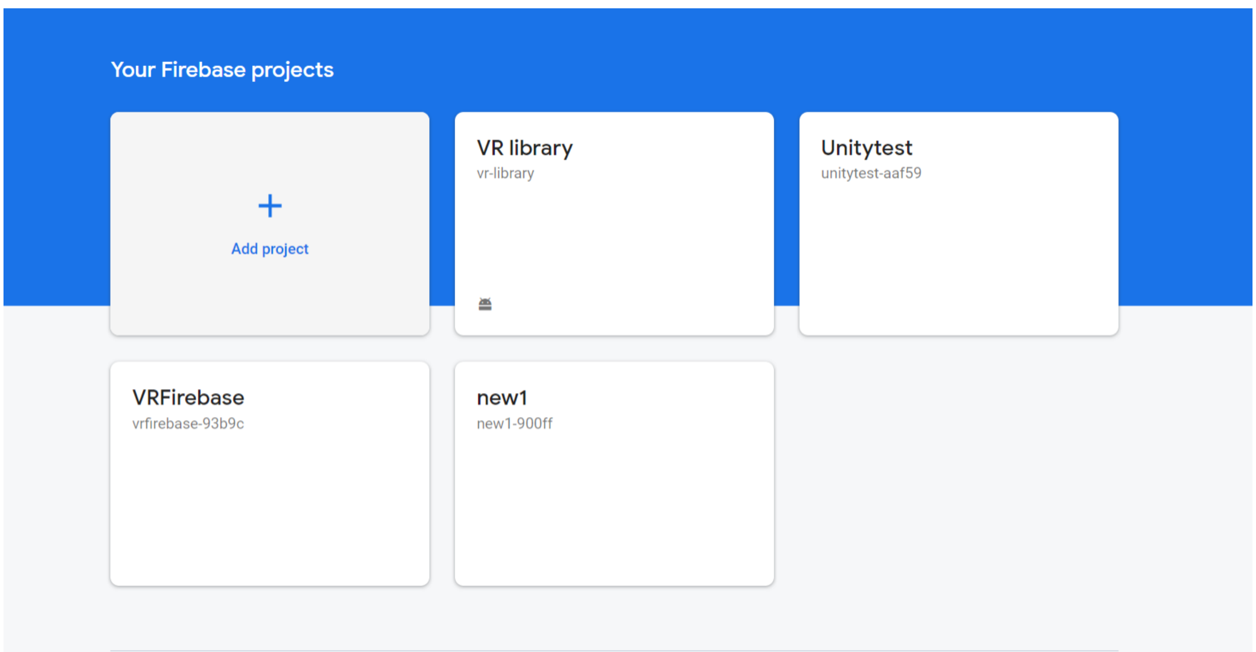

Figure 15.2 Creating a new firebase project

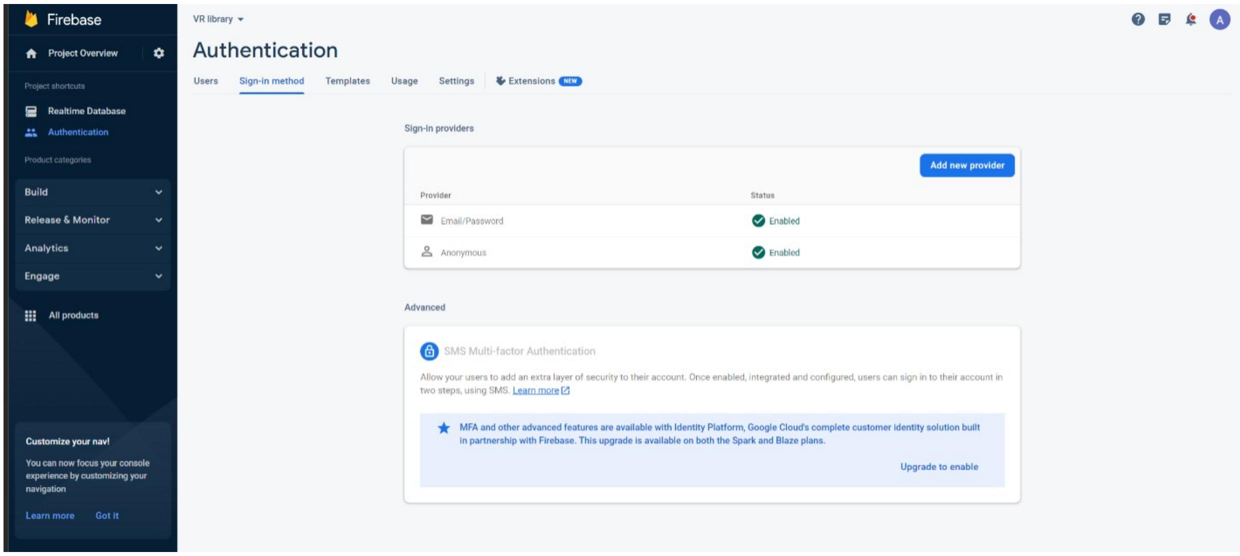

Figure 15.3 Configuring Authentication settings

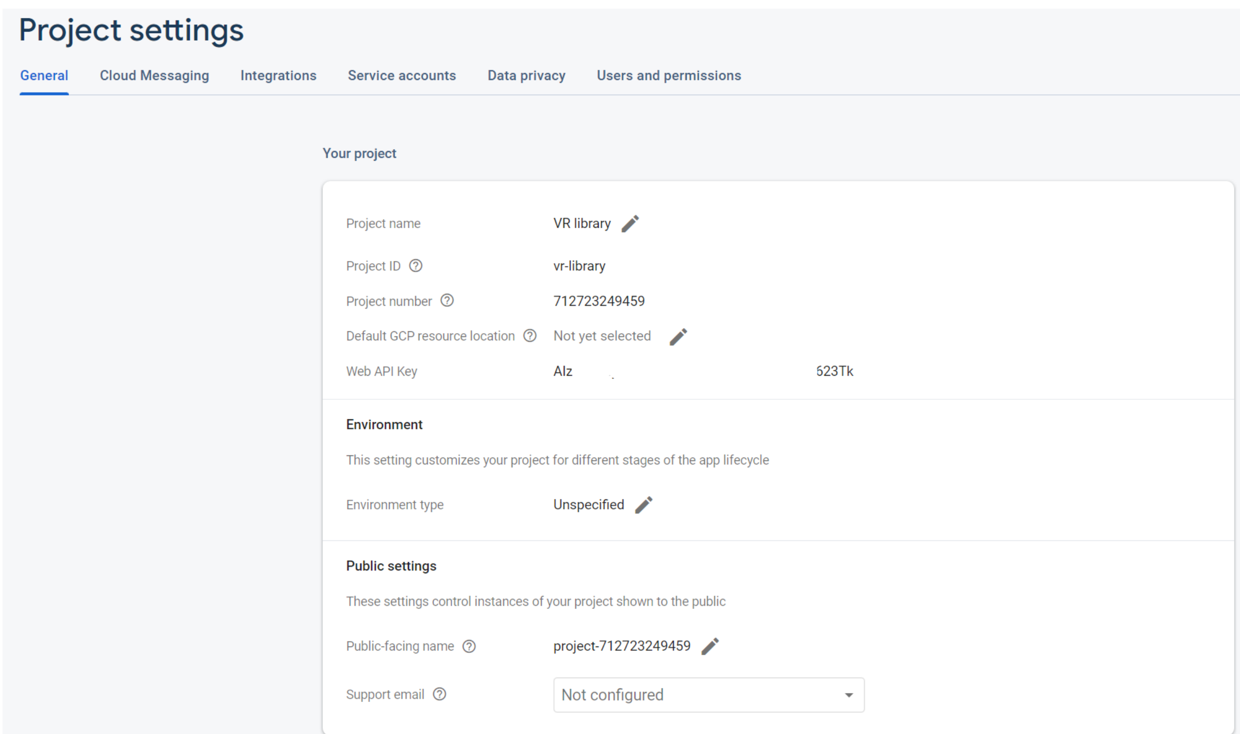

Figure 15.4 API key from firebase setings

Package installation guide in unity platform for the project implementation.

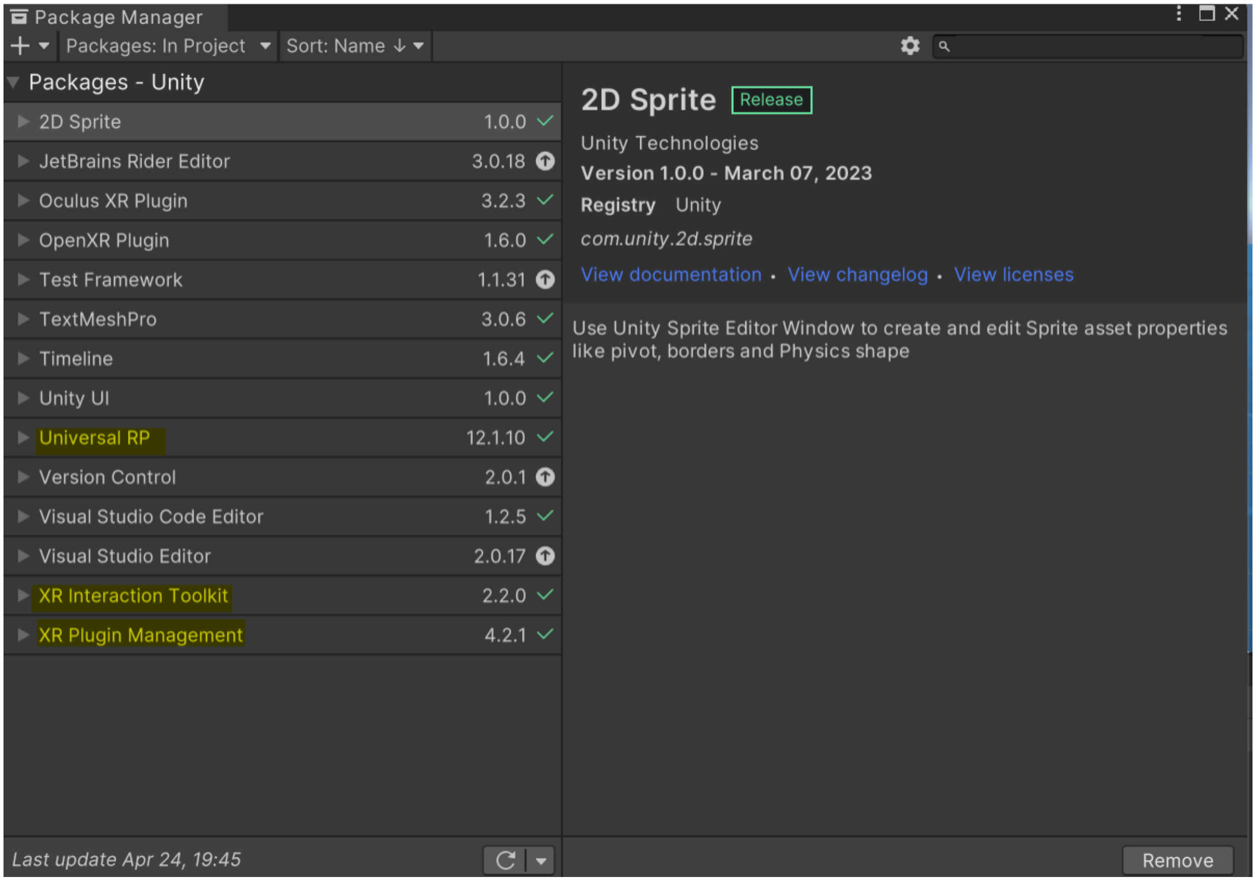

Figure 15.5 Package selection required for project from Unity VR platform

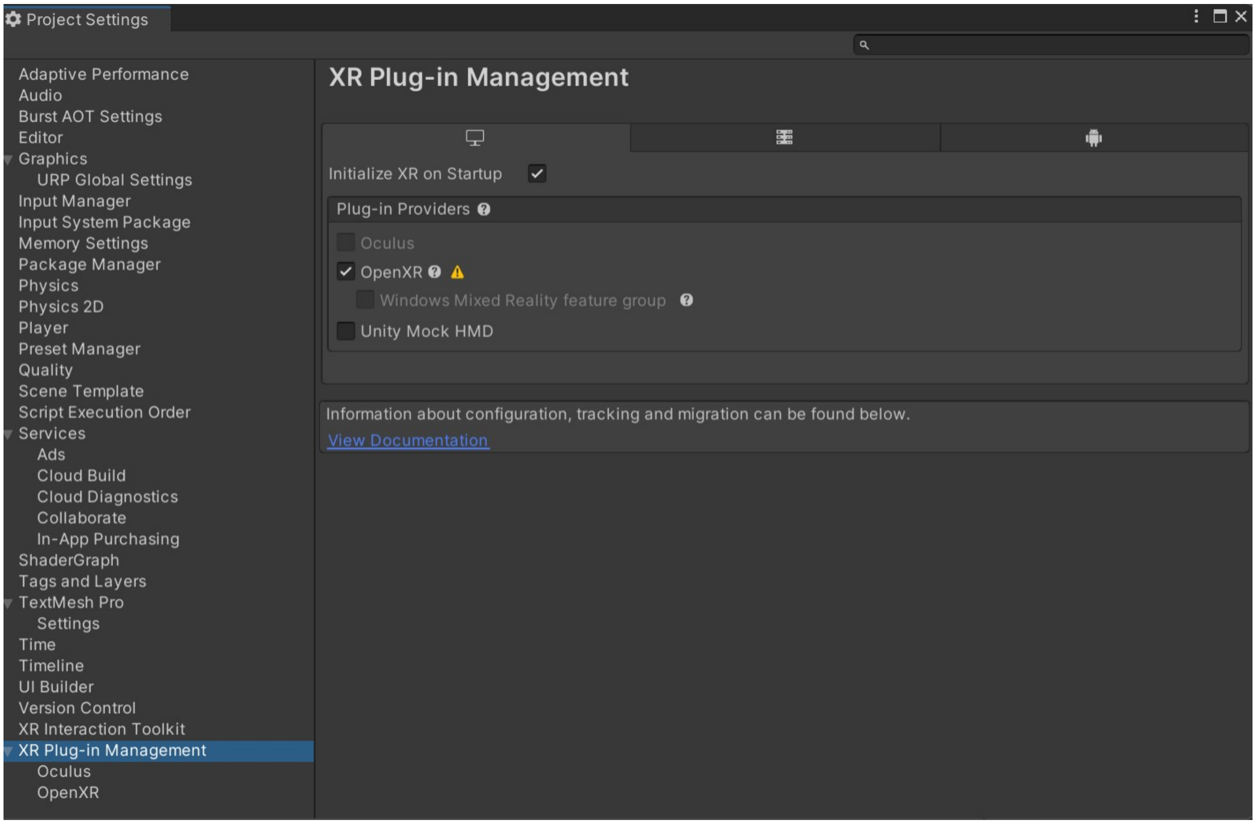

Figure 15.6 XR plugin settings for working with all types of VR googles

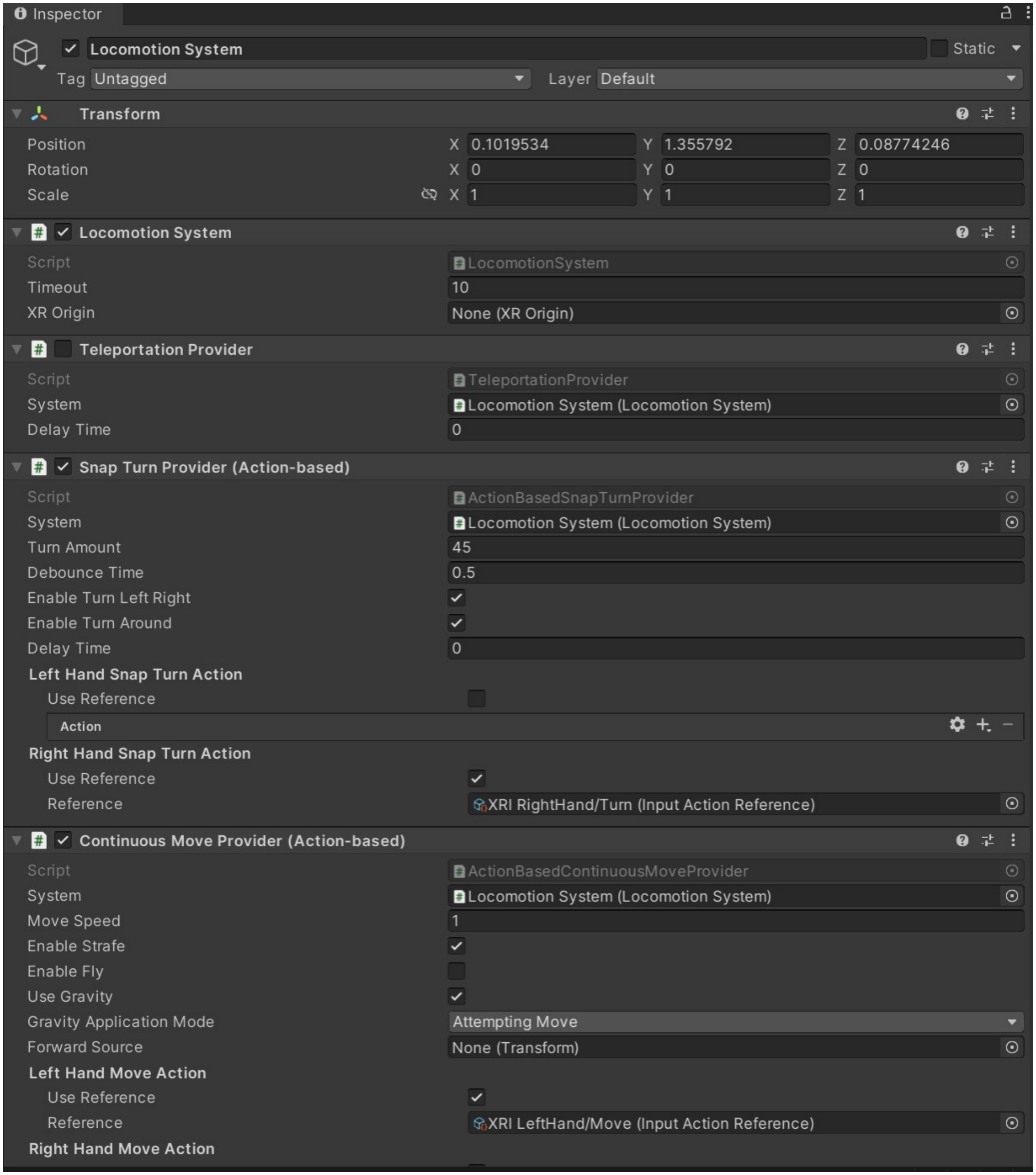

Figure 15.7 Settings required for human movement in virtual world in the locomotion system properties