## Virtual Reality

Virtual Reality (VR) is a technology that creates a simulated environment in which users can interact with digital objects and spaces in real-time. VR has its roots in the early 1960s, when Ivan Sutherland developed the first head-mounted display (HMD) at the Massachusetts Institute of Technology (MIT) [1]. Since then, VR has evolved and expanded in different areas of application, from entertainment and gaming to education and training, and has become increasingly accessible to a wider audience due to the development of more affordable and portable devices.

### The Mixed Reality Continuum

The Mixed Reality Continuum (MRC) is a framework that describes the range of virtuality and reality that can be experienced by users in digital environments [2]. The MRC includes four categories:

* Reality-Reality (RR), which refers to the physical environment without any digital augmentation.
* Augmented Reality (AR), which overlays digital content onto the physical environment.
* Augmented Virtuality (AV), which places users in a virtual environment with some elements of the physical environment.
* Virtual Reality (VR), which immerses users in a fully digital environment.
* The MRC highlights the different levels of immersion, interactivity, and presence that can be achieved with different types of digital environments and devices.

### Components of Virtual Reality

VR experiences can be analyzed in terms of three dimensions of immersion, interactivity, and impression [3]. The concept of 3I is a powerful framework for understanding the potential of VR technology and its applications.

1. Immersion:

The concept of immersion in VR refers to the extent to which the user feels present and engaged in the virtual environment. According to Slater [4], immersion can be achieved through a combination of sensory inputs, including visual, auditory, and haptic feedback, as well as through the creation of a plausible and coherent virtual world. Bailenson and Blascovich [5] further argue that the use of avatars, which allow users to represent themselves in the virtual world, can enhance immersion by enabling social interaction and a sense of embodiment.

1. Interaction:

The concept of interaction in VR refers to the ways in which the user can engage with and manipulate objects and environments in the virtual world. According to Bowman et al. [6], interaction can be facilitated through a range of input devices, including controllers, haptic interfaces, and speech recognition. Slater and Wilbur [7] suggest that interaction is essential for maintaining immersion and a sense of presence in the virtual environment, as it allows the user to actively explore and manipulate the virtual world.

1. Imagination:

The concept of imagination in VR refers to the ways in which the user can use their creativity and cognitive processes to interpret and engage with the virtual world. According to Riva et al. [8], imagination is closely related to the concept of presence, as it involves a sense of being mentally and emotionally present in the virtual environment. Sanchez-Vives and Slater [9] further argue that the use of imagination in VR can lead to a sense of consciousness and self-awareness, as users become more attuned to their thoughts, feelings, and bodily sensations.

### VR Devices

Virtual reality devices are an essential component of the VR experience, as they provide the means for users to enter and interact with the virtual environment. Two of the most commonly used types of VR devices are head-mounted displays (HMDs) and room-scale motion tracking devices (RMDs).

HMDs:

HMDs are devices that are worn on the user's head, covering the eyes and sometimes the ears, and display a stereoscopic image of the virtual environment. These devices typically include a tracking system that detects the user's head movements and adjusts the displayed image accordingly, providing a seamless and immersive experience. HMDs range in quality and price, from basic models like Google Cardboard to high-end devices like the Oculus Rift and HTC Vive.

HMDs are particularly well-suited for applications that require a high degree of immersion and individual exploration, such as gaming and entertainment. HMDs are also commonly used for virtual training simulations, where users can practice real-world scenarios in a controlled and safe environment.

RMDs:

RMDs, also known as positional tracking devices, are devices that track the user's movements in a physical space and translate them into the virtual environment. RMDs can include handheld controllers or full-body motion tracking systems, such as the HTC Vive and the Microsoft Kinect. RMDs are particularly useful for applications that require physical movement and interaction, such as virtual sports and physical rehabilitation.

RMDs can also be combined with HMDs to provide a more immersive and interactive experience. For example, the Oculus Rift S includes both HMD and RMD capabilities, enabling users to move and interact with objects in the virtual environment using handheld controllers.

Overall, HMDs are ideal for individual exploration and immersion, while RMDs are well-suited for physical interaction and collaboration.

### Haptic Devices

In addition to visual and auditory feedback, haptic feedback is an important component of the VR experience, as it provides a sense of touch and physical presence in the virtual environment. Haptic devices are designed to simulate tactile sensations, such as pressure, texture, and vibration, allowing users to interact with virtual objects and environments in a more realistic and immersive way. This can improve the user's engagement and enjoyment of VR applications and provide more effective training in certain industries. Additionally, haptic feedback can provide valuable information to users in situations where visual or auditory feedback may not be sufficient, such as in high-pressure or high-risk environments.

Haptic gloves are a common type of haptic device that use embedded sensors and actuators to simulate the sensation of touch on the user's hands. Haptic gloves are particularly well-suited for applications that involve fine motor skills, such as surgery training and mechanical assembly. According to a literature review by Wang et al. [10], haptic feedback has been shown to be effective in medical training simulators, including those that use haptic gloves for surgical training. Pratt and Hennings [11] also found that haptic feedback enhances force skill learning, which may have implications for the use of haptic gloves in other domains.

Other types of haptic devices include haptic vest, haptic chairs, haptic floors, and haptic feedback controllers, each designed to provide a different type of haptic feedback and enhance the VR experience.

### Simulation Environment

Simulation environments are software platforms that provide developers with the necessary tools and resources to create and develop virtual reality applications and experiences. These platforms serve as a foundation for creating virtual environments, modeling objects and characters, and integrating different features and functionalities.

Two of the most widely used simulation environments are Unity and Unreal. Unity is a cross-platform engine that supports the development of VR applications for various platforms such as Windows, macOS, Android, iOS, and Web. It is known for its intuitive user interface and extensive library of assets, which includes pre-made 3D models, animations, and sound effects. Unity also offers advanced features such as real-time rendering, physics simulation, and artificial intelligence.

Unreal, on the other hand, is a game engine developed by Epic Games that has gained popularity for its photorealistic graphics and advanced physics simulation. It offers a range of tools and features for creating immersive VR experiences, including support for VR headsets, advanced lighting and rendering options, and an extensive material editor for creating realistic textures and surfaces. Unreal also supports a wide range of programming languages, including C++, Python, and Blueprint.

Both Unity and Unreal provide developers with access to a range of development resources, including online communities, documentation, and tutorials. This makes it easier for developers to learn the ropes of VR development and troubleshoot any issues that may arise during the development process.

In conclusion, simulation environments such as Unity and Unreal are essential tools for developers looking to create VR applications and experiences. They provide a range of features and resources that simplify the development process and enable developers to create immersive and engaging virtual worlds.

### VR Applications in Engineering Industry

Virtual reality (VR) has emerged as a promising technology with vast applications in different industries, including training and education, design and prototyping, marketing and advertising, remote collaboration, and maintenance and repair. Its adoption is rapidly increasing, driven by the numerous benefits it offers, such as improved efficiency, safety, and effectiveness.

According to a study by Deloitte, VR is expected to become a $1 billion market for enterprise use by 2020 [12]. One of the key applications of VR in industry is training and education. VR can provide a safe and controlled environment for individuals to learn and practice complex tasks, such as surgical procedures and flight simulations [13]. VR training has been shown to be more effective than traditional methods in improving learning outcomes and retention [14].

Another application of VR in industry is design and prototyping. VR can be used to create digital prototypes and models, allowing designers and engineers to test and refine products before they are physically built. This can save time and money and lead to better designs [15]. VR can also be used for marketing and advertising, allowing customers to experience products and services in a more engaging way. For example, real estate companies have used VR to provide virtual tours of properties, leading to increased sales [16].

VR can also facilitate remote collaboration and communication, allowing team members from different locations to work together in a virtual environment. This can be especially useful in industries such as architecture and engineering [17]. Finally, VR can provide maintenance and repair technicians with virtual training and support, allowing them to diagnose and fix problems more efficiently [18].

VR has numerous applications in industry, and its adoption is rapidly increasing. The benefits it offers, such as improved efficiency, safety, and effectiveness, make it an attractive technology for many industries. As technology continues to advance, it is expected that the potential uses of VR will continue to expand, leading to further adoption in industry.

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