

Regarding the Immersion of VR, What do We Need to do to Make it Better?

Likai Yuan *

University of Wisconsin-Madison, Madison, WI, United State

* Corresponding author email: lyuan45@wisc.edu

Abstract. Immersion is an objective factor for the virtual reality experience. It is important to VR experience. By analyzing the application of VR entertainment such as games and movies, the meaning of immersion is shown. Then looked at how to improve immersion through VR hardware, virtual design, and more. After a brief introduction to the definition of virtual reality, this paper analyzes the impact and importance of immersion through the application of two critical areas of VR entertainment, movies and games. Then, the paper roughly classifies VR hardware into two kinds of output and input devices and studies how to improve VR's sensory stimulation and sense of substitution through hardware. Finally, in the areas of sense of embodiment, reality experience, empathy, and socialization in VR environment design, the role of immersion in all aspects of VR entertainment and ways to enhance it are described. The article concludes with a summary and outlook on the development of VR.

Keywords: Virtual Reality; Immersion; Device; Design; Experience.

1. Introduction

The term virtual reality (VR) originated in the imagination of technology in the 19th century, when it was still the fantasy of science fiction. In the 1950s, Morton Heilig wrote an article, Experience Theatre, arguing that VR should effectively encompass all the senses, drawing audiences to events on the screen. In 1962, he made a visual prototype called Sensorama, in which he showed five short films, involving multiple senses at the same time (sight, hearing, smell, and touch), which can be seen as the origin of modern VR technology. A straightforward definition of virtual reality is an artificial world experienced through sensory cues like sight and sound in which an individual's actions influence the environment in some way. As a means of conveying information, it can also be called a medium, and it has always given people the impression of mystery and novelty before. With the progress and development of the times, virtual reality is no longer a strange thing to people. People can experience the wonderful senses brought by virtual reality in playgrounds, virtual reality experience halls, and even at home.

As a simulation-based experience, it presents a feeling that may be similar to the real world or completely different, but they all have one thing in common, which is the ability to immerse the user in the scene. In the development of virtual reality, immersion has always been a concern of engineers. Immersion in virtual reality is the perception of a physical presence in a non-physical world. By surrounding the user of the VR system with images, sounds, or other stimuli that create an engaging overall environment, this perception is created. It can be seen that the provision of immersion is an objective factor, and the enhancement of immersion can bring a better experience to users. VR entertainment is one of the most popular applications of VR technology, and immersion plays an important role in games, movies, and other entertainment. The construction of a VR environment is based on hardware, so how to provide users with more immersion through hardware such as display devices and controllers is a very important issue. On top of the hardware cornerstone, engineers will also study how to create reality-based sensory simulations and immersive experiences through VR environment design. Compared with other media, virtual reality emphasizes immersive experiences. Due to the importance of immersion to the VR experience, this study hopes to analyze the form, meaning, and development direction of immersion through past research results and successful cases (Fig. 1-Fig.2). This paper mainly focuses on VR applications in the field of VR entertainment (mainly

games and movies), and considers how to achieve a better immersive experience through input and output devices that focus on user experience in VR hardware. of embodiment, realistic experience, real emotion, and social interaction, etc., analyzes how to build an immersive VR environment to give users a more in-depth experience. Among them, the paper also takes the games in science fiction and the developing metaverse as examples to expand the future prospect of VR technology [1].

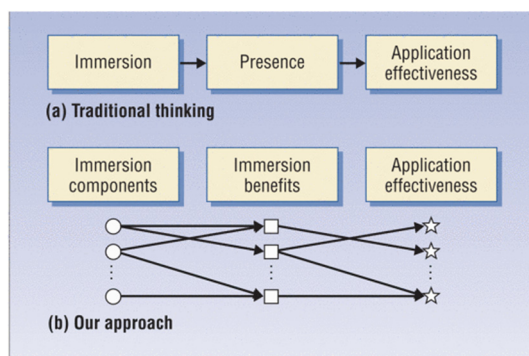


Fig 1. Benefits of immersion [1]

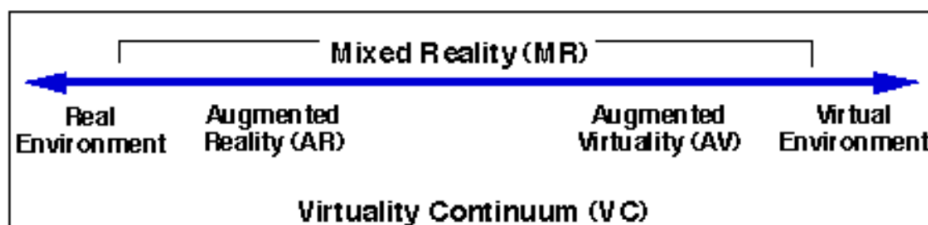


Fig 2. The virtuality continuum, how to get into the VR [2].

2. The Importance of Immersion to VR Entertainment

2.1 Game

The word immersion is widely used to describe virtual reality, but people don't necessarily know what immersion is. Immersion in VR content is best described as an objective assessment of how well a system exists relative to its actual working equivalent. For VR engineers, this is one of the most important factors in formulating a VR environment. So how to make it better has always been one of the most important research topics in VR. For VR games, the sense of immersion needs to allow players to bring the characters they control in the game, and further integrate into the virtual world. Some players may get so addicted to the game that they forget the time, and when they come to their senses, it has been a few hours. And some players will be happy to travel in the virtual world and experience the beautiful environment and customs. What's more, they will empathize with the virtual characters and experience their joy, sadness, and even pain. This kind of experience is very real but dreamy, and in order for players to have such an experience, all that needs to be done is to increase the sense of immersion. Disney is a good predecessor to VR game engineers' exploration of immersion. They started research on the use of VR technology in theme parks in 1992. In order to improve the immersion of VR games in theme parks, their outstanding team of engineers has carried out research in multiple directions. Among them are pioneering research into head-mounted displays, stereos, VR environments, VR gameplay, and more. Their games like Aladdin's Magic Carpet Ride and are fun and engaging by today's standards [2-3]. Back in modern times, Half-Life: Alyx is yet another VR gaming milestone. In the 20th century, which gradually broke through the shackles of technology, this work showed people how realistic VR games can be done, combined with attractive game stories and gameplay. Half-Life: Alyx takes the immersion of VR games to a new level, opens the game, and put on the device; the player is like crossing into this game world (Fig.3).

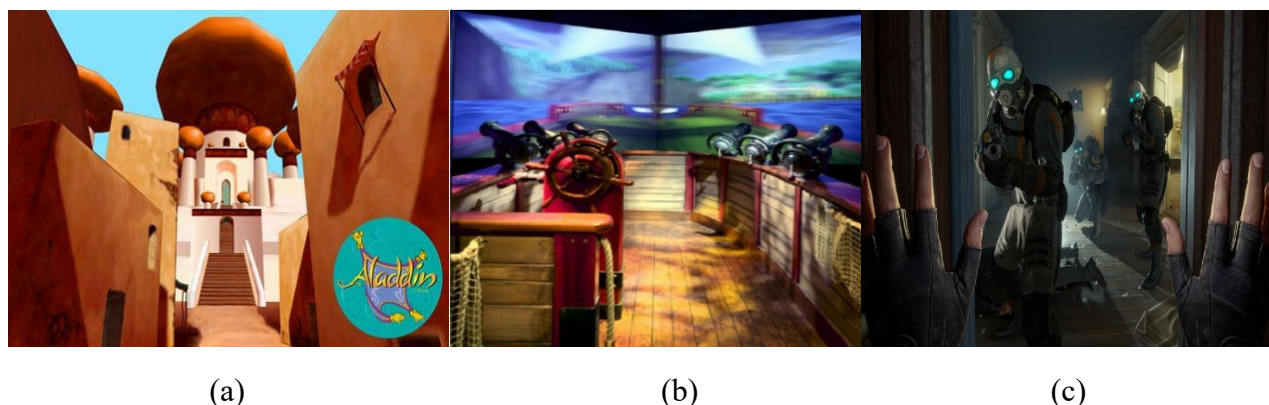


Fig 3. (a) Aladdin's Magic Carpet Ride (b) Pirates of the Caribbean (c) Half-Life: Alyx

2.2 Movie

Another entertainment that uses deep immersion is VR movies. Today's movies have been able to bring a very exciting viewing experience through 3D, and those pictures have gained volume and distance as if they really jumped out in front of people's eyes. And virtual reality technology will undoubtedly make this feeling even better because they will be closer to reality. Unlike VR games, VR movies do not require the control of the audience and are a specialized experience of visual and auditory stimulation. These stimuli can better attract the audience's attention to the picture and give the audience a full shock. Allowing the audience to watch the entire film from the perspective of an on-site bystander (that is, to gain a sense of presence) is the immersion that virtual reality needs to provide. Ready Player One, released in 2018, is a good movie that is very suitable for viewing in VR theaters. This film is a vision for the future of VR technology (Fig.4). The setting and plot of the film are full of people's technological imagination of VR. Although the current VR technology is still far from what is in the film, people can get a glimpse of it by entering the film world through the current technology. Through VR, the future seems to be within reach.

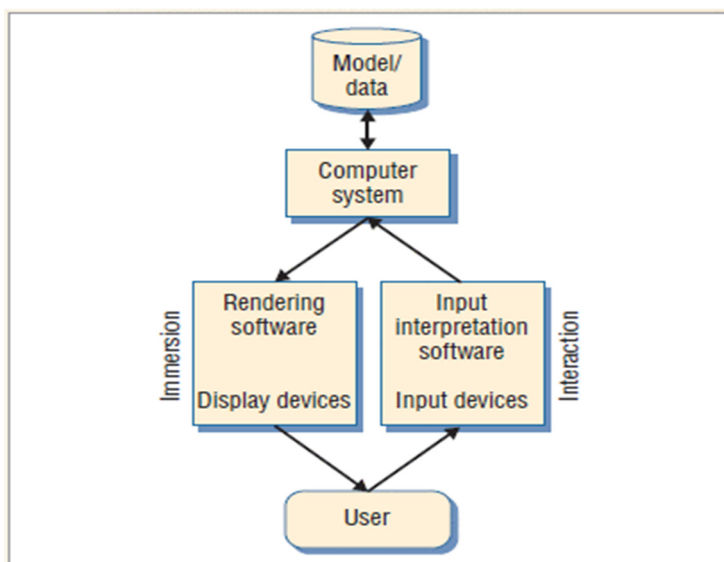


Fig 4. Human-Machine interaction loop. Immersive components are usually divided into display software and hardware [1]

Of course, with regard to immersive experiences, 3D and IMAX technology can now do it, but VR movies go a step further. The first is panoramic stereo vision and surround sound, which entirely transcends the confines of traditional cinema and allow viewers to get fully submerged in the visual, aural, and emotional experience of the story [4]. What's more, it can adjust the presentation of the

image in time through the motion capture of the audience's head, eyes, hands, and other parts by the device, and then form the interaction between people and scenes, and have the right to choose the plot, especially for the key plot and the fate of the characters. Depending on the variations of each pick, each viewer has their unique film after the movie is over. This kind of substitution and playability that enables the audience to contribute to the development of the tale or even build their own version of the movie will elevate the aesthetics of film art and draw more viewers in comparison to the visual and aural sensory stimulation [5-6].

3. Enhance Immersion through Hardware

3.1 Improve Immersion through the Output Device

Current VR technology (especially home consoles) lies in the visual and auditory experience, and sight and hearing are the most commonly used of all the senses. Therefore, enhancing immersion and enhancing the visual and auditory experience is critical.

3.1.1 The Vision Output

The perception system that uses the most neurons in the brain are vision, and the biggest source of VR immersion is also the picture. In order to make the picture more realistic, VR engineers have made many attempts, such as an all-round surround projection hall, a virtual projection room consisting of 3 sides, and the commonly used head-mounted display, all of which are their efforts in display equipment. A taxonomy of mixed reality visual displays mentions that the obvious distinction between the terms real and virtual shows that there are many different aspects, depending on whether one is dealing with real or virtual objects, real or virtual images, and viewing these things directly or indirectly. For VR, being able to show objects as much as possible can mix real and virtual [7]. High fidelity is what a real visual experience needs most, and advances in high-resolution graphics rendering are so rapid that it is now possible to interactively assess the aesthetic quality of objects in a virtual environment. And improvements in lighting and material properties have also enabled near-real products to appear in virtual spaces. Process engineers at Ford FiVE Lab, for example, use HMDs to understand the aesthetic qualities of 3D automotive designs [8]. If this technology can be used for entertainment, it will be a very extreme experience. Now the racing games on the market have been able to provide players with equipment to simulate cabs with complete hardware. If it can be matched with the above-mentioned high-fidelity VR vision, players can get a complete driving experience without leaving home (Fig.5-6).

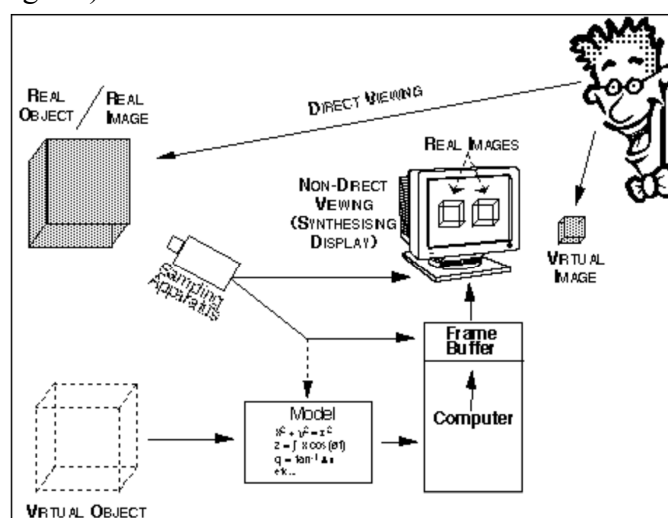


Fig 5. Different aspects of distinguishing reality from virtuality [6]



Fig 6. Person wearing a headset working at a Ford Factory [8]

3.1.2 The Sound Output

The immersion brought by hearing is also very important. The best way to enhance auditory stimulation is surrounding sound, which makes users feel like they are inside the environment. The further improvement is to make the sound produce a sense of space, which is closer to the feeling of the real world. These sensory stimuli will become the source of immersion. When users see a three-dimensional, real picture, and hear a sound with a sense of space, they will feel that they have entered a virtual world, and a sense of presence is generated. Now, there are many manufacturers figuring out how to create such VR sound effects. For example, Oculus licensed VisiSonic's RealSpace 3D audio technology and incorporated it into the Oculus Audio SDK. This technology processes sound information through the spatial information sent by the tracker, making the listener feel that the sound is emanating from the object. NVIDIA has also launched a dedicated virtual reality scene, the first physical-based acoustic simulation technology VR Works Audio, which draws on the idea of ray tracing rendering, fully considers the rendering of 3D scenes, and maps audio interaction to 3D. on objects in the scene, making the audio sound more natural (Fig.7). Valve has released the Steam Audio SDK, a new product of Photon's sound effects tools. This solution can enhance the VR immersion experience through spatial sound effects, allowing the game's audio to interact and bounce back from the scene geometry to enhance the experience. The way they implement VR sound effects varies, but they all aim to achieve a more realistic, natural sound that enhances VR immersion [9].

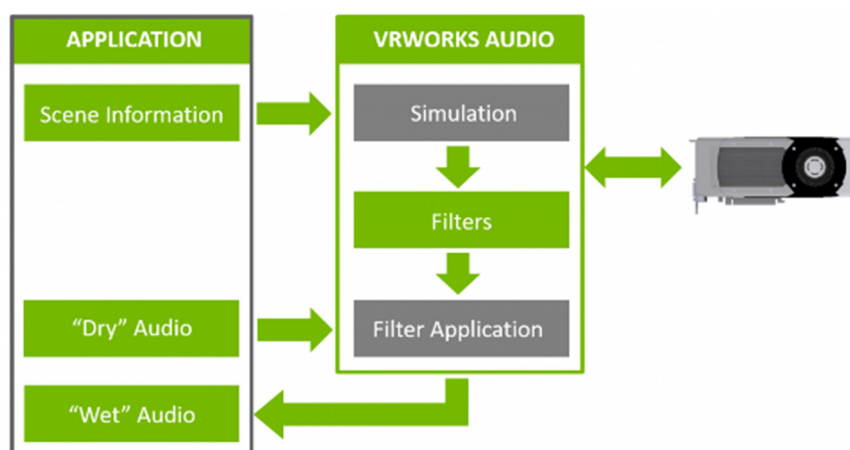


Fig 7. NVIDIA VR Works Audio Pipeline [10]

In addition to vision, sounds are another major aspect of the VR experience, and their development can bring virtual reality closer to reality, which VR engineers have been working on. As can be seen from the above, VR has developed very rapidly in this regard. By continuously improving the realism of vision and hearing, the boundaries between the real world and the virtual world have become blurred and mixed. Such a real experience perfectly interprets the requirements of immersion.

3.2 Improve the Immersion through the Input Device

It was mentioned earlier that a simple definition of virtual reality is an artificial environment experienced through sensory stimuli such as sight and sound, and in which a person's behavior partly determines what happens in the environment. And behavior is better-called interaction here, and is also a fundamental and important part, especially for VR games. Therefore, how to help people achieve immersive interaction in the virtual world by designing better controllers is also one of the research topics of this article. Today's VR devices have been able to restore hand movements well (Fig.8), such as Oculus' VR controller and Meta's VR gloves, etc. The best of them can even provide haptic feedback so that users can fully grasp and touch experience [7].

Not only that, but the VR environment also requires the use of many different controllers. Like the racing game mentioned above, it needs to simulate the driving equipment, so a complete simulation cab will be an excellent VR racing game controller and physical environment. For the controller, the aforementioned full simulation is one of the focuses, while the other is flexible and simple to use. Take the simulated cab of a racing car as an example. For experienced players, a fully reproduced cab will be the best choice, but for the novice or young players, this is not an easy choice. In this regard, Nintendo's LABO series is a good inspiration, its simple controller is not very realistic, but still provides a good sense of immersion, which is inseparable from its ease of use. Therefore, the development of VR controllers will be a variety of choices, whether it is the applicable environment, sensory feedback, ease of use, or professional level of reality simulation, it is very worth considering. And an excellent VR controller is bound to bring users an excellent immersive experience.



Fig 8. Hand tracking in VR [11]

4. Enhance Immersion through VR Environment Design

4.1 How do Let Users Bring Themselves into VR?

For users to bring themselves into VR, they need to fully bring themselves into their virtual body, and this feeling is also called the sense of embodiment in virtual reality. It consists of three main subcomponents: self-orientation, agency, and bodily ownership [12].

4.1.1 Self-orientation

The key to elevating the sense of embodiment in virtual reality lies in these senses. The sense of self-positioning comes from one's own perspective. It has to be said that the first-person perspective of VR perfectly meets this requirement. The user is always in the center of the spatial orientation through the control of the viewing angle of the VR device. Vision is one of the most important senses for most people, which has been emphasized many times above. So visual confirmation is immediate and important for self-positioning [13]. In the past media, the first-person perspective was also a common narrative device used to emphasize the sense of substitution. In VR technology, this perspective is better presented, no longer a flat screen, but a 360° free perspective. At the same time,

people's turning, looking up, bowing, etc. can be synchronized with reality, instead of being realized by conventional controllers (Fig.9). Combined with the spatial sound effects mentioned earlier, people's spatial perception in the VR world is as close to the same as in reality. In this way, the positioning of the self and the body, which is dominated by the senses as vision and some others, is perfectly realized.

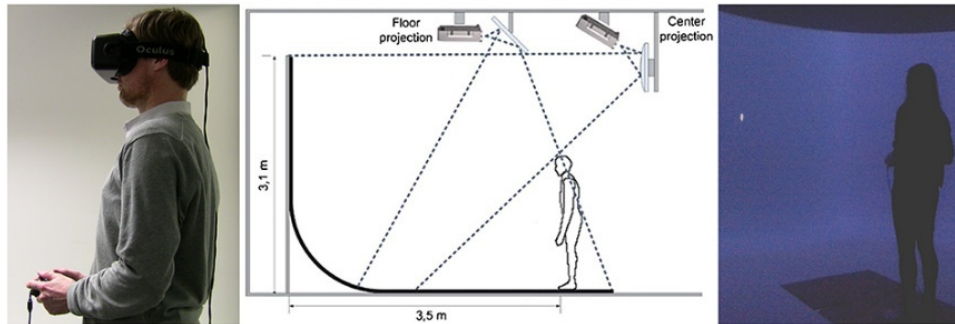


Fig 9. VR viewing angle setting [13]

4.1.2 Agency and Bodily Ownership

A sense of agency and bodily ownership requires them to be fully integrated into the characters and bodies they control, which requires timely and logical feedback [12]. Motion blur is the perfect experience of the real world. High-speed motion blurs the surrounding vision, and this feedback, which is logically in line with reality and very synchronized with the virtual world, allows users to truly experience the feeling of motion. At the same time, reducing the user's discomfort when manipulating the virtual body can also help increase the sense of body ownership. For example, the motion blur mentioned above can easily lead to this drawback: motion sickness. One of the reasons VR is prone to discomfort is motion sickness caused by vision. How to reduce the conflict of this sensory input is the key to solving the problem and improving the sense of ownership of the body. Close to the realistic sensory feedback and sports experience, and then reduce the discomfort caused by sensory conflict. This virtual body becomes the user's self in the virtual world. They can feel that they own this body and are also the protagonist of this experience, so they can better substitute and control it.

After completing these requirements, users can gain a better sense of self-positioning, agency, and body ownership. When their every move, such as reaching, grasping, walking, etc., feels and feedbacks tend to be consistent with the real world. When synchronized and consistent, users can truly enter the virtual world through this virtual body.

4.2 How to Make User has a Good Experience in the Virtual World?

4.2.1 Virtual Interaction and Behavior Pattern

Let users get the same experience in the virtual world as in the real world, such as interactive feeling and behavior pattern. For example, how to make players feel like they are really stepping on the ground in the virtual world. To enhance immersion, it's important to let them travel in the right way. If players are only allowed to blink in the virtual world, then the realism will definitely be greatly reduced, so let them walk in real life, which is the choice of virtual experience at the interactive level.

4.2.2 Limitations in the Virtual World

Another experience that needs to be in line with reality is limitation. In fact, the walking mentioned above is already a kind of limitation, but there are more. For example, the common limitations of blood and physical strength in the game, the protagonist who will not be injured and tired is difficult for people to substitute, just like walking, injury, fatigue, hunger, weight, etc. constraints make the virtual journey become more authentic, rich and meaningful. Of course, restrictions can easily make users feel negative, so considering the balance of restrictions is also an important part of the design.

An easier way would be to do something like Minecraft with a limited survival mode and a creative mode that lets players do whatever they want (Fig.10). Let users choose their preferred experience.



Fig 10. Creative Mode in Minecraft

4.2.3 Virtual UI and Items

Also in games, there is other key element, the user interface (UI) and props. Making UI and props more realistic is the easiest way to bring a real experience, such as a map on the table, realistic and delicious food, etc (Fig.11). But surreal elements can also make virtual reality more fun without detracting from the experience. Since people are in the virtual world, they will naturally acquire surreal abilities. Using Magic UI and props will be a wonderful experience in the virtual world. For example, the walking above, occasionally using flying and teleportation to move will also be a great experience [14]. As long as they are logical and easy to use, they can become normal. Combining normal reality with a surreal experience can better bring the exclusive immersion of the virtual world, even beyond the real world.

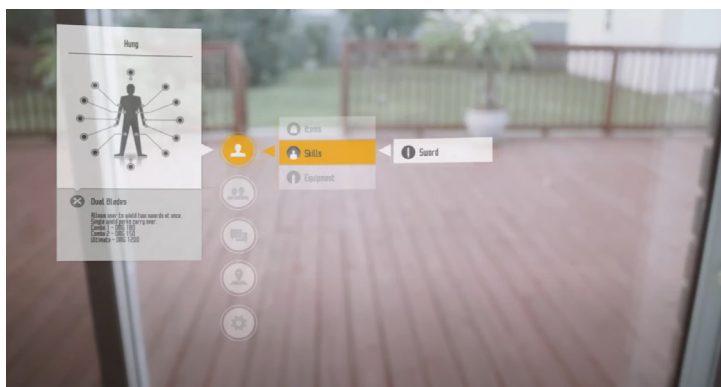


Fig 11. Sword Art Online UI [15]

4.3 Immersion from Better Empathy and Social Interaction

4.3.1 Emphasis on Emotion and Empathy

Compared with ordinary media, the multi-sensory stimulation of VR can restore the story more completely, and simulate the interaction between people (and virtual characters in games and movies). This can be a good way to promote people's empathy and social experience, and then achieve a deeper sense of immersion. Combined with many of the features mentioned above, users can truly enter the world of games and movies and use their minds and bodies to interact and make choices. In the process, they truly become part of the story. Imagine that people can fully enter a role-playing game, operate in a more realistic way, or become their own characters. Experience the story entirely by yourself, going on adventures and talking to non-player characters (NPCs). Such emotional stimulation is far beyond other multimedia games, and thus a sense of presence and empathy arises spontaneously. Similarly, the ultimate goal of VR movies is the same, allowing the audience to

participate, choose, experience, affect the audience's emotions, and sublimate the art of the movie. Under emotional mobilization, people are more closely connected with the virtual world, so they are immersed in it together with their mood [16].

4.3.2 Create the World, Build the Social Environment

When it comes to interaction, now a new concept has entered people's horizons: the metaverse (Fig.12). It and VR can be described as a match made in heaven, and the birth of the Metaverse is inseparable from the development and application of VR. Through games like VRchat and Second Life, one can already glimpse a glimpse of a future metaverse. This also shows the huge potential of VR in social, economic, and other aspects. The current VR social media cannot achieve the realistic sensory stimulation imagined, why is it still so attractive? This is due to the attractiveness of social interaction, which can increase people's satisfaction with the environment, both in reality and in virtual worlds. In the current VR social interaction, your face-to-face may still virtual animation view, but your conversation is a real social experience. Meeting in a virtual coffee shop, sitting down and chatting, is as natural as the real world, but also adding a surreal romantic image, immersing in such a social interaction is also immersing in this virtual reality environment [17-18]

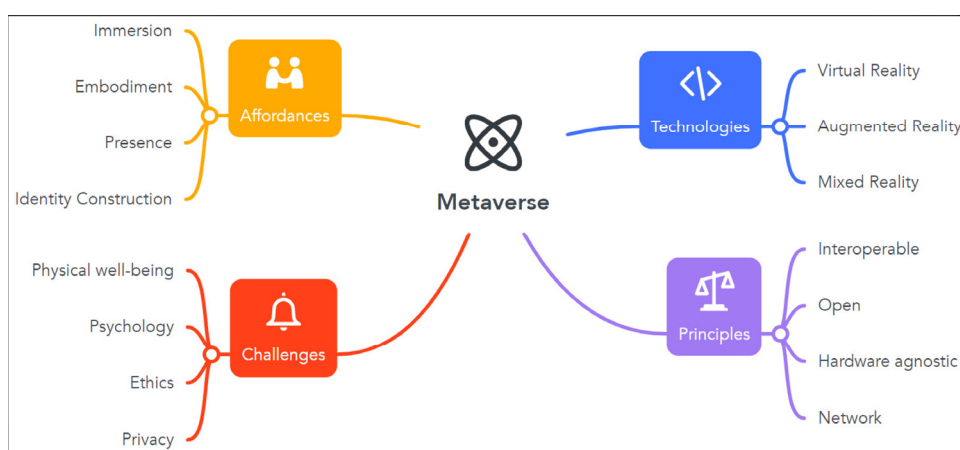


Fig 12. The Metaverse [18]

5. Conclusion

In conclusion, this article highlights the importance of immersion in VR entertainment. The development direction of VR can be analyzed in terms of hardware and software. The impact of vision, hearing, and other senses, and the control method full of substitution make players integrate into the virtual at the physical level. Realistic but surreal virtual experience and real, three-dimensional, if touchable views or modeling allow users to go further into the virtual world. Virtual reality builds an immersive world with hardware as the cornerstone and software as the bricks. VR technology allows people to enter the virtual body to write stories and adventures in a beautiful fantasy world. Further, people's emotions and social interactions will also be brought into these virtual worlds, making the world composed of data more colorful. If these technologies can be implemented and applied to VR entertainment (and more other areas), it can make the user experience better and bring the word virtual reality closer to its literal meaning. Given the speed at which technology is developing, the virtual reality that people imagined is no longer just a fantasy. The efforts of today's VR engineers will lay a solid foundation for the true metaverse that people imagine. The dream of Zhuang Zhou, which aims to achieve a happy and free world by attaching importance to the construction of a spiritual pure land. Such a dream can also be developed into reality through future VR technology.

References

- [1] D. A. Bowman and R. P. McMahan, Virtual Reality: How Much Immersion Is Enough? in *Computer*, 2007, 40, 7: 36-43, doi: 10.1109/MC.2007.257.
- [2] Mine, Mark. Towards Virtual Reality for the masses: 10 years of research at Disney's VR Studio. *Proceedings of the Workshop on Virtual Environments*, 2003. 11-17. 10.1145/769953.769955.
- [3] Half-Life: Alyx. SteamVR - Valve Corporation. 2, 2022, from <https://www.half-life.com/alyx/>.
- [4] Warnerbros.com. (n.d.). Warnerbros.com. Retrieved September 2, 2022, from <https://www.warnerbros.com/movies/ready-player-one>.
- [5] Gödde, M., Gabler, F., Siegmund, D., Braun, A. Cinematic Narration in VR—Film Conventions for 360 Degrees. In: Chen, J., Fragomeni, G. *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry. VAMR 2018*. vol 10910.
- [6] Milgram, P., & Kishino, F.. A taxonomy of Mixed Reality visual displays. *IEICE Transactions on Information and Systems*, 1994, E77-D (12), 1321–1329.
- [7] C. Anthes, R. J. García-Hernández, M. Wiedemann and D. Kranzlmüller, State of the art of virtual reality technology, 2016 IEEE Aerospace Conference, 2016:1-19.
- [8] Berg, L.P., Vance, J.M. Industry use of virtual reality in product design and manufacturing: a survey. *Virtual Reality* 2017 21, 1–17 .
- [9] Serafin, G., & Serafin, S.. Sound design to enhance presence in photorealistic virtual reality. *Georgia Institute of Technology*.2004, 6:13-21.
- [10] VRWorks - Audio. NVIDIA Developer. <https://developer.nvidia.com/vrworks/vrworks-audio>.
- [11] What is hand tracking in VR? Ultraleap.com, 2022, from <https://www.ultraleap.com/company/news/blog/hand-tracking-in-vr/>.
- [12] Kilteni, Konstantina & Groten, Raphaela & Slater, Mel. The Sense of Embodiment in Virtual Reality. *Presence Teleoperators & Virtual Environments*. 2012, 21. 10.1162/PRES_a_00124.
- [13] van der Veer, A. H., Longo, M. R., Alsmith, A. J. T., Wong, H. Y., & Mohler, B. J. Self and body part localization in virtual reality: Comparing a headset and a large-screen immersive display. *Frontiers in Robotics and AI*, 2019, 6, 33.
- [14] Bowman, D. A., McMahan, R. P., & Ragan, E. D. Questioning naturalism in 3D user interfaces. *Communications of the ACM*, 2012, 55(9), 78–88.
- [15] Tran, H. *Sword Art Online UI - VFX Test*. 2014 .8 Youtube. <https://www.youtube.com/watch?v=ALGcJVfb5oo>.
- [16] Schutte, N.S., Stilinović, E.J. Facilitating empathy through virtual reality. *Motiv Emot* 41, 708–712 (2017). <https://doi.org/10.1007/s11031-017-9641-7>.
- [17] Hudson, S., Matson-Barkat, S., Pallamin, N., & Jegou, G. With or without you? Interaction and immersion in a virtual reality experience. *Journal of Business Research*, 2019, 100, 459–468.
- [18] Mystakidis, S. Metaverse. *Encyclopedia*, 2022 2(1), 486–497.