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Author:
Sophia Hölzl

Student identification number:
2110475167

Supervisor:
René Goldschmid

Date:
dd.mm.yyyy

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List of Abbreviations

VR	Virtual Reality
VE	Virtual environment
HMD	Head-mounted device
IVE	Immersive virtual environment

Key Terms

Virtual reality

Immersion

Contents

1 Abstract

2 Introduction

Virtual reality (VR) has become more present in the last few years. It has changed the way people watch movies or play games. VR is not only used for entertainment, but also for therapy session and has even offered students and younger children a new study technique in a learning environment. Virtual environments (VE) that completely separate the user from their real surroundings increase the degree of immersion immensely and therefore changes the way people experience VR. It offers a distinct edge by delivering increasingly dynamic and emotionally heightened encounters. [1]

VR is considered to be a high-presence medium. The terms presence and immersion are oftentimes used interchangeably. The user's engagement with a VR system leads to immersion, resulting in the user entering a flow state. Sensory immersion, which is defines as "the degree which the range of sensory channel is engaged by the virtual simulation", is a significantly factor of immersion to VR systems. [2] The term presence is often used to express the sense of "being there" in the virtual environment. [2]

There are several elements that significantly contribute to the immersion of a user in a VR game. To get a player feel completely present in a game, you have to prioritize usability, clarity, and visual appeal in the VE design. Besides the design aspects of the VE, user-friendly menus, intuitive interaction elements, and realistic interfaces that allows user to navigate through the VE are also a big part of the immersion. [3]

3 VR Games

When we talk about virtual reality, it is important to understand the three most important features, the so called three I's of virtual reality. The first two I's are interactive and immersive. These two features go hand in hand. However, most of the people forget about the last feature of virtual reality. Virtual reality is not only accessible for the medium or high-end user. It can also provide solutions to real problems in engineering, medicine, military and so on. It depends on the user's imagination, if an application can solve a particular problem. Therefore, virtual reality is an intertwined concept with the so called three 'I's of VR - immersion, interaction and imagination. [4]

3.1 State of the art

3.2 Use of immersive VR

3.3 Motion sickness

4 Immersion

The word immersion can be used for many different departments. In the world of VR, immersion means being plunged into a virtual environment. Immersive VR can have a tremendous impact on the users experience and their motivation.

4.1 Level of Immersion

Within a VE setup, a computer produces sensory stimuli that are transmitted to the human senses. The level of immersion and the feeling of presence in VR is determined by the quality and type of the stimuli generated by the computer. Ideally, the high-resolution, high-quality, and consistency over all the displays, information should be presented to all of the user's senses. In order to maintain the illusion of immersion, the VE should react accordingly to the user's action. In practice, VE systems only stimulate one or a few of these senses. VR systems can be categorized based on the degree of immersion they provide to the users. [5]

4.1.1 Non-Immersive (Desktop VR) systems

This type of immersion is very easy to implement in many applications, for the reason that it does not need special equipment. It is the simplest type of VR systems. Nevertheless, it is still commonly used today. Desktop VR is when the user experiences the VE using one or more computer screens. One characteristics of a non-immersive VR system is that the user can control and interact with a character, but the environment is not directly interacting with the user and therefore not fully immersed in it. The only sensory output is the display. Because of the real time visualization and interaction within a VE that simulates a real world is the reason it became popular in the first place.[5]

4.1.2 Semi-Immersive (Fish Tank) systems

Semi-immersive system is a combination of non-immersive and fully immersive VR. It provides users with a partially virtual environment where they remain connected to their physical surroundings. It generally does not support sensory output. [5] The user can experience the VE without any physical sensation and still provide them with the feeling of being there, by using a VR headset and controllers. By using a VR headset, the user will not be able to see the real world, only the virtual environment, which will create a strong immersive experience. Semi-immersive VR is the most cost effective form and therefore the most commonly used form of VR after non-immersive VR. It can be both device-based and web-based. Many businesses such as real estate websites, hotels and locals bars or pubs, universities and schools use semi-immersive VR to promote their location. [6]

4.1.3 Fully Immersive VR (HMD-VR)

This type of immersion allows the user to completely dive into VE with the help of head-mounted-devices (HMD). They can be enhanced by audio, haptic and sensory interfaces.[5]

Although this type of VR is the most expensive one, because you need to buy pricey accessories like VR glasses, gloves or even a body suit with body connectors with sense detectors. In addition, fully immersive VR needs advanced technology that can detect and handle the movement of the users with powerful graphics processing units (GPUs) that all together create a seamless and responsive virtual environment. [6, 7] It is different from other types of VR in that they capture full body motion. The core hardware of a fully immersive VR is the Head-mounted Display (HMD). Users wear this device on their head, and it contains two displays for each eye, which create a stereoscopic 3D effect. Oftentimes, these HMD have integrated sensors that can track head movements, which allows the users to look around in the VE. Haptical feedback is another characteristic of fully immersive VR. It includes gloves, vests or controllers that allows the users to feel and touch objects within the virtual environment. Haptical feedback plays a significant role in the immersion of the user. [7]

4.2 Type of Immersion

4.2.1 Tactical Immersion

This type of immersion is experiences when performing tactical operations that require skills. Users feel "in the zone" while perfecting these skills that result in success. [5]

4.2.2 Strategic Immersion

Strategic immersion is more intellectual. The VE offers strategic problems that are mentally challenging the players. Users feel immersed when they find a working solution resulting in mastering a demanding problem.[5]

4.2.3 Narrative Immersion

Uses get so invested in a game story that they feel like they are actually in the game. It is a similar experience when reading a book or watching a movie. [5]

4.2.4 Spatial Immersion

Spatial immersion occurs when a player feels the VE is perceptually convincing. The player feels that he or she is really "there" and that a simulated world looks and feels "real". [5]

4.2.5 Psychological Immersion

This type of immersion happens when the user confuses the VE with the real life. [5]

4.2.6 Sensory Immersion

The player experiences a unity of time and space as the player fuses with the image medium, which affects impression and awareness. [5]

5 Design of Virtual Environment

Virtual reality is a convenient tool to simulate real-life events and study human behavior as it allows researchers to fully immerse participants into a controlled virtual environment. VR is considered to be a high-presence medium and allows for a high degree of experimental control. Therefore, VR has been used for diagnosis, clinical education, and clinical and experimental intervention. Although the terms "presence" and "immersion" are sometimes used interchangeably, researchers have made a distinction between the subjective psychological sense of presence and immersion, which is associated with the quality of technology used. (vielleicht weglassen, weils in der Introduction steht) VR has the potential to study human behavior without exposing the participants to the risk and inconsistencies that can occur in the real-world environment. Another advantage of studying human behavior in immersive virtual environments (IVEs) is the full control of the social interaction and other environmental factors, such as noise and crowding, that can take place in the real-world environment and change the way a human would react naturally. [8]

An IVE that was designed with highly visual content, spatialized sounds, and haptic feedback are considered more immersive than a scene that was rendered on a computer. Thus, portable Head-mounted displays (HMD) that have the ability to block out the real-world surroundings are preferred while studying human behavior. Besides the advantages of HMDs, there are also some disadvantages that need to be considered when designing an IVE. As participants do not see their real body, developers need to consider the fact to include avatars. Participants also need the ability to navigate through the virtual space. The design of the IVE plays a crucial role in the immersion of the user, therefore developers need to consider a few elements when designing a IVE. Factors like, avatars, audio, light, and other context need to be carefully studied. [8]

5.1 Degree of detail in the environment

Researchers proposed that typical element features, such as furniture, need to be included in an IVE. However, they should have an appropriate amount of detail according to the kind of behavior that researchers want to study. When studying gambling behavior, elements like paper slips, pens and stools in the betting shop need to be considered and included. Realistic textures are very important in studies where participants are expected to move around the environment and pick up items to investigate them. [8]

Providing elements with a realistic texture can improve the participant's sense of immersion. Visual realism has two components: the geometric realism and the illumination realism. The former investigates the similarity between virtual and real objects and the latter concentrates on the fidelity of the lighting model. However, designing complex IVEs can be very time-consuming, need heavy computational algorithms and can decrease frame rate when users view the IVE. Before committing to a final design, researchers need to decide the level of complexity of their IVE, as a suboptimal design can have a serious impact on the user's behavior. It also needs to be considered when using a high level of visual realism, it might rise the participants expectation for other aspects (e.g., nonvisual, and tactile) of the virtual

environment. Researchers also need to consider what elements are relevant and irrelevant, hence users could pay more attention to irrelevant elements. [8]

5.2 Context

Relevant and irrelevant elements Prior to developing IVEs for behavior analysis, researchers must determine the essential contextual cues and assess VR's capability to integrate all the necessary elements. The intricacies of social elements, which are elaborated on in the next section, present particularly complex tradeoffs. Participants often put their focus on objects most relevant to looking behaviors, such as windows. They also engage in more exploratory behavior, which are not very prominent in the real environment. Exploratory behavior in this context can be explained as paying more attention to objects that are not relevant to the research question. [8] Participants put their focus more on irrelevant parts of the IVE, like "see-through" objects (e.g., windows) instead of practical objects with functionality. The intense attention to display surfaces or windows underlines the concept of multiple incorporation of elements during interaction in virtual environment. The spatial awareness of a participants in an IVE is however still embedded in their real surroundings. For example, if participants are more observant of windows or display surfaces that display information's about the exterior, participants may be creating a mental model of the IVE's location and themselves in the virtual space. Therefore, researchers and developers should deliberate on whether certain features, like windows or displays, should be incorporated, or left out, given the fact that participants pay more attention on irrelevant features. [8]

Stimulatory and instructional cues Cues, like stimulatory and instructional cues, can be very helpful to participants, considering they provide relevant information and navigation within the IVE. For example, using lighting and moving traffic allows the participant to develop a sense of time. However, such cues should be used carefully as it should only emphasize an emotion of the participant and not affect the playability and navigation in the IVE. Instructional cues can assist participants in navigating through the. [8]

Animating interactions If IVEs contain features that are animates (e.g., walking avatars, moving cars), it is important to consider the right animation speed. It should also be considered the age and gender of the avatars when choosing their animation speed. To maintain the feeling of immersion there should be minimal to no movement mismatches. These mismatches can happen when participants rotate or move their body. [8]

5.3 Social cues

Social cues are features that a participant can interact with, like avatars. In certain cases, avatars can enhance the realism of the IVE. However, they can also distract the participants and distract their focus to something unimportant. When avatars or self-avatars are introduced, it is essential to animate them appropriately. [8]

5.4 Self-avatars

When introducing self-avatars in an IVE, there is a possibility that it can enhance a participant's immersion. Users feel more immersed when there is a representation of themselves in the IVE and other avatars recognize them.

5.5 Nonvisual sensory information

5.6 Audio

There are not only visual aspects of VR, that can have an impact on the immersion. Non-visual aspects such as audio or haptic feedback can also change the way a user feels immersed in a VE. [9]

5.7 Light and shadows

Not only the design aspect of the assets has an impact on the immersion of a user. The realisticness of the assets is also very crucial. If a model is placed under light, the user expects the models to throw a shadow. The user not only expects there to be shadow but also awaits the asset to look darker in the shade than in the sun. If there is water or something else fluid inside the VE, the player also wants to see some refraction of the light. [9]

6 Interaction and Navigation

7 Storytelling

8 Character Design

9 Desktop VR vs Head-mounted VR

10 Discussion and Results

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List of Figures

List of Tables

Appendix

(Hier können Schaltpläne, Programme usw. eingefügt werden.)