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THE CURRENT TECHNICAL CONCEPTION OF VIRTUAL AND AUGMENTED REALITY

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Abstract

This article discusses the overall conception of virtual and augmented reality considering modern technological approaches to the practical application of these concepts. The main aim was to assess available technology in respective fields of simulation. It analyses a consumer approach to the general ideas of these phenomena. A basic technical overview is included. The current state is reviewed using commercial sources of devices focused on delivering stimuli necessary for sensory experiences connected to simulated environments. A short discussion of future development concludes the presented study.

Keywords: virtual reality; augmented reality.

1. Introduction

As the main aim of the associated longer study, the suitability of augmented and virtual reality as a training tool for police forces is being researched. The idea of a simulated or semi-simulated environment appears to be suitable for training tasks of dangerous nature or in a hazardous environment. An example of learning and training activities in virtual reality already in use can be found in NASA's EVA (extravehicular activity). In its complexity, it represents tasks outside the relative safety of a cosmic vehicle, notably exterior repairs. Mistakes and out-of-ordinary events during these activities - possible on-site training included - may increase risks the astronaut and the whole crew are already facing. From a logistical point of view, it is unwise to perform the exercise of this character on the actual objects. In this case, we try to replicate an utterly different environment and its attributes, i.e., gravity or optical conditions. [1]

Virtual reality can also be used to simulate known and accessible environments. In these environments, we focus on the simulation of possibly dangerous situations. As a typical representative of this fact, training of combatant and non-combatant military units is suitable. Exercises in the simulated environment called "Virtual Battlespace" by Bohemia Interactive Simulations aim at tactic and procedural processes in the context of combat situations. [2]

Following the stated logic, we can deduce the suitability of these technologies for exercises and training in selected aspects of police work. Before suggesting an applicable simulation training model, it is appropriate to assess the current condition of available simulation means and define attributes of widely used terms virtual reality and augmented reality.

2. Virtual reality

The literal definition of the name "virtual reality" may seem like an oxymoron, for it combines words with the meaning of "pretended, unreal", and "real". This conceptual mismatch may be explained using the practical application of virtual reality, where its "virtual" or pretended part, meaning abstract environment and objects, overwrite perception of the real world. It would be more precise to call this concept a "substitute reality ". [3]

To "overwrite" perception of the real world, we must establish what senses are used to perceive reality and what to overwrite to achieve the desired effect. In modern practical applications, the interaction between the user and substitute reality can be divided into sensory and motor levels. [3]

On a sensory level, we can discuss what senses are used to perceive the real world (sight, hearing, touch, etc.) Motor level deals with ways of environmental interaction of the user - position and orientation of the user as well as his direct interaction with objects of a simulated environment. [3]

Based on this analysis, a conceptual description of the defined cyberspace of the virtual reality user can be formulated. The user is in a virtual environment, which he perceives using a motor interface. A motor interface captures his acts (movements and gestures) and transfers them into a computational unit (computer), where they are interpreted as purposeful changes in an environment. The same unit evaluates changes in an environment and mediates them to a user using a sensory interface. [3]

Environments with such capabilities may correspond with the physical properties of the real world and thus be considered a type of real-process simulation. By overwriting some senses, a simulated environment and its processes are perceived. A user can feel his presence in a simulated environment. His perception is "taken" out of the real world, and we may claim that the user is in a space defined as a virtual reality.

2.1. Overwritten senses

When overwriting a sensory perception of the real world to achieve a feeling of presence in a simulated world, it is necessary to limit the perception of the real world.

The current practical use of virtual reality doesn't require overwriting all senses. By practical use, we mean commercially available resources of virtual reality. The required hardware is worn directly by a user. It integrates sensory and motor interfaces of the user's head and usually the motor interface of the user's hands. In figure no. 1, we can see such a device under the consumer branding "Oculus Quest 2". [4], [5], [6], [7]

Fig. 1. Ocullus Quest 2 [9]

The primary aim is visual and hearing projection of a simulated environment. [4], [5], [6], [7]

2.2. Hearing

Hearing overruling in the environment of discussed purposes doesn't require customized hardware. Already high demands on audio projection, including dampening sensory perception of the real world, allow its utilization for virtual reality.

One of the attributes concerning an undamaged auditory system is the ability to distinguish the direction, in some cases even distance, of the sound source relative to the observer. Simulation of an environment with a natural feeling requires focusing on this fact. Based on current knowledge, we can claim that humans use the following acoustic phenomena [8]:

- Time difference
  - If the sound source is not directly in front of or behind the observer, each auditory system pair organs receives acoustic waves with different feedback or interauricular time difference. [8]
- Intensity difference
  - Suppose the sound intensity lowers with a longer distance to the auditory organ. In that case, the position of the sound source out of the direct view axis of the observer can be perceived as a difference in incoming sound intensities. [8]
- Acoustical shade
  - If there is an obstacle between a sound source and the observer, the acoustic attributes of the said obstacle are usually exhibited as dampening or reflection of acoustic waves. [8]

A human perceives these observed acoustic phenomena in a close connection with visual perception. In some cases, previous experiences with an expected sound source may influence perception experience. For example, the assumed intensity of the sound source can affect its perceived distance. While using appropriate recording technology and techniques, necessary acoustic characteristics of sound can be recorded and reproduced in a way simulating surround sound. It can be achieved using multiple loudspeakers, as in the 10.2 configuration, meaning ten loudspeakers and two subwoofers (Fig. 2.). [8]

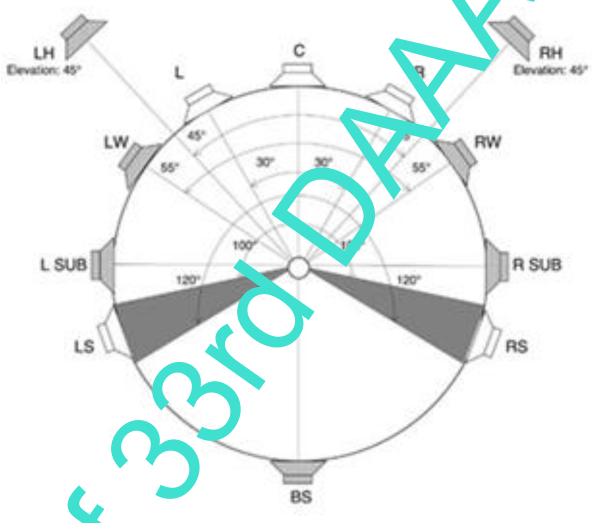


Fig. 2. Spatial sound projection in 10.2 configurations [8]

In this scheme, individual loudspeakers are marked with a corresponding direction letter L (left) and R (right), excluding the center speaker (C) and back surround speaker (BS). All other loudspeakers are marked with a letter determining their acoustic character. H means high speaker, ideally above the observer, W labels wide acoustic spectrum speakers, SUB subwoofers, and S for surround speakers.

A comparable effect may be achieved using headphones. In this case use of technology is limited by the size of the reproductory device. Fig. 3 shows a chart of an earphone shell equipped with multiple drivers. Using this method, we can achieve the desired acoustic range to simulate the sound experience in its original environment. [8]

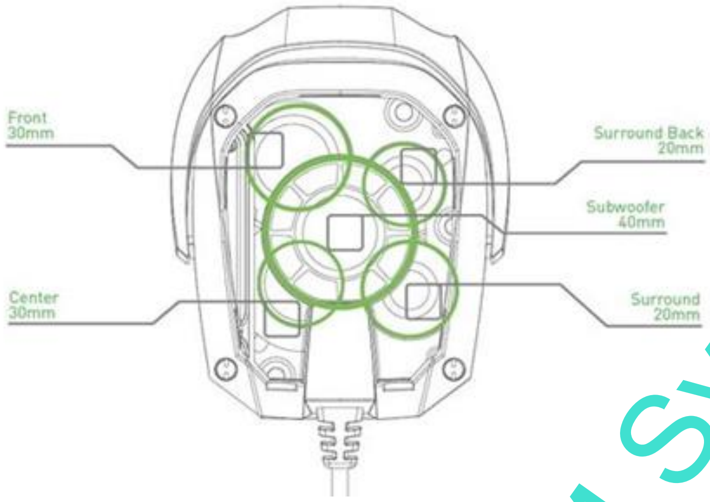


Fig. 3. Chart of surround sound headphones Razer Tiamat 7.1[12]

2.3. Sight

As for visual perceptions, higher levels of sensory overwrite can be achieved more efficiently while real-world visual perception is blocked altogether. For this purpose, a harness-like device is used. Its main goal is to hold displaying device in the desired position for the user and block his visual stimuli of the real world. This set is called a "head-mounted display" (HDM). Apart from display or displays and optics, it also includes various hardware, depending on before mentioned technology conceptions. [7]

Sight may be considered the primary human sense for spatial orientation. Approximating the distance between observer and object and a similar practical distance estimation between two things allows humans basic spatial orientation. Said tasks are processed using the following principles: [8]

- **Static distance estimation**
  - These are common elements for a static and dynamic scene. It includes basic physic and geometry optic phenomena suggestive of an object's distance. The brain perceives objects' relative position, the picture's size, linear perspective, shades, brightness, and changes in texture perception. [8]
- **Movement parallaxes**
  - Perception of a speed difference between objects at various distances. [8]
- **Physiologic indexes of distance**
  - An eye of a person, looking at objects at various distances, is moved by respective muscles to achieve an optimal picture. Concerning distance, these movements are:
    - ***Accommodation***
      - Bending of the eye lens using muscles. These muscles are registered by the brain and utilized to estimate the distance of the observed object. [8]
    - ***Convergence***
      - Convergence of eyesight. The whole eyeball is moved, and this process is again registered by the brain and interpreted as an index of the distance between the object and the observer. [8]
- **Stereoscopic sight**

Physiologic eye placement allows for a slightly different picture perception by each eye. It varies in the angle between the eye and the observed scene. A three-dimensional image is perceived by a subconscious combination of these different pictures. [8]

Knowledge of these principles can be used in creating an artificial digital scene where its purpose is for a user to perceive this scene as a fully three-dimensional space. Generally, the difference between the perception of each eye of the observer needs to be determined, and accordingly, various images should be presented to them.

This task can be achieved using multiple methods can be used: [8]

- **Passive**
  - ***Anaglyphic method***
    - The principle of this method uses a combination of two pictures with vastly different colors and shifted perspectives. While watching such pictures with accordingly tinted lenses, a three-dimensional image is imagined. This method requires a strict color palette, which narrows its applications. [8]
  - **Polarization method**
    - A projected image includes scenes for both left and right eye. While observing such pictures through dedicated polarization filters, each picture is perceived by the corresponding eye. Contrary to the anaglyphic method, color use is not significantly limited. [8]
- **Active**
  - ***Active shutter method***
    - An observer is subjected to alternating scenes for the left and right eye. He wears goggles with liquid crystal shutters (LCD shutters) that are synchronized with a projection device allowing only images for each eye to be seen by a respective eye, left or right. [8]
  - ***Direct calculation***
    - Modern HMDs contain two separate displays (in some cases, one display may be used for both eyes, such as Google Cardboard). This way, the device can project individual pictures directly to each eye. Principles of spatial awareness and orientation are used for modeling a realistic scene.

2.4. Construction of HMD

The construction of HDMs varies between manufacturers, depending on used conceptions and the hardware price range. The following scheme (Fig. 4.) shows the schematic principle of HDM construction.

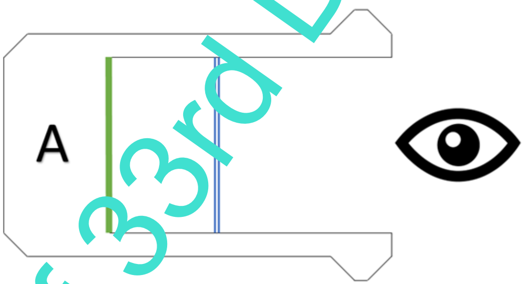


Fig. 4. Construction of virtual reality HMD

Depending on the individual type of virtual reality device, HMD contains most of its hardware in the area labelled A in Fig. 4. Based on used hardware, especially considering "standalone" versions of HMDs (these include naturally heavy technology, such as batteries) and ergonomics of the device and interaction with a simulated environment can be affected negatively. Due to its placement on the head of the user, this limitation can be more profound during more extended use. The outer shell of the HMD usually contains the device's interface and sometimes tracking cameras. [7]

HMD also contains display or multiple displays (in Fig. 4. marked with green colour) and lenses (in Fig.4. marked with blue colour.) Distance between lenses and eyes depends on the preferences of individual users as well as their respective sight irregularities. The distance between the lens and the display is not permanently fixed. It can vary based on many factors. Predispositions of the users can be one of them. Therefore, some HMDs allow for an adjustment of this distance. The distance can also be different with the used lens and display type. This distance is in the order of centimeters. [9]

The display unit and user's eye isolation achieve more realistic immersion and limitations of real-world perception.

2.5. Examples of current HMDs

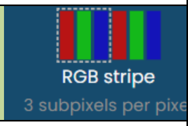
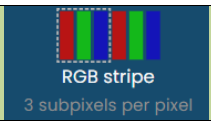
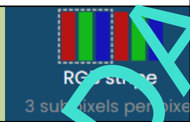
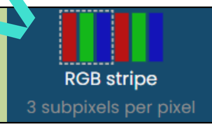
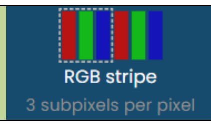
	VRgineers XTAL 3 Mixed Reality	Pico Neo 3 Link	Varjo Aero	Skyworth W1 Pro	Huawei VR Glass 6DoF
					
Computing Hardware	PC	Standalone	PC	PC	Smartphone, PC
Release	31. 5. 2022	24. 5. 2022	20. 1. 2022	31. 12. 2022	17. 11. 2022
Optical correction	-	Fresnel lenses	Aspheric lenses	Flat lenses	-
Real world view	Yes, HD color	Yes	No	No	-
Display type	2x LCD	1x LCD	2x Mini LED	2x LCD	2x LCD
Subpixel layout					
Resolution	3840x2160 / eye	1832x1920 / eye	2880x2720 / eye	1600x1600 / eye	1600x1600 / eye
Refresh rate	120 Hz	90 Hz	90 Hz	72 Hz	90 Hz
Visible field of view	180° horizontally 90° vertically	98° horizontally 90° vertically	102° horizontally 73° vertically	94° diagonally	90° diagonally
Preferential rendering	-	No	Dynamic in direction of view	No	No
Motion tracking	6 degrees of freedom, through HMD	6 degrees of freedom, through integrated cameras	6 degrees of freedom, through external stations	6 degrees of freedom, no position tracking	6 degrees of freedom, through integrated cameras
Eye tracking	Yes	No	Yes	No	No
Hand tracking	No	Yes	No	No	No
Controllers		2x 6 degrees of freedom	-	1x 3 degrees of freedom	2x 6 degrees of freedom

Table 1. Selected commercially available virtual reality headsets

3. Augmented reality

If we can place (at least visually) virtually simulated objects, we can talk about augmented reality (AR). Unlike virtual reality, perception of the real world is not entirely blocked. Instead, it is expanded by adding simulated objects from a virtual environment. Depending on the desired application of augmented reality, these expansions may extend information about the real world. We can say that the virtual environment of augmented reality copies and expands the natural world. [10]

Without the need to limit real-world perception, two main options can be deduced:

- **Handheld devise with a camera and display**
  - Such a device should be able to process an image in real-time. An essential part of processing is the addition of simulated objects. In consumer applications, we see smartphones and tablets primarily.
- **HMD**
  - The main difference between virtual and augmented reality headsets is the inherited need to perceive the real world and simulated environment. The most utilized concept is, therefore, a see-through display. The basic scheme of such HMD is in Fig. 5.

3.1. Construction of HMDs

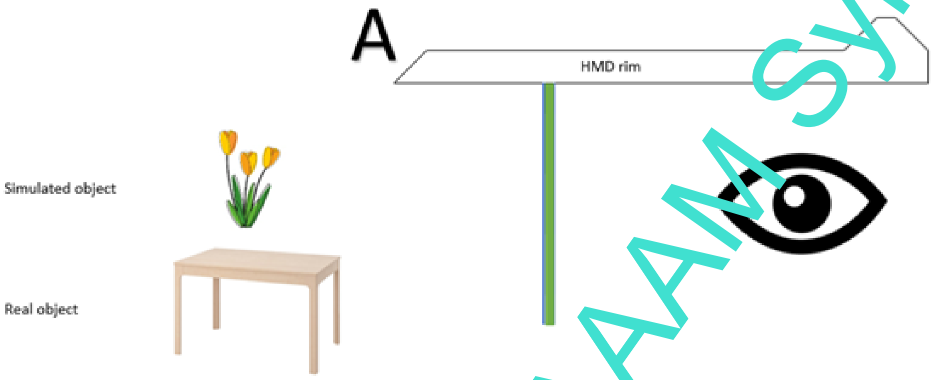
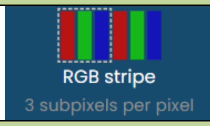


Fig. 5. Construction of augmented reality HMD

HMD-type augmented reality devices strive to achieve the best user comfort concerning the perception of the real world. The idea is for the user to be limited in the least way by the HMD hardware. For this reason, most HMDs have the look and feel of glasses with a thick rim around the user's head. This rim holds inside necessary hardware. In its front (labelled A in Fig. 5.), there are sensors - usually cameras - assessing their surroundings and providing the required data for the correct image of the simulated object. There is a see-through display device (green rectangle with a blue contour in Fig. 5.) between the real world (object) and an eye of a user. It shows an appropriately distorted image of a simulated object to the user. Distortion aims to liken size, proportion, and perspective to natural conditions. [7]

3.2. Examples of current HMDs

	VRgineers XTAL 3 Mixed Reality	**Pico Neo 3 Link**	**Varjo Aero**	**Skyworth W1 Pro**	**Huawei VR Glass 6DoF**
					
Computing hardware	Smartphone	Smartphone, tablet, PC	Standalone	Standalone	Standalone
Release	[illegible] 3. 2022	4. 3. 2022	3. 3. 2022	24. 1. 2022	7. 11. 2019
Display type	2x Micro OLED	2x Micro OLED	Single Micro-LED		2x LBS
Subpixel layout					
Resolution	1920x1080 / eye	1920x1080 / eye	640x480 / eye	1920x1080 / eye	1440x936 / eye
Refresh rate	90 Hz	75 Hz			60 Hz

	VRgineers XTAL 3 Mixed Reality	Pico Neo 3 Link	Varjo Aero	Skyworth W1 Pro	Huawei VR Glass 6DoF
Visible field of view	46° diagonally	43° diagonally	28° diagonally	90° diagonally	43° horizontally 29° vertically 52° diagonally
Motion tracking	3 degrees of freedom, no position tracking	3 degrees of freedom, no position tracking	3 degrees of freedom, no position tracking	-	6 degrees of freedom, through integrated cameras
Eye tracking	No	No	No	No	Yes
Hand tracking	No	No	No	No	No
Controllers	No	No	No	1x 3 degrees of freedom	No

Table 2. Selected commercially available augmented reality headsets

4. Conclusion

In this study, we have tried to assess the currently available technology and terminology of simulated environments, namely virtual and augmented reality. Following formulated ideas and views are formed according to the presented findings. Currently, options for virtual and augmented reality simulations are increasing. As for now, it is possible to create visual and auditory simulations complemented with motoric elements.

As can be observed throughout currently available HMDs for augmented and virtual reality, as presented in tables 1. and 2., the development of consumer technology is directed at improving visual perception. [13], [14]

Considering the overall topic of the overarching study, the immersion achieved so far is unsuitable for training physical aspects of police work. Lack of motoric feedback from environment interaction, considering mainly the sense of touch, renders such simulated environments more appropriate for managerial and logistic aspects of police work. Our future research will consider virtual and augmented reality options in this branch of police departments and organization elements.

Options for other senses simulations are being researched to increase immersion in a simulated environment. Other senses possibly simulated in discussed virtual environments are touch and smell. [15], [16]

Consumer touch simulation devices focus on force feedback created by pneumatic pressure. To the user, this gives a feeling of being touched or hit. More precise technology, using actuators and allowing for the feel of handling a presented object, is still being developed. [17]

Olfactory simulation relies on aroma cartridges being excited upon pre-programmed events. Simulated smells are primarily used in a therapeutic context. [16], [18]

Both technologies are required for deeper simulation considering police forces and emergency services training. Unfortunately, from available open sources, it seems that the commercial part of the technology segment is not momentarily focusing on their further development. Simulation of olfactory senses appears to have a stable place on the market. The current conception of the touch simulation does not appear to be widely spread, but unlike in the case of smell, more research towards new concepts is more active. [15], [16], [17], [18]

5. Acknowledgments

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