Virtual Reality Safety Limitations

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Abstract: *Virtual reality is currently a phenomenon that is transmitted from the scientific field to real life more and more, and its application can be observed in several sectors. This technology provides a whole new perspective on various areas that we, as ordinary mortals, would find very difficult to reach. It allows us to see and even feel things, that are often very difficult to reach in real life. Starting with various simulations of dangerous work activities and ending with complicated scientific experiments, virtual reality provides a wide utilization, that pushes the boundaries of research and human capabilities further again. But is VR suitable for anyone, is it safe enough? Does VR have any limitations that make it impossible for it to be fully exploited and put into practice?*

Key Words: *virtual reality, simulation technology, air forces, training, scientific approach, safety limits*

1. INTRODUCTION

The Armed Forces and specifically the Air Force is one of those broad and important areas of social theory and practice, in which the means of modelling and simulation (hereinafter referred to as M&S) in today's understanding have been used since ancient times [1]. Throughout its history, it has performed important cognitive and military-practical functions. Based on the action of unexpected negative geopolitical, natural phenomena, but also based on the needs of systematic professional and practical erudition, there is a growing need for the preparation of individual Air Force adjusted structures, because of technical and technological progress, which directly affects these facts. The requirement of effective training should reflect the logical and systematic analysis of dependencies and contexts in all procedures and processes of identifying negative phenomena, to stimulate and create thought stimuli of staffs

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(crisis staffs) and those were able to minimize losses and maximize opportunities [2]. Utilization of the potential of individual types of simulation technologies, by implementation of new HW elements, application SW and their simulation tools, is actually one of the potentials means to achieve the already mentioned requirements for effective and comprehensive training. Creation of synthetic (not only virtual) environment, which is in sufficient compliance with the real environment, is financially expensive.

Virtual reality comprises wide range of problems. Defining the direction in this multidisciplinary environment is not simple. Virtual world generation and its realistic visualization in real time is a relatively young area, because realistic visualization systems working in real time did not flourish until the last decade, which was related mainly to their costly implementation and insufficient HW as well as to software support. Virtual reality was initially presented as the so-called total simulation, where the illusion of physical presence in a simulated (virtual) environment generated in the context of a close human-computing system connection was created [3].

2. SYSTEMS AND SUBSYSTEMS OF VR COMPOSITION

"Virtual-reality system represents an interactive computer system, creating an illusion of physical presence at a given time of non-existent only synthesized space or even more precisely, we can talk about the so-called perfect simulation in the environment of tightly bound human-computing system interaction". At present, VR technologies are one of the substantial adepts for massive use as GPU and parallel platforms in general as well. In addition to the typical concept of virtual reality, it is also possible to encounter the apparent (Fuzzy) reality (the number of frames is lower and the quality, let us say execution rate is not so perfect, most often due to technological complexity and price) and mixed, let us say augmented (mixed, augmented, enriched) reality (the view of the real world is supplemented let us say extended (enriched) by the display of synthesized/ generated elements). Observer, let us say user of VR systems is also called a cybernaut and a virtual representative of the user in virtual world is called avatar. Avatar is actually a psycho-morphological structure representing the user in a virtual environment. The term itself is derived from Sanskrit, where the avatar represents the incarnation of the highest/higher being on Earth [4].

VR system and its subsystems

VR systems provide a better experience and are more interactive, however the complexity of its implementation is much greater. VR subsystems are divided according to the senses they affect:

- Visualization subsystem,
- Acoustic subsystem,
- Kinetic and statokinetic subsystem,
- Tactile and contact subsystem, as well as other senses.

Visualization subsystem

Visual perception processing has been and is the number one priority in VR systems, as human perceives its surroundings 80% by means of visual sensations. Visualization subsystems currently use three-dimensional displaying, that is natural to humans. Two basic principles are used for this purpose:

- Watching a static monitor (projection system): This includes, in particular, displaying into the user's surroundings on projection screens with a high resolution and a size larger than the observer's angle of view. Of course, this type also includes regular watching of a classic monitor.

- Watching a mobile display unit: This includes displaying using a display unit that moves with the user. This procedure is used especially when deeper and more convincing immersion into the virtual world is required. Data helmets are most often used for displaying.

Acoustic subsystem

In second place right after visual perception is sound perception represented in the VR system by an acoustic subsystem. This subsystem can be divided according to the direction of information flow into input and output [5].

Audio input (user speech) to the VR system can be divided into two levels:

- Interaction with a “living” person: In this case, the user communicates with another person who is in the VR world with him. In such communication, it is sufficient to digitize the input and then transfer it to the output of the acoustic system of the person.
- Interaction with a “non-living” object (e.g., generated by computing system): During this interaction, there is a problem of understanding the scanned input data by the VR system. The solution is human speech recognition.

The output subsystem has an easier role. It is possible to say, that in the current VR systems, only this component is almost unilaterally preferred. If the received sound does not correspond to what the user sees, the illusion of reality is corrupted (the same applies e.g., when the picture and sound in scene is shifted). Although generating output sound in the current “HiFi” era would not seem like such a problem, the opposite is true. VR systems of the first, perhaps even of the second degree, are often satisfied with stereo sound. However, for complete VR systems to achieve spatial effect and subsequent sound placement, the mentioned solution is not enough. For the audio output of this type, 3D (stereo) format is primarily used in VR systems, due to a better immersion of the user into the VR environment.

Another problem is to handle different elements, especially “psychological”, of human listening. A typical example is a human ability to select from the quantity of incoming sounds just those he is interested in at given time (so-called party-effect).

Kinematic and statokinetic subsystem

The third most important VR system function is the simulation and determination of the user's movement. Based on this, it is possible to divide the devices used in this subsystem into two groups:

- Devices enabling position monitoring: The main tasks of these devices include the determination of head, hands, legs or the whole-body position. Data gloves, a data suit or sensing/monitoring devices can be used for this purpose.
- Devices enabling motion simulation: These devices allow the user to move in the VR world while standing still (more precisely, the user is moving, but the device moves him to the starting point all the time).

Based on the sensing result the virtual world adapts to the user. According to the scope and quality of the sensing of individual elements of the human body, the VR systems are divided to:

- systems with local sensors;
- systems with global monitoring.

Tactile subsystem

Touch or feeling of touch is also an important aspect of a human interaction with the environment. In real life, the impermeability of the mass is completely natural and it is difficult to pass e.g., through the walls. This is not so unnatural in current VR systems. It is not a trivial problem in terms of design and implementation. For example, for feeling of gripping the user must have possibility to grab, to weigh in his hand, squeeze or otherwise process (e.g., lean on it) the relevant virtual thing. The things, that would "not put up" a natural resistance, or no natural effort or feeling of exertion would be needed, then would not be real and the user would have a disturbed feeling of reality of the world in which he moves. Contemporary design solutions are relatively robust and not flexible. These designs are called "exoskeletons". They are mostly based on a mechanical-gyroscopic or Bowden basis. These devices simulate resistance for the hands, and a device for simulating the resistance for legs and other parts of the body is under development. So far, the natural movement in virtual worlds is flying and especially no resistance walking. In this context, it is necessary to subsequently solve collision situations, what mostly happen by software [6].

Subsystems for other perceptions

These perceptions include, for example: smell, taste, sensitivity to pheromones, sleep, pain, or thoughts. Many of these perceptions are insignificant in the VR world, so there is no point in considering their simulation. Some of them also make significant sense in the real world, but their implementation into the VR world is debatable. An example of such a sense is taste.
The most elaborate in this area is the use of olfactory perception and basic thought tracking.

Partial evaluation

In the advanced Air Forces around the world and especially in NATO countries, the situation in the field of use and application of simulation tools is incomparably better. Simulation technologies belong to the most important training facilities at all levels [7].

Command staffs have their own training facilities and lower organizational units their own. Between them, at various and international levels, there are joint exercises, that are being prepared for a long time. In addition, means of training individuals, operators of various techniques (air, sea, land, medical) and the like are introduced and are being introduced. Practically with the introduction of new technology or in advance, the corresponding simulation technology is procured and introduced, so that after the arrival of real technology, the operators or attendant are ready to deploy.

During joint simulated international exercises, they practice in an unfamiliar environment and communicate and coordinate in a foreign language. In the advanced armies of the world and NATO, the relevant sums are also planned in budget to modernize and maintain the existing simulation technology, so that it is constantly at a high training level and compatible with real combat means.

Virtual simulation has been generally accepted as a way of effective training with lower costs. The Air Forces generally focuses on industry to find advanced and effective virtual simulation solutions with a high degree of immersion of participants into the synthetic environment - what will prepare them to meet the challenges they will face during the conduct of the real operation. In line with the above, the aim is to find and apply virtual technologies that will create different environments for professionals, that will best prepare them for the scenarios they are likely to encounter on a real battlefield - at a reasonable price, better than traditional methods.

Future trends confirm the orientation not only towards perfect control of entrusted facilities and technologies, but after mastering them - at the same time, the emphasis shifts to a collective training virtual environment (specialized workplaces), where all participants are immersed in various tactical virtual scenarios, while they have to communicate and coordinate their activities with the team in which they work or cooperate with other teams [8, 9]. Thus, the trend is, but also will be, training on interconnected systems that will provide not only training for the individual - but also the whole team or teams, including complete communication and combined weapons. At the international level, we are already talking about large-scale joint force exercises.

With the gradual development of technologies in the next decade, the fidelity, appearance, impression and functionality of virtual simulation platforms will increase. The continued high interest and calls on these technologies in the Air Force is highly expected. With the development of technology and dimensions of suitability, their application and integration in real and synthetic environment is also highly expected.

The training by means of information and communication means, simulators and trainers enables the demonstration and explanation of the subject matter, in which interactive connection, direct demonstration, direct application and gaining experience intertwine. In real conditions, the application of such training is often impracticable due to financial or operational reasons, and that's why it is important to pay close attention and logic to their gradual implementation, and it is also important to set the conditions for sustainability and to set the conditions for their direct use in advance.

3. RESEARCH METHODOLOGY AND EXPERIMENT FINDINGS

Research and active solution of the topic in question requires the use of several scientific methods. In order to solve the set goals of the work, during the solution of the subject problem several methods were used, which complemented and conditioned each other. These were:

- analytical-synthetic method,
- induction and deduction methods,
- the method of abstraction, which was based on the study of relevant knowledge and resources in the subject matter,
- method of comparison,
- an observation method, which made it possible to obtain facts during the experiment,
- statistical methods.

The above methods and the knowledge, facts and data obtained from them form the basis of the benefits and formulations of the conclusions of the scientific research and they intersect with each other.

Respondents

The selected target groups were chosen in terms of different actions, but with the same denominators. The same denominators, that connect all groups, are no experience with new elements of the VR, active experience from the implementation of simulated exercises in a virtual environment and the affiliation of the Armed Forces.

The groups of respondents were divided according to years of birth and each of them met the above denominators.

1. Group: physical age up to 20 y.
2. Group: physical age up to 30 y.
3. Group: physical age up to 40 y.
4. Group: physical age up to 50 y.

Such a division into individual groups enabled the implementation of experimental research, which was focused on selected areas of scientific research and enabled the monitoring of responses to uniform simulated scenarios, where the new elements of VR were used. The objectivity of the research was achieved by a suitable selection of target groups as well as the diversity of their composition - age, knowledge, personality, but also professional focus.

The Concept of Experimental Research

The aim of the experiment was to monitor the defined reactions of the respondents when performing activities with VR elements in a synthetic environment.
Areas that were monitored let us say that were measured:

- Adaptation to environment: time period for direct application of VR elements.
- Reaction time: selected uniform theme scenario lasting 15 min.
- Application time: maximum time period for effective training.
- Other aspects: subsequent mental exhaustion, headaches, eye strain, loss of orientation in time and space.

Each group was instructed on the possibilities of the VR elements and the set scenario before carrying out the research.

Results of the Experiment

For relevance, we mediate basic questions, resulted from the implementation of the experiment. During the experiment, other measurements were performed, which we do not provide in details, but they are evaluated in the conclusions.

Adaptation to environment: time period for direct application of VR elements

Adaptation to VR environment represents the organized orientation of the respondents in the new work environment (VR environment). The result should be the fastest possible adaptation of respondents in the environment, their ability to process individual stimuli from the environment and thus the ability to start working fully in the VR environment. Orientation in the environment is closely related to adaptation by complementing and streamlining it.

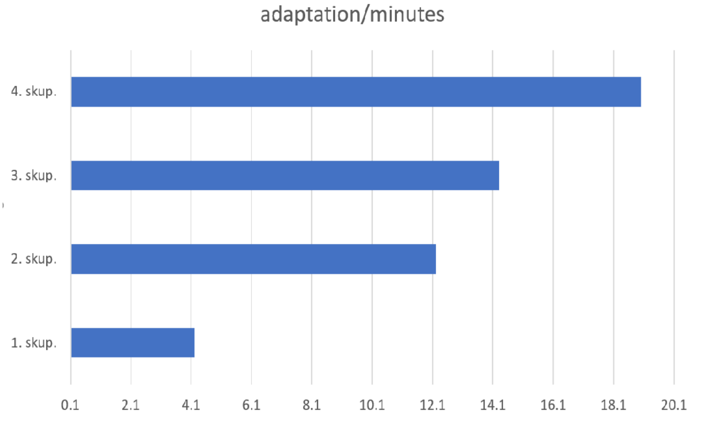

Fig. 1 – Adaptation of VR environment

The aim of the measurement was to find out the time period (in minutes) over which time are the respondents able to start working in the VR environment with new VR elements (3D glasses, controllers). It is evident from the Fig. 1 that age plays an important factor in adaptation to the new environment. The fourth group has obviously a longer time for the ability to perceive VR. Synchronization of the vestibular system and visual perception causes major problems for this group. The 1st group had an average of about 4 minutes to synchronize perceptions with the VR environment, which is a relatively short time.

Reaction time: selected uniform theme scenario

Human decisions and reactions are made by complex electrochemical processes of nervous system. The speed at which we make decisions and act is also conditioned by this complex system. A person gets into situations in which speed can decide his success, failure or death or life.

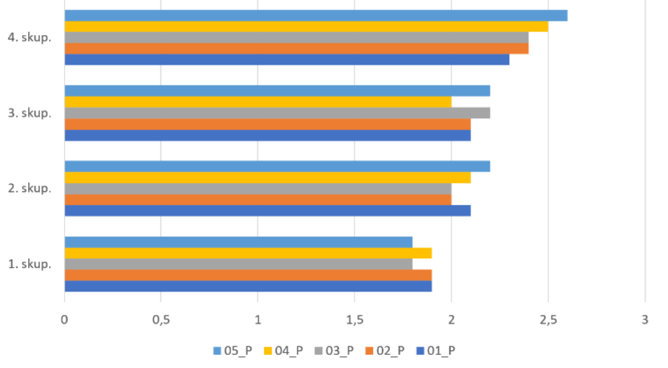

Fig. 2 – Respondents Reaction Time

The aim of the measurement was to find out the reaction time of individual groups to individual stimuli (simulated actions), which were the subject of the theme scenario. The resulting Fig. 2 mediates the ability of respondents to react to individual stimuli (audio, visual), which were simulated in a synthetic environment. The fig. 2 shows the reaction values in seconds for individual simulated reactions in individual groups of respondents. From the results shown in the Fig. 2, the ability of react of individual groups is different. It is evident that the age limit affects the very ability to react to simulated stimuli. By this the equalities of reactions are not maintained i.e., the objectivity of the training in the initial stages has no real (objective) relevance.

Application time: maximum time period for effective training

At present, there are high demands on the conduct of the Air Force training. Despite the indisputable advantages of simulation technologies, the use of new sophisticated elements is somewhat limiting. That means that airmen professionals must carry out the training effectively and without time constraints, so that the training can be considered as beneficial and purposeful. Efficiency is the use of techniques and technologies, that brings the max. level of satisfaction achievable with the inputs and technologies. It shows that resources are not wasted, and they are used efficiently and fully.

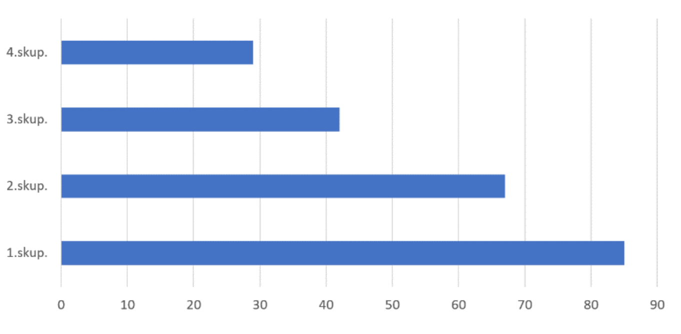

Fig. 3 – Application Time

The fig. 3 shows the values in minutes. It represents the values measured in individual groups, how long are the respondents capable of perceiving the synthetic environment (actions and reactions to stimuli). It is evident that the first group of respondents can effectively conduct training in a simulated environment with VR elements for a significantly longer time (85 min) than the fourth group, which can interact with this environment for less than half an hour.

Other aspects: subsequent mental exhaustion, headaches, eye strain, loss of orientation in time and space

Referring to several studies in the field of VR, it has been found that space mapping neurons in the brain respond to VR differently than to the real-world environment. The subject of the study was the area of the brain (hippocampus), which provides short-term memory . This area of the brain also plays an important role in the formation of new memories and creation of mental maps of space. For example, when one examines a room, hippocampal neurons become selectively active and provide so a "cognitive map" of the surrounding space. The hippocampus reacts completely unnaturally under the influence of VR, engaging only less than half of the neurons as under normal influence, whereas engages only half of the neurons as under the influence of normal reality.

VR tries to confuse not only user's sight, but also hearing and the vestibular system. It is located in the inner ear and is an organ of dynamic balance. Vestibular reflexes serve to prevent a fall when the body deviates from an upright position by the action of an external force. Damage to the vestibular system causes dizziness, balance disorders or collapses. Because the human body cannot guess what is real and what is not while in virtual reality, games like roller coasters are recommended for the user in a sitting position.

Another risk is a possible visual impairment. Not enough relevant research has been done on this issue yet, but the low-resolution screen just a few centimeters from the eye is not very natural at first glance for humans. Several factors can affect the eyes of a VR user. The light intensity is the first. Some VR devices can produce much more than 1,000 lux. An important factor is the distortion of the lenses at the edges, what our eye tries to straighten, whereas it is stressed during this activity, what can lead to nausea.

Another risk factor that can cause concern is contrast and its effects. If we're looking motionless at a light spot in a dark environment, such as a display in a dark room, our pupils expand and let more light into the eye. Increased amount of received light leads to eye fatigue. However, with the VR set, our eyes are usually surrounded by light and focus on different points of the scene, so thanks to eye movement, this effect should not normally occur [10].

Health risks of using VR

Eye strain

The VR kit cause severe eye strain of the user. There is pressure on eyes to focus on the pixels of a screen, that uses a single refractive optical element. Headsets usually do not deal with problems of optical devices being close to eyes and after a few minutes they quickly become uncomfortable.

Mental exhaustion

Using the VR for more than a few tens of minutes can cause tension or anxiety. mental exhaustion. Application of training by means of VR can cause, that the airmen will feel fear, stress and shock. Overcoming this anxiety can take a while, because a person experiences everything as if he were on the scene of a real combat activity.

Headache

Some people who use VR kits complain of subsequent headache and nausea. Realistic simulated movements can affect a person's perception of time and space and can cause headaches, fatigue or nausea.

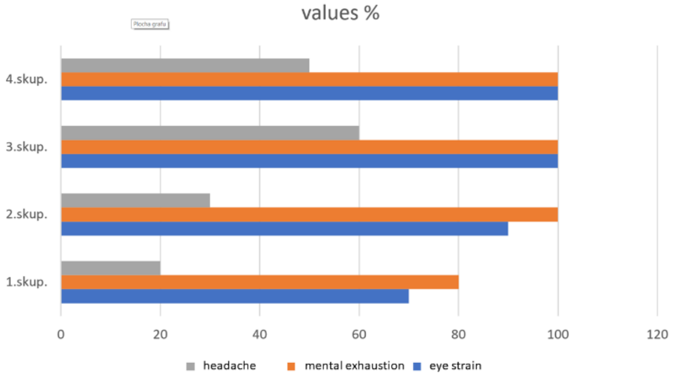

Fig. 4 – Health Risks of using VR Sys

The Fig. 4 mediates the adverse effects that individual groups of respondents encountered with during the simulated theme. The impact of the VR on the subsequent mental exhaustion and the need for rehabilitation after such training is evident. Besides the exhaustion, it is clear that the impact of VR on eye strain is significant and respondents had problems with accommodation of the ocular system after such training.

Other undesirable aspects of using VR

Radiation:

The VR user is exposed to harmful electromagnetic radiation. These devices use wireless connections such as BT or Wi-Fi to connect to other HW components and are equipped with intelligent sensors that enable VR experiences.

Numerous studies have already shown how mobile phone radiation can affect the human reproductive system, disrupt sleep or cause mood swings. The VR kits can connect wirelessly to Wi-Fi, which means that they also produce radiation and in fact, they could pose long-term health risks.

Injuries:

Nausea and subsequent vomiting when flying a fighter jet, loss of balance e.g. in simulated parachute jumps and tripping over cable infrastructure, broken monitor, injuries after falls, are part of the impacts of the VR application, that need to be addressed.

Neurological and mental illnesses:

VR may be the trigger for various diseases e.g. epilepsy in some more sensitive individuals. Some psychiatrists also assume the risk of depression, post-traumatic stress disorder and even schizophrenia. As VR is an escape from reality into the synthetic world.

Partial Conclusion

Despite the undeniable benefits of the VR environment, it is necessary to focus on all aspects related to it.

By carrying out the experiment, we identified several critical areas that can play significant limiting factors in the deployment of VR in practice. VR is not suitable for all age categories. The current HW solutions (peripherals, display elements, etc.) are still in the development phase and are currently sufficient for commercial solutions. For deployment in an environment, that has high demands on credibility, reality, modularity and functionality, this technology is only in the stage of experiments and promo products.

The scientific experiment made it possible to define the areas that need to be focused on and take them into account when setting new requirements when purchasing new synthetic environments let us say simulators, which will be procured together with new technology.
The training and educational process of preparation via computers, computer systems mediating virtual reality and simulators is a common trend today. The positive effect and benefits are in the attractiveness and targeting of such training. From the point of view of practitioners, it enables to understand the issue qualitatively better, to acquire practical habits, skills and to develop practical habits, skills and possibly to learn new knowledge. Training by means of information and communication tools, simulators and trainers allows the demonstration and explanation of the issue in question, in which interactive binding, direct demonstration, direct application and gaining experience are intertwined.
By applying forms, methods and computer software techniques, computer systems mediating virtual reality, simulators and trainers, a higher ability to understand, memorize knowledge and skills is documented than when presenting theoretical background or lecture forms.

4. CONCLUSIONS

Virtual reality involves a wide range of issues. Defining the direction in this multidisciplinary environment is not easy. Generating the virtual world and its realistic visualization in real time is a relatively young area, because realistic visualization systems working in real time did not flourish until the last decade, which was mainly related to their costly implementation and insufficient HW as well as software support [11, 12].
Virtual reality (even augmented) is a technology that provides not only unique experiences, but also a lot of data about everyone who works actively with it in any way. The new boundary and space, on which these data are summarized, are the "bodies" of individuals or groups. Immersion systems need to monitor the movement of individuals (head, limbs, eyes, etc.), by built-in microphones and cameras, monitor sound, image and 3D scan the surrounding area. It is necessary to realize, that VR is an object of our attention and at the same time an object, that is able to observe the surrounding space. In other words, they are complex systems that can be understood as un-conscious recognizers i.e., these systems know a lot about individuals, they just do not realize they know it. Nevertheless, that does not mean, that they would not have the ability in the future. In this context, it is important that we know at least on what principle they work and what their application (or implementation) brings, because in the near future there is a risk in these complex systems, which application we certainly will not avoid and we already are part of it, that we will be conscious, but unaware.

We briefly present a general summary of the virtual reality environment:

Hardware:

- Virtual helmets that do not work fully autonomously but need additional hardware. It calculates and renders synthetic scenes.
- A new generation of VR helmets, that work even without a connection to a PC.
- Large 3D stereoscopic projections (CAVE) used more in the past. Their advantage was to mediate the VR to several individuals at once, but their financial requirements for procurement and sustainability were in the order of tens to hundreds of thousands of €.

Effects:

- Complete replacement of the world around us by a computer-generated interactive simulation of the 3D environment of the area of interest, let us say surroundings around us.

- Visual, acoustic and other perceptions are replaced by the most realistic stimuli from the simulation.
- The individual acquires the feeling of being elsewhere than he actually is physically (strong presence).

Characteristics:

- 3D stereoscopic display.
- Binaural stereoscopic sound.
- Interaction with virtual objects, often with a simple (tactile) response (e.g. vibrations in joysticks).
- Movement 3-6 DOF (Degrees of Freedom).

Sector:

- Preferentially science and research.
- Creative work.
- Manufacture and production.
- Gaming industry.
- Education and training etc.

Type of applications:

- Virtual training, abstract data visualizations and simulations, but also specific visualizations in individual industries.
- Also suitable as a working tool for creative work (modelling and animation) or communication on the platform of training - game applications or event sharing in virtual worlds.

The VR is an area that is currently developing, it is a "young" technology that is presented as a universal form and is trying to find its justification in every sector. VR is "pushed" into each segment and its presentation undoubtedly leaves a significant impression on every individual who has the opportunity to try its application. Thus, it must be said that it is a technology, that is only evolving and in the future, there is an assumption for its full-valued deployment [13]. However, until then, it is necessary to focus on all aspects and effects that are related to it.

It is necessary to analyze and evaluate them and thus achieve its direct, appropriate and tuned application, without any side effects, let us say without negative effects on the individual. There is a very desirable and justified need in this area to define the limits of applicability, as well as to define the way in which the resulting data is accessed and processed.

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