Virtual Reality vs. Reality in Engineering Education

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***Abstract*—Virtual reality has become significantly popular in recent years. It is also widely used and more frequently implemented in education, training, and research. This article discusses the potential and the current state of virtual reality, and its tools in engineering education. The focus is put on some opportunities, challenges and dead ends of implementation faced by the authors. In this point of view, virtual reality is the future of creative learning, however it has its limits in terms of practical experiments, learning by doing, which is still more effective as virtual ones.**

I. Introduction

Merriam webster dictionary defines virtual reality (VR) as an artificial environment, that is experienced through sensory stimuli (such as visual and audio input) provided by a computer and in which the person's actions partially determines what happens in the environment [1]. Burdea and Coiffet [2] encompass the basic characteristics of virtual reality as the three 'I's of virtual reality, specifically immersion, interaction, and imagination. This is a VR triangle presented in Fig. 1. Immersion is achieved by removing as many real sensations as possible and replacing them with sensorial feedbacks provided by the virtual environment (VE). Interaction enables the end-user to change the state of the VE in real time. Imagination is needed to design a VE in order to make it credible and adapted to the target use case.

The phrase "virtual reality" was first formed in the mind of Jaron Lanier, during an intensive research period in 1987 [3]. Before this action in 1984, Jaron Lanier has set up the VPL Research (Visual Programming Language). This company was the pathfinder of virtual reality and 3D research, and sold the first VR gears, such as: data gloves, VR glasses, and later a complete data suit. A major cultural impact which brought the topic of virtual reality into mainstream had been evoked in 1999 by the cult film The Matrix [4].

Around this time the VR technology became very common, although this anticipation soon dropped by a yawning gap between technological limitations and public expectations. VR technology has been around with no significant achievement and acceptation in mainstream applications or commerce adaption [5].

Nowadays, virtual reality technology is dynamically evolving with the help of low-cost devices and the interest by large companies (Microsoft, Facebook, Sony, Google, NVidia, and HTC [6]) to invest in entertainment, communication and visualization. Generation of lightweight technologies are also considerable, hence the rise of smartphones having high-density displays and 3D graphic capabilities have practically enabled us to have personal VR devices. Sensors like depth cameras, different interfaces and motion controllers are already part of daily human computing tasks.

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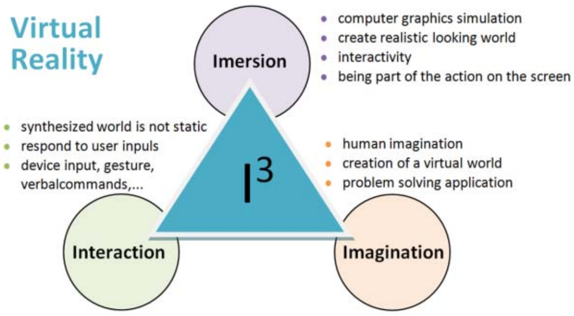

Figure 1. The three I's of Virtual Reality [2]: immersion, interaction and imagination

Current personal VR technologies tend to fall into one of three trends: computer peripherals, smartphone-based and self-contained headsets. These personal solutions were introduced since 2014, when Goolge released interim VR products such as the Google Cardboard, a DIY headset that is driven by a smartphone. This affordable, fun and simple system brought an immersive experience to everyone. 2014 was also the year when Facebook acquired Oculus Rift (a VR headset company) for $2 billion. This acquisition was a signal to other companies of the industry that virtual reality is promising to invest in the future [7].

Samsung had extended this concept further with Galaxy Gear, which is being mass produced and contains features such as gesture control. In 2015 YooTube introduced the possibility to upload 360° videos, while Facebook a year after builds its VR empire a 22,000 square-foot hardware lab. The following years Facebook will prototype its solar drones, Internet-beaming lasers, VR headsets, augmented reality devices and next-gen servers. In terms of 3D sound engineering Google released Omnitone, an open source 3D audio for web-based VR and launched the Daydream platform for high-quality mobile VR technologies. Daydream View powered and used by any Daydream-ready mobile phone is an easy-to-use and comfortable, headset designed to be adaptive as a choice in mind [8].

Year 2016 was a breakthrough of virtual reality technologies. Big names hit the marketplace in commercial production, hardware like the Oculus Rift, HTC Vive [9] and PlayStation VR all hit the marketplace, which started a flood of content, clever implementations that had made early adopters to promote this exciting new technology. In the near term, all of the company focused on trying to bring in more developers, attract a larger audience and get more content for their systems.

It is also key reason that there has been an increasing interest in the utilization of virtual reality in education [10]. VR education solutions are able to empower students by primarily engaging with their subject through immersive interactive experiences. The virtual reality method gives opportunity to hinder memorization from the learning process. By transiting from the traditional approach, students are given the possibility to apply, analyze and evaluate their knowledge. This approach, improves the user's creativity, critical thinking, problem solving, decision-making, communication and teamwork.

In this paper, the authors discuss the current use of virtual reality tools and their potential in engineering education. The focus is put on some opportunities, challenges and dead ends of implementation.

II. Best Virtual Reality Headsets

As we have discussed above, we have encountered virtual reality "explosion" over the last half year. In this year, 2017 there is a wide multiformity of VR headsets available.

Which is the most interesting VR headset out there?

For user money it's the best HTC Vive [11], for its use of room-scale tracking to offer gamers and users the freedom to walk around and interact in the virtual world like never before.

The Oculus Rift and HTC Vive headsets pack have dual OLED displays with a resolution of 1,080 × 1,200 per eye, both have a 90 Hz refresh rate and 110-degree field of view, and both need very similar PC requirements to run. In addition to the 37 sensors in the Vive headset, which provide a fluid and seamless motion, there is also a front-facing camera included. All these can make a VR environment of difference. HTC's cameras allow to make use of the Chaperone safety system. This technology is able cast a blue safety outline on walls and even objects when you move in a close distance. It can be even set as a Matrix-like look on all environmental obstacles at once [9]. The key to the HTC Vive's popularity is the Lighthouse room tracking solution, which enables the user to move around when the headset is on. Meanwhile, the Vive's Tracker tech is able to bring any real world object into the virtual image. The current generation of hardware has connected the user to a powerful PC via annoying cables. The Vive can also function in a wireless mode, thanks to the it's TPCast module, and even eye tracking is on its way. The VIVEPORT subscription service is also beneficial, which gets the user whole bunch of VR content for a monthly fee of $6.99.

VR has its bright future. The potential in this technology is anticipated by many-many start ups that were able to raise a huge amount of money, more than $100 million in funding and $1.46 billion in venture capital. According to Kota Ezawa, it is expected, that the VR market will grow to a $15.9 billion business 2019 [5]. This will have an impact on the network, hardware market, software and generated content will increase up to a $200 billion value by the year 2020 [5]. The user base explodes and numbers will grow rapidly. 2017 will witness a massive jump in user counts. From 2014 with around 200,000 to a projected 90 million in 2017. These numbers represent a 450% increase, from which around 10% of the 90 million will be probably gamers, while the rest around 23 million early adopters [12]. This indicates that the next few months will present the ideal opportunity to put new VR application into the hands of an engaged and motivated audience. One of the forecasts expects, that 500 million people will own a VR headset by the year 2025 [13].

There are various challenges to face along the path to a global mass adaption. BC analyst Mark Mahaney expects VR mass adaption will take place from 3 to 5 years from now [6]. Today the VR headset technologies require a vast of computing power, not to mention health and the factor of the outer environment Moreover a commercial setup remains expensive. Most of today's users remain largely gamers

Google hopes, that mass acceptance will come sooner as expected. The first-generation of Google Daydream View was announced on October 4, 2016, and has become more or less available to hundreds of millions of smartphone users [6].

III. The Benefits of Virtual Reality in Education

VR solutions, starting from simple graphic applications made for entertainment and studies are now used more frequently in many professional fields [14, 15]. An important area of application has always been as a training possibility for real-life activities such as: job training, introducing audience to a new concept, gaining experience and practice. Simulations can provide trainings equal or nearly equal to real life practice, with reduced costs, greater safety, non devastating or demoralizing mistakes, not being damaging to our environment, and not capable to cause unintended capital damage and wasting materials [10]. These aspects show that, to use VR in education is cost sawing and a new effective way of learning. They include fact that it provides motivation; can more precisely illustrate processes, features and physical phenomena than other means, moreover it allows extreme close-up and distance object examination , showing the subject in a whole rather than a part, allows disabled persons to participate in different environments, experiments or when they are not able to do so otherwise. This possibility also gives the opportunity to view the presented subject in a new perspective, allows the learner to proceed and improve his/ her abilities through a new experience [16].

VR has it many benefits in government and military solutions as well. In 2014, the British government made an announcement, that it would incorporate the Oculus Rift technology into its trainings used by medical emergencies on the battlefield. Other military uses include e.g. simulations to treat improvised explosive devices [14]. VR gear simulations are used also by Astronauts and jet pilots. These are usually implemented in head-mounted displays that make possible to navigate and react to unexpected situations, before they actually fly a space shuttle or jet aircraft in real action [10].

VR training and assessment is more frequently used for 5 key fields: health care, industry, commercial training, gaming, rehabilitation and remote education such as

Massive Open Online Courses. Adaptation can be realized on five core VR technologies including haptic devices, adaptive content, stereo graphics, assessment and autonomous agents. Automation of virtual reality trainings can contribute to various procedures including remote and robotic assisted surgery, which can reduce injuries and improve accuracy of any procedure. Automated haptic interaction enables presence from a distance, virtually controlled interaction from either remote or simulated environments. Such automation and machine learning play a considerable role in providing a trainee-specific, adaptive and individual training content.

Rapid technical advances that would nowadays support more complex VR applications open new challenges. The interactions are associated with improved learning outcomes related to nontechnical skills in particular, communication, teamwork, and decision-making. The findings suggest that the VR method is applicable to various disciplines and may play a significant role in preparing students for practice and development of individual schema enabling transfer of learning of nontechnical skills to new situations.

VR in the classroom could mean virtual field trips, immersive games, and even utilization for children with special needs. The main focus is put on science centered subject that are hard to memorize and understand. These include anatomy, geography, astronomy etc. All these curricular subjects are considerably extended through interaction with 3D objects, living beings and environments [5]. VR modeling and architecture technologies are used to construct and examine architectural, engineering schema, models, recreations of historic or natural sites and other special renderings.

IV. Virtual Reality in Engineering Education

Engineering is a practicing profession. This profession devoted to harnessing and modifying the three fundamental resources that humankind has available for the creation of all technology: energy, materials, and information [17]. The overall goal of engineering education is to prepare students for the practice of engineering and, in particular, for the solution of forces and materials of nature.

Thus, from the earliest days of engineering education, instructional laboratories have been an essential part of undergraduate and graduate programs. Indeed, prior to the emphasis on engineering science, it could be said that most engineering instruction took place in the laboratory [18].

According to practicing engineers go to the development laboratory for two reasons [17]. First, they often need experimental data to guide them in designing and developing a product. The development laboratory is used to answer specific questions about nature that must be answered before a design and development process can continue. The second reason is to determine if a design performs as contemplated. Measurements of performance are compared to specifications, and these comparisons either demonstrate compliance or indicate where, if not how, changes need to be made.

What is the role of VR in the education of these engineers?

One of an interesting possibility is useful for architects e.g. Field Trips. These technologies enable students to virtually visit locations that they aren't able to examine physically. See technical solutions and realizations. While our community has long conducted virtual field trips using video technology virtual reality promises to enhance student engagement and outcomes through increased immersion [19].

Another really useful option is Training. It's well known that learning by doing (75%) is for many learners more sufficient as compared to just visual inputs (20%) or audio materials (10%). Virtual reality offers the users the chance to experience the action and process they are faced, whether it is a flying an airplane, or conducting technical measurements.

One of many challenges of particular applications is faced in the field of Design. One of the early uses is dated in the field of architecture. Being able to visit, examine and explore a building in a close up before any construction is an extraordinary useful approach. Nowadays the VR technology is anticipated in all technical fields.

VR has its potential also in Distance Learning. For example the Stanford School of business offerings a VR certificate program. In addition students and faculty at Penn State has illustrated how the implementation of virtual reality can improve study outcomes [19].

Probably the most important way how the VR technology is being used is collaboration. It has implications not only in the field of research, but practically in any other fields. Virtual reality is going to change the way how we cooperate over distance.

Interesting possibility is to utilize VR in Recruitment of future engineers. When choosing which university to attend, new joiners like to visit the campus to get a better feel and understanding of the institution itself. Some schools are already making this possible for students by offering virtual campus visits [14].

Most of the discussed possibilities can be implemented as a Virtual Lab. Benefits and Challenges Associated with Virtual Laboratories Solutions can be assessed as follows [17].

The benefits of virtual labs are discussed by both teachers and researchers in terms of convenience, flexibility and hands-on learning. The challenges to be faced by administrators include educator's preparation, changes in technology, software solutions and teacher's resistance. Other challenges faced by educators included the student's competency, failure to handle the equipment, lack of communication, adequate knowledge and training. Solutions offered by administrators included the following: to provide funding for training and technical resources. Teacher's solutions listed the collaboration with other educators and seminar leaders, training and knowledge transfers, arranging alternative plans, and the competencies of students. The considerations of development, planning and implementation of virtual labs, according to both administrators and seminar leaders included infrastructure, audience, student characteristics, qualifications, and mode of instruction [20].

Even the initial steps of development of a virtual laboratory may be expensive, there are cost saving benefits in the long term run. New cheaper equipment will be commercially available. This means that the developers are able to recoup their expenses after some time and should not be discouraged by initial costs.

Among many other options e.g. in the case of the utilization of dangerous and expensive materials and chemical solutions, using virtual labs prove to be safe, cost-saving options. Not to mention, that students are not exposed to real dangerous environments. In cases when too many participants are involved, virtual labs can be used to reduce overcrowding since students will be doing the labs at a location of their convenience.

A. The Model of Blending Virtual Labs with Physical Labs

Similarly as in e-learning, the model of connecting virtual labs with real ones should be considered in relation with the best model of enhanced education Blending Virtual and Physical Labs can, indeed, become beneficial for learners. The most effective way to assist students to learn the curriculum as effective as possible is to blend these two environments together. The research participants encouraged to use virtual labs prior to physical labs, which should ensure students to be at a higher level of understanding at the point once they enter the real lab environment. They have also considered the case when resources are limited, when expensive equipment are unavailable and materials for physical labs are not common, using virtual labs would reduce resources needed to establish physical labs. In other words, with the increasing number of publicly available electronic devices and those that will be introduced in the future, mixing virtual instruments with real labs may be beneficial and easier than currently thought.

In order to achieve success, a virtual lab needs to be interactive so that each concept is presented in form of exercises and laboratory tasks that are challenging and can enhance problem solving abilities of students. This satisfies the aspects of constructivism, since when students encounter difficulties, they will have to decide how to take action and find solutions.

It is very important, that if students want to achieve success in a virtual lab education, they have to accomplish certain prerequisites in advance to real life participating. These prerequisites should include technological background and competence, and academic skills in safety questions and measurements. If students are not proficient in all of these topics, their chance to be successful will be low [20].

Virtual Lab is a unique support, a practice for the real experiment. One it is not able to provide is the real experience. Example on this is sample preparation and contacting (Fig. 2) which is not possible to reproduce virtually, due to the need of fine movements and motoric functions that are important to handle in reality. It is therefore needed to consider the applications where VR can have effective solutions for engineering education.

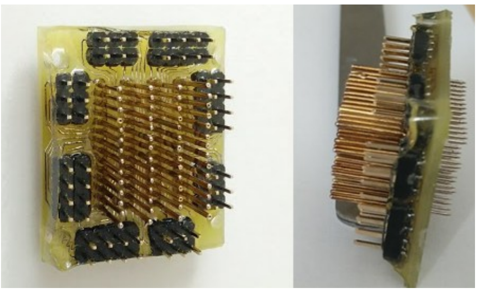

Figure 2. Real contact field in Physical Labs

Hypothetic virtual laboratory in clean rooms (Fig. 3) for the OLED growth is a great example of benefits and limitations of virtual reality in engineering education. In a real clean rooms laboratory, costs of devices, energy, materials and people is very high, skilled personnel is needed, view through the eye-slit does not provide any educational information, the entire process is very time consuming and only a certain number of people can be present in clean rooms before the ventilation is overloaded. Virtual reality can show the physical process, students and teacher do not have to worry about damaging the devices and destroying samples and many more experiments can be accomplished in shorter time. Creating the VR laboratory allows all the students to experience the clean rooms and if they are interested they can later choose an individual project that deals with device processing in the real clean rooms.

It is necessary to consider the utilization of the VR laboratory, because hardware and software requirements are still very high.

B. Summary of Virtual Reality in Engineering Education

Nowadays gap between public expectations and technological limitations of VR decreases. 3D visualization is used extensively in research and industry. VR and virtual world are gradually becoming an essential part of modern academic education and/or an achievable alternative in comparison to traditional learning, thanks to the rapid development of information technology and the VR hardware/gear. We can easily introduce VR in higher education, because our target groups will already be prepared. Future trends will bring VR applications to support every engineering education program. In our opinion visualization is essential in the learning process. In case of electronics and photonics VR can help students to understand physical principles of semiconductor materials and devices, functionality of circuits that are not visible. It can be used in places and situations where the actual reality is not able to provide further information about the object, when it is not accessible for students due to costs or dangerous environments.

VR has a major role to play in engineering education in the future. VR will change the way of education and training. Engineering education will benefit from it. Very important in our technological society is implementation of VR as one of several forms of technology enable us to educate tomorrow‘s technological elite.

V. VIRTUAL REALITY PROBLEMS

2016 was stated to be ‘the year of VR’, and that with a good reason. While 2015 experienced only a potential in two VR headsets entering the market, Samsung Gear and Google Cardboard, , last year welcomed the leading new joiners like HTC Vive and Oculus Rift and, as well as Google entering the race with Daydream View [21].

It is important not to forget that with above mentioned great VR opportunities there always come some disadvantages, dangers and risks. There had emerged stress or anxiety between people after use of in many occasions [22]. There are more of these as eyestrain, nausea or motion sickness. Last but not least we cannot forget maybe the biggest danger - loss of contact with real

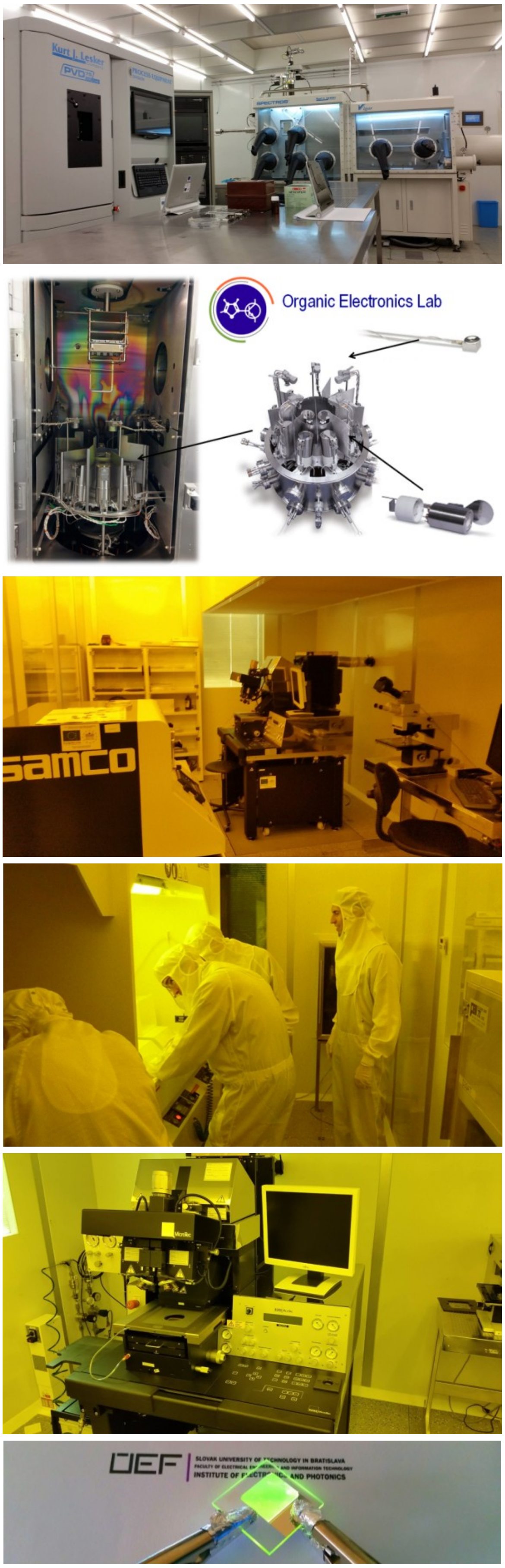

Figure 3. Clean rooms as Physical Labs

world. We have to learn from current situation - even though our technology is still limiting us, this problem appeared with social media or with normal video games.

Gaming and entertainment are only few reasons to use VR. Quality VR content is the gap in new utilizations. Publishers are already ready, creators not [23]. Possible heath issues are also subjects of many debates. VR sickness or cyber-sickness, is one of the side-effect experienced by some users. Symptoms are comparable to motion sickness, disorientation, nausea, pallor, sweating and headaches leading to vomiting [21]. It's widely discussed that this is related to a conflict within the biology of the brain. Our auditory and visual sensor inputs tell us that we are moving through a real space, while our inner ear is not able to detect the corresponding motion. Many these short-term side effects and problems have been reduced by adequate technological solutions and developments, which were introduced over the last few years and will continue refined as time rolls by. Among others, improved resolution and screen refreshing rates have had a positive impact together with proper game designs, when developers gained a deeper understanding of the conditions that make a stable VR experience [21].

Experiments of team Professor Mayank Mehta made possible to conclude, that VR activates less neurons as true reality. However other researchers think, that is too early to draw any final conclusions. Development, research is ongoing, and many studies are contributed on the topic, to define what impact this technology may have on the brain. At least this intimates the industry and researchers to take this issue serious enough to examine physical and mental health more cautiously [21].

A huge problem of VR can be social immobility with isolation and reclusive behavior of everyday users, that can even cause depression, suicide attempts and even virtual-world conflicts that are transformed into real-world violence.

VI. CONCLUSION

Development of low-cost devices (Oculus Rift DK1), as well as the expanding interest of large electronic entertainment companies (Samsung, Microsoft, Sony) leads to commercialization of the VR technology. This has a primary affect on the virtual world and the utilization on VR in various disciplines, like higher education where it has a great potential.

The rising acceptance of virtual reality in the e-learning field brings new challenges of implementation, training and producing student-centered courses, which are automatically customized for individual student's needs. Thanks to all the sensors and hardware of VR, learners of kinesthetic, visual, and auditory modalities can benefit from virtual reality based education, and as a primary result of this to achieve higher levels of cognitive abilities.

VR education solutions directly engage with the subject matter through immersive interactive experiences, and empower students to learn by-doing. This transition from traditional memorization makes possible for students to be able to analyze, use evaluate and judge their acquired knowledge by problem solving, and communication. VR training based self-adaptive technologies help students to learn faster, decide better and remember longer.

Authors see virtual reality as the future of creative learning but also consider the other side, where virtual reality is not able to substitute real experiments. Real learning by doing in many cases are still more suitable than virtual reality ones.

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