VIRTUAL AND AUGMENTED REALITY

Juan Jose Castano Moreno
Department of Engineering
Elizabethtown College
Elizabethtown, PA 17022 USA

I. ABSTRACT

Augmented and virtual reality have been booming in the last decades. However, their differences and characteristics are commonly not very discussed or well-known. This paper will provide a deeper insight on what exactly these technologies are. Furthermore, their current applications and developments are also going to be discussed. Based on all of this information, the future scope of these technologies will be analyzed as well.

II. INTRODUCTION

In the last decades, two of the technologies that have been most developed are Virtual Reality (VR) and Augmented Reality (AR). It is in the most special interest of many companies to take these technologies to the next level, like Apple Inc. that is constantly developing Augmented Reality sensors and cameras in their devices, or Microsoft, which has also released various Virtual and Augmented Reality cutting-edge headsets and gadgets with partnerships made with other companies. In **Figure 1**, it is shown one of the latest HTC VR headsets, the HTC Vice Cosmos Elite, which was released in partnership with Microsoft as it works on Windows operative system.

Although virtual reality seems to attract more attention from customers, the popularity of augmented reality is also on the rise and, even if it is not as mentioned, it has also taken over the entire digital market, maybe even more than virtual reality. One of the most popular examples of augmented reality is the widespread game Pokémon go.

Nonetheless, many people are not aware of the differences between augmented and Virtual reality, and it is important to know since, even if both have similarities and are being developed simultaneously, they have different purposes and they have different utilities.

Figure 1: HTC Vive Cosmos Elite VR System [1]

On the one hand, virtual reality consists on a computer-generated virtual environment. It is the use of a specialized headset to get immersed in a totally digital world. It is very used in the videogame industry and also, in learning environments. On the other hand, augmented reality is the combination of computer-generated data with the real world. In AR, the real world serves as a base to be enhanced by the virtual elements added by the computer, like in Pokémon go.

According to Dawait Amit Vyas and Dvijesh Bhatt [2], "One can envision AR as a technology in which one could see more than others see, hear more than what others hear and perhaps even touch and feel, smell and taste things that other people cannot feel." These definitions are crucial to understand the different scopes of these two technologies and their relevance.

Furthermore, this appears to be just the beginning of these two technologies. There are thousands of engineers working on this, and there are several projects being developed, from realistic and more advanced displays, to specialized 3D audio embedded systems to make the VR and AR experience more immersive. With all of these advances being made, it is probably that in the near future, these technologies are going to become indispensable and are going to be used in everyday life, just like smartphones today.

III. Discussion

Booming of AR and VR

The popularity of Augmented Reality is indisputable, even if it is not very noticeable. Pokémon go is one of the best examples as it mixes real world images with computer-generated visuals. Nonetheless, it is not the only example of this technology becoming widespread, there are several other applications that are making use of this revolutionary technology, like Snapchat. This application uses AR in order to put filters in people's faces. And it is not the only application doing this. Several of other social media applications also implemented this system, like Instagram or Facebook. In addition to this, there are many headsets specially dedicated to AR that have already been released, like the Microsoft HoloLens that can be appreciated in **figure 2.**
As stated by Dawait Amit Vyas and Dvijesh Bhatt [2], this technology has applications in several areas, and they classify all of those applications in the following categories:

Figure 2: Microsoft HoloLens in use in a warehouse facility in The Netherlands [3]

- Military
- Medical
- Maintenance & Repair
- Entertainment
- Gaming
- Advertisement & Promotion
- Navigation
- Pharma
- Architecture
- Navigation
- Education
- Mobile Applications

Thus, augmented reality has a lot of potential to become an extremely useful tool to enhance the work of people on every field mentioned above.

Moreover, virtual reality does not fall behind, and it is predicted to have a huge impact on the market. According to the Statista Research Department [4], it is estimated that the VR market is going to reach the value of 16.3 billion US dollars by 2022, and both the AR and VR are estimated to reach 34.1 billion US dollars by the same year.

Advances in AR and VR

According to Sutherland et al. [5], the recent booming in these two technologies is due to "advances in smartphone display technology, improvements in graphics processing units (GPUs), and tracking technology including revolutions in inertial measurement units and optical tracking systems." All of these features are key to the possibility of implementing AR and VR on all of the fields mentioned above.

The Microsoft's HoloLens, for example, has a system that [5] "uses inside-out computer vision tracking and the reflection of high-definition light projectors onto the retina in a mobile form-factor." This is only one aspect of all the advances that this Microsoft device integrates to be revolutionary.

Applications

In this section, some of the applications of augmented and virtual reality are going to be further explained to fully understand the impact that these technologies currently have.

In the medical field, the roles that implementing AR and VR has is very broad. These technologies can serve as [5] "intervention planning aid," and they can also make therapy under the guidance of a doctor more effective. Moreover, AR and VR are also useful for patients to learn about their health, or even for delivering treatments. Reference [5] identified three main benefits of VR and AR from the perspective of doctors: Training, surgery planning, and medical image interpretation. Regarding training, several studies [5] suggest that clinicians trained with VR equipment are better prepared than those who are trained traditionally. Furthermore, the possibility of VR and AR devices to represent 3D models perform an important role to enhance surgery planning, and that way, reduce the amount of invasive procedures that occur. When it comes to medical image interpretation, augmented reality [5] "could potentially be used to identify and assess microcalcifications in the breast," and "for studying pathology, the HoloLens AR tool has been considered as ideally suited for digital pathology and has been tested for autopsy as well as gross and microscopic examination." Hence, these technologies have a huge potential to enhance doctors' work in a way never seen before, facilitating it for them to do clinical tasks more efficiently and precisely.

Regarding the military field, one of the most popular uses of AR is the so-called Heads-Up display [2]. It consists of a transparent display that is put on aircrafts in order to show important information such as altitude, speed, and the horizon line. In addition to this, AR is also used by ground troops by the use of headsets. These headsets show information like enemy location, and they are also used for training simulations.

When it comes to advertisement and promotion, many companies are using AR to make their brand more appealing. Apple Inc., for example, has an option on their website to display their products using AR so that costumers can see what those products look like in different places. IKEA is another company that takes advantage of augmented reality to promote their products. They released a mobile app specially dedicated to display their furniture on real world images. That way, people are able to see what their furniture would look like in their homes before ordering products. There are many companies that are incorporating these technologies as a strategy to promote their products. When *Avatar* was released [2], their campaign strategy included was pushed with augmented reality. The movie's toys included cards that could be read by webcams and it would display characters from the movie. The cards also included a button that made the character say a line from the movie or perform a characteristic action.

Figure 3: Oculus Rift S headset and controllers [6]

Augmented reality is a marketing strategy that has experienced a big growth, and it is most likely going to continue being implemented by more companies.

Moreover, gaming is probably one of the fields where augmented and virtual reality is most used. As advances in computing continue being made, headsets and VR and AR devices overall become cheaper. Sony, for example, released their own virtual reality set, the PlayStation VR, that works with their latest console, the PlayStation 4, to bring a better user experience, and make players more immersed into the different games. Simultaneously with the PlayStation VR, Oculus also released their own virtual reality gaming headset called Oculus Rift, but, contrary to the PlayStation VR, the Oculus Rift does not work with a gaming console, instead, it is meant for PC gaming. The Oculus Rift has had some upgrades, and in **Figure 3,** their latest VR headset, the Oculus Rift S, is shown. These are some of the most popular VR devices in the market but not the only ones. There are several devices that work with cellphones like the Google Cardboard, a VR headset where people can put their cellphones in order to use mobile VR applications. The Google Cardboard is shown in **Figure 4.**

Perhaps one of the most impressive uses that augmented reality and virtual reality have, is in The National Aeronautics and Space Administration (NASA).

Figure 4: Google Cardboard [7].

According to the International Technology Education Association [8], as of 2004, "transmissions from the Mars rovers involve massive amounts of data that must be quickly viewed, studied, and shared. NASA scientist are interactively planning rover movements using 3D photorealistic virtual reality reconstruction of the Martian surface, powered by NVIDIA graphics." Therefore, virtual reality plays an important role in the studies of the red planet, letting commands that get to rovers be successfully gathered. This is one of the best examples to visualize how big the scope of VR and AR is, and how much it can facilitate various tasks, even in another planet.

With all of these applications, it is more than clear that VR and AR technologies, although being perfect gadgets for gaming, are not only for that, and are changing the way people go about their daily lives. In words on Logan Kugler [3], "it's no longer just for fun and games; thanks to relatively cheap and better technology, VR and AR are poised to transform how we work."

Development and Future Scope

As mentioned before, there are hundreds of engineers and specialist working every day to improve these two technologies and make them even more suitable for all of the applications they may have. According to Eduard Muslimov, Thibault Behaghel, Emmanuel Hugot, Kelly Joaquina, and Ilya Guskov [9], advances on curved CMOS (Complementary Metal-Oxide-Semiconductor) sensors and OLED (Organic Light-Emitting Diode) suppose a substantial enhancement on VR and AR displays. As they said, "this latest development opens new prospects for the creation of optical systems with curved focal surfaces." They also said they it can make better illumination uniformity and reduce image distortion. Several studies [9] of this type of displays were made, and they got to positive conclusions. They found that this kind of display "should have a high accuracy and the display should be well isolated from all other external loads." They propose to use these displays in specialized headsets to reach a better image accuracy as it would permit to show any image at any position in depth without any alteration in the quality of the image. **Figure 5** shows a sketch of this system put on a human head model, and the curvature of the display can be appreciated.

Microsoft researcher Ivan J. Tashev [10] explains some of the 3D audio or special audio technologies that are being developed at Microsoft. He explains that spatial audio is a group of algorithms and specialized devices to make the listener perceive different sounds as if they were coming from different directions and distances. This is a crucial element that all VR headsets should have in order to provide a more realistic experience. He also explains how the brain perceives sounds, which is important to know in order to cause this sensation of special audio. He writes, "to determine the direction and distance to the sound source the brain uses auditory localization cues: interaural time and level differences, spectral differences, reverberation and reflections, dynamic and multi-radial cues." Also, they model the propagation of a sound wave to the ears with a different function of time for each ear in order to have better precision.

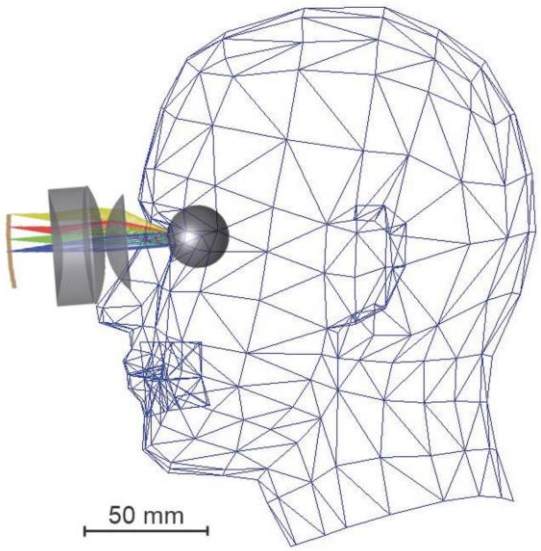

Figure 5: Model of the VR curved projection system on a human head [9].

These functions are known as head-related transfer functions (HRTF) and are some of the most important aspects to take into account when developing 3D audio systems. In Microsoft, Tashev [10] explains, they test all of these functions in HRTF measurement laboratories. The setup of that they use can be observed in **Figure 6.**

It is important to mention that 3D audio systems are already being implemented in some devices like the PlayStation VR released in 2016, but there is still space for improvement and this technology represent a crucial part for a good VR experience. These researches are some of all of the improvements that are constantly being made in augmented and virtual reality.

Furthermore, these technologies are growing so fast that their scope in the near future seems to be humongous.

Figure 6: Head-related transfer function measurement setup in Microsoft Research [10]

As quoted in Logan Kugler [3], "Phones will disappear, everything is moving to wearable tech and everything will be viewed with AR, so you can still capture your true environment. Everything will be synced from voice commands and eye tracking with potentially a watch for touch. The tech already exists." This idea does not sound very far-fetched taking into account all of the advances that are being made in augmented reality.

Challenges

Nonetheless, there are still some challenges that need to be fixed in order to make augmented and virtual reality an ideal tool for work. As stated in reference [5], "the computational demand of inside-out computer vision tracking currently places limits on the rendering capability of the HoloLens, which potentially results in image latency and additionally poses a limitation in model detail (resolution) which can be detrimental for medical applications." This means that the latency and the resolution of the Microsoft's HoloLens still needs to be fixed in order to fully trust it as a tool for medicine. Taking into account that the HoloLens are possibly the most popular AR headset, as stated in [5], more improvements need to be made.

Furthermore, in a study made by Alaric Hamacher, Jahanzeb Hafee, and Roland Csizmazia [11], it was found that, when compared to a traditional mouse, the HoloLens goes below average in efficiency, and it was also evaluated to be less precise than the mouse.

This means that there are still some challenges for engineers and developers before current augmented and virtual reality become an optimal tool. However, considering the rapid pace at which these technologies are being developed, it is most likely that these limitations will be fixed sooner rather than later.

IV. Conclusion

The purpose of this paper was to analyze the current situation of augmented and virtual reality. Many of the applications that these technologies are currently having were mentioned, showing the broad range of utilities that they have.

Some of the challenges and limitations that AR and VR were also discussed. That means that they still need to be improved, and engineers still need to continue working on them in order to make them more optimal. However, as improvements in technology are being developed at a rapid pace, like the 3D audio and the curved displays, these limitations are most likely going to be fixed very soon. Hence, AR and VR are going to become the perfect tools for any kind of work, and the scope of these technologies is going to be even wider.

REFERENCES

[1] Microsoft Corporation. (2020). HTC Vive Cosmos Elite VR System. Retrieved from: https://www.microsoft.com/en-us/p/htc-vive-cosmos-elite-vr-system/8r84pztn8dbk?icid=ARVRcat_Hero1_HTCVIVECosmosElite&activetab=pivot%3aoverviewtab

[2] Vyas, D. A., & Bhatt, D. (2017). Augmented Reality (AR) Applications: A survey on Current Trends, Challenges, & Future Scope. *International Journal of Advanced Research in Computer Science*, *8*(5), 2724–2730.

[3] Kugler, L. (2017). Why Virtual Reality Will Transform a Workplace Near You. *Communications of the ACM*, *60*(8), 15–17. https://doi-org.proxy-etown.klnpa.org/10.1145/3105444

[4] SuperData Research. (January 24, 2019). Immersive technology consumer market revenue worldwide from 2018 to 2022, by segment (in billion U.S. dollars) [Graph]. In *Statista*. Retrieved April 26, 2020, from https://www-statista-com.proxy-etown.klnpa.org/statistics/936078/worldwide-consumer-immersive-technology-market-revenue/

[5] Sutherland, J., Belec, J., Sheikh, A., Chepelev, L., Althobaity, W., Chow, B. J. W., Mitsouras, D., Christensen, A., Rybicki, F. J., & La Russa, D. J. (2019). Applying Modern Virtual and Augmented Reality Technologies to Medical Images and Models. *Journal of Digital Imaging*, *32*(1), 38–53. https://doi-org.proxy-etown.klnpa.org/10.1007/s10278-018-0122-7

[6] Microsoft Corporation. (2020). Oculus Rift S PC-Powered VR Gaming Headset. Retrieved from: https://www.microsoft.com/en-us/p/oculus-rift-s-pc-powered-vr-gaming-headset/8vbm8nh7hwwk?icid=ARVRCat_CP2_OculusRiftS&activetab=pivot%3aoverviewtab

[7] Google LLC. (2020). Google Cardboard. Retrieved from: https://store.google.com/us/product/google_cardboard?hl=en-US

[8] Martian Imaging. (2004). *Technology Teacher*, *63*(7), 3.

[9] Muslimov, E., Behaghel, T., Hugot, E., Joaquina, K., & Guskov, I. (2020). Variable Curvature Displays: Optical Designs and Applications for VR/AR/MR Headsets. *Applied Sciences (2076-3417)*, *10*(2), 1–10. https://doi-org.proxy-etown.klnpa.org/10.3390/app10020712

[10] Tashev, I. J. (2019). Capture, Representation, and Rendering of 3D Audio for Virtual and Augmented Reality. *International Journal on Information Technologies & Security*, *11*, 49–62.

[11] Hamacher, A., Hafeez, J., Csizmazia, R., & Taeg Keun Whangbo. (2019). Augmented Reality User Interface Evaluation: Performance Measurement of Hololens, Moverio and Mouse Input. *International Journal of Interactive Mobile Technologies*, *13*(3), 95–107. https://doi-org.proxy-etown.klnpa.org/10.3991/ijim.v13i03.10226