**Group 25:**

**Virtual Reality**

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In this project, we will be laying out an overview of the field of Virtual Reality, as it relates to Computer Science. We will cover some of the technology developed in different VR systems, versus current Virtual Reality systems. Namely the development of the Head Mounted Display and full-body and hand tracking system, which every Virtual Reality headset currently uses in some form or another. Similarly, we will list and discuss each current VR headset on the market and compare their specifications. We will also be discussing a number of video games released in VR and explaining the impact they had on how VR systems are developed and how they have furthered the field of VR. Then we will look to the future of VR, at systems like Augmented Reality and how we believe they may change the field of VR for the better, or for worse.

Virtual reality headsets are widespread today. They have been created by many companies in unique, creative forms. We will look at some of the most popular virtual reality, or ‘VR’, headsets that have been released to the public today.

Arguably the most popular VR headset would be the ‘Oculus Rift’, designed by a division of Facebook. This headset was shipped on March 28th, 2016. The first model was named ‘CV1’, standing for ‘Consumer Version 1’, and was released on May 21st, 2016. It boasts a 1080x1200 display per-eye, leading to a combined resolution of 1080x2400 overall. ‘CV1’ also has a 90Hz refresh rate, with a 360-degree positional tracking system, 110-degree field of view, and integrated audio output[[1]](#footnote-1). With this model, there was a clear focus on ergonomics and overall beauty of the headset. Shortly after ‘CV1’, the ‘Rift S’ was developed. Shipped on May 21st, 2019, this headset came with a 2560x1440 LCD 80Hz display, a 115-degree field of view, positional tracking, and in-built audio[[2]](#footnote-2). This headset uses ‘Oculus Insight’, which is its method of tracking motion in the real environment using five cameras on the headset. These cameras observe the surrounding area and notice changes, reflecting these changes in the gameplay[[3]](#footnote-3). The ‘Rift S’ also uses ‘Oculus Home’, which is outputted to the headset when there is no other output to be displayed. This displays things such as a VR store, list of applications and more, making it easy to access applications and other things quickly. This headset, compared to the others that will be mentioned, was one of the pioneering products in the VR world.

Sony’s take on VR was nothing short of the quality of the ‘CV1’. Shipped in October 2016, ‘PlayStation VR’ contained a 5.7-inch OLED panel, which had a resolution of 960x1080 per-eye, giving a combined resolution of 1920x1080 overall, with a refresh rate of 90-120Hz[[4]](#footnote-4). One flaw of this headset is that there is no official option to transfer use to another system. ‘PlayStation VR’ is only officially supported to be used on PlayStation 4 or, in the future, PlayStation 5. This headset also boasts 3D audio, a 100-degree field of view, and has 9 positional LEDs to track 360-degree movement of the head[[5]](#footnote-5). With ‘PlayStation VR’ supporting a refresh rate of 120Hz, it is clearly a high-tier headset, and seeing as most PlayStation 4 titles only support up to 60FPS, the headset used “a motion interpolation technique” called asynchronous reprojection (Wikipedia, n.d). This technology is aimed at improving the smoothness of the framerate of video, especially in virtual reality headsets, achieved by “warping” the previous frame into a prediction of how the next frame will look[[6]](#footnote-6). This allowed the ‘PlayStation VR’ headset to view these high framerates, even if the game wasn’t designed to run at this level. Another advantage of this headset would be the compatibility. This headset has one design, and anything designed to be run by the headset only needs to be designed to suit one specification. This leads to less compatibility issues, which can not be said for any of the other headsets that have been/will be mentioned. In terms of quality, however, ‘PlayStation VR’ certainly matches the hardware quality and ergonomics of the other headsets.

The ‘HTC Vive’ was released on the 5th of April 2016. The quality and beauty of the Vive certainly matched that of both the Oculus and the PlayStation VR headsets. Developed by HTC, and using technology developed by Valve (who, in turn, develop their own VR headset), the Vive grew to become one of the most popular VR headsets upon release for their high quality. This headset comes with a 1080x1200 display per-eye, combined for a 2160x1200 display overall. Using a 90Hz refresh rate, there is also a 110-degree field of view, leading to great immersion whilst playing/watching using the headset[[7]](#footnote-7). The Vive uses a safety camera and software, similar to ‘Oculus Guardian’, labelled as a ‘Chaperone system’, and it displays a virtual wall for the user if an obstacle is nearby in the real world[[8]](#footnote-8). The Vive uses many infrared sensors on the headset to detect the infrared pulses from the ‘base stations’ that are set up around the play area. This is its method of detecting movement of the headset in the play area, which differs slightly from other headsets. The base stations are 2 black boxes, which create a 360-degree play virtual space, known to all as the ‘play area’. These base stations emit 60 pulses per second, so that the user is tracked consistently, and doesn’t wander outside the play area. The Vive also comes with handheld controllers, which contain around 24 infrared sensors on the ring of the controller in order to determine the location of the controllers in the play area (extremely accurate). In comparison to the other headsets, the HTC Vive is certainly one of the higher tier headsets. While things like display may not reach the highs other headsets have, the build quality, ergonomics and mechanics of this headset is arguably the best.

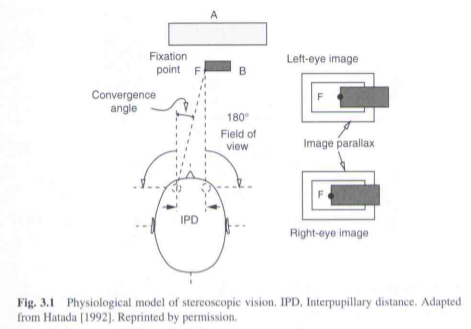
The ‘Valve Index’ is the most recent VR headset to be released, shipping in June 2019. The Valve Index certainly boasts the highest quality (and retail price), with a 1440x1600 per-eye resolution, combined for a 2880x1600 LCD display. One can select the refresh rate, either 80, 90, 120, or an experimental 144Hz. The Index also uses a field of view of 130 degrees[[9]](#footnote-9). This field of view is what sets the Index apart from its competition. The lenses being closer to the eyes means a wider field of view, which is essential to feel more immersed in the headset[[10]](#footnote-10). Similar to the Vive, Index uses the Valve lighthouse system as a means of motion tracking, but it is an improved version. It also has the option for Valve Index controllers, which are also compatible with the Vive. For the most part, the operation and mechanics of the Index is similar to the Vive, with a much higher production quality.

This section of the essay relates to the technology and architecture behind Virtual Reality, the systems the user interacts with and how they all work together to maintain a sense of immersion for the user.

Graphics Displays

The primary means of human-computer interaction in VR is the Head Mounted Display (HMD) which provides a graphics display using LCD or CRT-based technology although nearly all modern VR systems use LCD and even OLED displays. An effective graphics display needs to match its image characteristics to those of the user’s ability to view the synthetic scene. Essentially this means that each display, (one for each eye) must be similar in shape and render the synthetic scene in a similar manner to the human eye. (pg. 58 Virtual Reality Technology 2003)[[11]](#footnote-11) The human eye has an uneven distribution over the retina. The central area of the retina is called the fovea. It is a high-resolution, colour perception area. This area is surrounded by low-resolution, motion perception photoreceptors covering the rest of the eye. With this in mind the HMD must display a focused image over the fovea. Many systems include eye-tracking to dynamically update this area, tracking the fovea. Early models, such as the first oculus rift did not have eye tracking.

Another aspect to consider in relation to the HMD is the human field of view. It is 180 degrees horizontally and 120 degrees vertically using both eyes. There is a central area called the stereopsis where both eyes register the same image. This overlap is 120 degrees horizontally and the brain uses it to measure depth. This is important when helping the brain measure depth in VR to keep the sense of immersion.



The point F in the diagram above will appear shifted horizontally between the eyes due to its position being different in relation to each eye. This image shift is called parallax and needs to be replicated by the HMD to help the brain interpret depth in the synthetic world. To do this each display outputs two slightly shifted images. If the HMD uses one single display instead of one for each eye the two images are either time-sequenced or spatially sequenced. Depth perception, high-resolution images and depth perception are important factors to sustain a feeling of immersion and also important for preventing the user from feeling nauseous or getting motion sickness. Depth perception is simulated using shadows, occlusions, surface texture and object detail. On single display systems depth perception is made using motion parallax, where closer objects seem to move further than distant ones when the user moves their head. (pg. 59 Virtual Reality Technology 2003)

User Tracking- Hybrid Inertial Trackers

Hybrid Inertial trackers are used in more modern VR systems and use microelectromechanical systems technology. These trackers are used to track an object, primarily the user to simulate their position and limb movement in the simulation. Using gyroscopes, the angular velocity of an object if measured. Three of these are machined on mutually orthogonal axes, measuring yaw, pitch and roll angular velocities. The trackers also measure acceleration using solid-state accelerometers, three are machined coaxially with the three gyroscopes to measure body-referenced accelerations. Such as using user movement to move in the simulation and to track arm movement for manipulation with the simulation. (pg. 38 Virtual Reality Technology 2003)

The advantages of using hybrid inertial tracking is the unlimited range, no line-of-sight constraints like with optical tracking and very low sensor noise. Although this can be filtered out through integration. All of this adds to reducing the latency of the tracking operation. Although there are significant drawbacks to inertial trackers, they have rapidly accumulating errors or drift and can lose synchronisation with the user. Once drift starts to occur the error in calculating the user’s position or the percentage error increases with time, such as accelerometer bias that increases by the time squared. To solve the drift problem data is used from other trackers to reset the output of the inertial trackers. (pg. 39 Virtual Reality Technology 2003)

Manipulation Interfaces

A manipulation interface is a device that allows the interactive change of the view of the virtual environment through selection and manipulation of a virtual object of interest. The manipulation can be through either absolute coordinates or relative coordinates. Trackers like the hybrid inertial trackers are absolute as they use the position and orientation of a moving object with respect to a fixed system of coordinates. Then the objects in VR are directly mapped to the absolute position of the user in the world. Relative sensors are an alternate tracking option which returns zeros when the user is at rest whereas absolute positioning data is a never zero set. (pg. 41/42 Virtual Reality Technology 2003)

One example of a manipulation interface which uses relative sensors is the Didjiglove, which even tracks the user’s fingers with the hand. To do this it users 10 capacitive bend sensors. A conductive layer of sensors is arranged in a comb like fashion, such that the overlapping surface is proportional to the amount of sensor bending. (pg. 51 Virtual Reality Technology 2003) The Didjigolve uses an A/D converter, a multiplexer, a processor, and an RS232 line for communication with the host computer. The 10-bit A/D converter resolution is 1024 positions for the proximal joint, which is the joint closest to the palm. The glove calibrates the finger position by reading the sensor values when the user keeps the finger extended, with the value of 0 and when the fingers are bent which the value is set to 1023 and any values in between relative to the fingers position. The Didjiglove was designed as an advanced programming interface from computer animation, for the 3D Studio Max toolkit but due to the glove’s low latency of 10 milliseconds, the glove was highly suitable for VR interactions as well. (pg. 52 Virtual Reality Technology 2003) The 5DT Data Glove measured each finger separately and also featured a title sensor to measure wrist orientation. Each finger has a fibre loop routed through attachments which allow for small translations due to finger bending with additional sensors for minor joints. These fibre-optic sensors are compact and light which grants greater comfort to the user. The 5DT communicates with the host computer similarly to the Didjiglove using multiplexers and RS232communcation ports. (pg. 49 Virtual Reality Technology 2003)

This section will be relating to the current development of games for virtual reality, and the security features that are making them more accessible for everyone. To begin, I would like to explain that much of my source for this information is first-hand experience. I have had an Oculus Rift S for about six months now and have played a plethora of games since. Examples of these include ‘Blade & Sorcery’[[12]](#footnote-12), ‘Arizona Sunshine’[[13]](#footnote-13), and ‘Beat Saber’[[14]](#footnote-14). After discussing these three, I will go on to cite sources on the development of triple-A games in VR such as ‘Half-Life: Alyx’[[15]](#footnote-15).

‘Blade & Sorcery’ is a prime example of the incredible capabilities of modern Virtual Reality systems. Available on Vive, Rift, and Index, this game uses a first-person perspective and smooth movement to drill home the dangers of medieval combat. By smooth movement, I mean the player-controlled movement wherein they use a joystick to move similarly to most console games. In contrast to this is the teleportation system that other games use, which was developed primarily to help people who get easily motion sick. The implementation of VR in ‘B&S’ is perfect, despite it being in early access. As the description of the game states: “The era of the VR weightless, wiggle-sword combat is over.” ‘B&S’ uses the Unity engine with realistic inverse kinematics, to make every interaction you have with your surroundings feel weighty and accurate. This game has had a huge impact on the current VR industry and is still receiving regular large updates.

‘Arizona Sunshine’ serves as the go-between between single-person teams like ‘Blade & Sorcery’, and the huge triple-A teams of ‘Half-Life: Alyx’. With a modest team of seventeen people, ‘Arizona Sunshine’ released in 2016 as the best VR Zombie Survival game of its time. With innovative fun gunplay, extreme tension, and fresh storytelling techniques, ‘AS’ showed the potential of larger VR games long before Triple-A companies had caught on to the idea. The tension present in this game is thrilling, with the pocket-lint.com explaining that “The lighting and atmosphere is where this game really shines, especially in the variety of moving between light and dark areas.”[[16]](#footnote-16) As mentioned, ‘AS’ also introduces new storytelling techniques only relevant to the VR scene. Rather than a quest journal, or any markers, your character cracks jokes and thinks aloud to himself. This leaves you to figure out what the Arizona cowboy means by his dark humour and temperamental attitudes. Overall, ‘Arizona Sunshine’ is mentioned here because of how integral it was to the creation of larger, better games in the current era of VR, like those which I will mention later.

‘Beat Saber’ is arguably the simplest and most addictive of the games I have mentioned. The premise is “a VR rhythm game where you slash the beats of adrenaline-pumping music as they fly towards you, surrounded by a futuristic world.”, as described by the Steam Store page I have referenced. I strongly believe that, despite being the worst game on this list, ‘Beat Saber’ is the biggest thing to pull new players to VR right now. Sitting at 1,276 concurrent players on Steam at the time of my writing this, 500 players above second place, there is clearly something that keeps people playing[[17]](#footnote-17). My explanation is mods. Mods are unlicensed additions to any video game by fans of said game. For ‘Beat Saber’, mods come in the form of new surroundings, coloured sabers, and most importantly new songs to swing along to. ‘Beat Saber’ without any downloadable content from the developers themselves, comes with roughly twenty songs to enjoy. With mods, that number is above twenty-six thousand, five hundred and twenty, with more getting added every day[[18]](#footnote-18). The innovations to VR that this title supplies includes beat based challenge, like Guitar Hero, and a variety of different difficulties. In conclusion, I think Beat Saber is a great example of the fun VR gaming can have, despite the obvious intensity of the medium.

The final game I will be speaking about in relation to current VR games is ‘Half Life: Alyx’. The only Triple-A game on this list, ‘Alyx’ is the next instalment in the long delayed ‘Half-Life’ series. Described by theguardian.com as “a spectacular immersive experience”[[19]](#footnote-19), ‘Alyx’ is truly a huge step forward in VR games. As with each instalment in the series before it, Alyx is Valve’s attempt to push PC gaming to a new level. Much like the introduction of the gravity gun, in Alyx the often-sought-after telekinesis in VR games is found through prototype gloves that you can upgrade throughout the game. The environment is the closest VR has come to real life as yet, with nearly every sprite being interactable, windows smashable, car doors openable, drawers closable, there is no limit to the immersion. ‘Alyx’ is the flagship game in Valve’s ‘Index’ launch, and absolutely lives up to the expectation that the franchise places on it.

‘Alyx’ was not developed in isolation though. The game has obvious influences from other VR titles, including Stress Level Zero’s BONEWORKS. Interestingly, there was only a few months between these two game’s launches, another example of the ‘Twin films’ phenomenon[[20]](#footnote-20), so prevalent in Hollywood. Despite their similarity, they approach the medium differently. ‘BONEWORKS’ takes a more arcade-y approach, with less focus on story and character. Despite this, the game is still highly enjoyable and difficult. As a whole, I think ‘Alyx’ is the better game, but it did have a dev team of “somewhere over 80”[[21]](#footnote-21).

The enthusiast VR space

In late 2019 at Oculus Connect 6 Chief Scientist at Oculus VR, Michael Abrash stated that VR is in a similar position as personal computers were in the nineteen eighties, only used by hobbyists and industry[[22]](#footnote-22), and that it has yet to see its inevitable explosion in popularity that personal computers did in the late nineties, but thanks to the internet and VR’s popularity among the average pc enthusiast it is growing at a much faster rate than PCs did in terms of the commercial use.

Virtual Reality’s primary application in the home is gaming and recently some key software releases have provided a much-needed boost in the platform’s popularity among the “hardcore” games market. This market had about 16 million users as of 20182 but Valve (creators of the Index and Vive VR headsets and the world’s biggest PC game store Steam3) announced a sequel to the highly acclaimed Half-Life 2: Episode 2 causing millions who were originally dismissive of VR gaming due to its lack of a “killer app” turned their attention towards the platform as it was the only platform that supported the next entry in the Half-Life series which had previously ended on a cliff-hanger ending plot-wise, leaving a massive amount of consumers begging for another entry in the franchise. This led to a mass shortage of stock for VR headsets that persists today (9th May 2020) as thousands rushed to get the headsets before each other to play it on launch day. Half-Life: Alyx is estimated to have brought almost a million new customers to high end VR.4

What this means for the future is, that due to the explosion in the enthusiast grade VR headsets’ (HTC Vive, Oculus Rift S, Valve Index) install base developers have begun to take the VR market much more seriously as a platform to release high budget software on, whereas previously many developers rightfully had little faith in the platform as it was relatively small compared to “flat screen” gaming. This means the platform will likely receive many more high-budget, cinematic experiences for those with powerful PCs and high-end headsets in the next decade.

The mainstream VR space

While the above applies to the VR/Computing/Gaming enthusiast community there is a much larger market that has only somewhat come into existence yet that companies will be much more interested in spearheading as it grows. For the most part the casual VR market currently consists of low-fidelity headsets that use a mobile phone’s screen for its display that but in May 2019 Oculus released the Oculus Quest HMD (Head Mounted Display) that was completely wireless and now has hand tracking that doesn’t require controllers, while having computing power almost on par with PC powered VR HMDs all for under 500 Euro.[[23]](#footnote-23) This massively increased the amount of things that people without much knowledge of PCs could do in VR. This increase in quality for wireless headsets means AR (Augmented Reality, Essentially VR but where the real world can be seen but with digital elements visible, similar to the parking assist camera on some cars.) and VR can be used in the industrial world to a much greater degree. One major use of AR that is inevitable is assistance in surgery and the medical field in relaying important information to EMTs and Surgeons that normally would require them to take their attention away from the patient. A headset could identify incision points and if there is an abnormality in the alignment of an insertion.[[24]](#footnote-24) As the use of head mounted displays in a professional environment is normalised we are almost guaranteed to see this come to fruition as it would be able to reduce to reduce the cost of surgery by reducing the amount of people needed to be present in an operation and would reduce the amount of accidents/mistakes that occur in surgery by reducing the number of human errors that can occur in communication.

This level of precision and ability to be able to see through objects in VR would be a breakthrough in the engineering world in order to test concepts before they have entered the prototyping phase as they can see their models in a much more realistic perspective than they can on a monitor.[[25]](#footnote-25)

The future of VR lies in mostly in industrial, non-gaming fields but they will simply be an extension of what we currently use our computers for in the professional space such as remote lectures for universities and remote calls for work that could exist in 3D in order to make it easier to communicate non verbally together. Eventually this technology will become required to function in modern society just like computers and smartphones once did.

For VR to reach this mainstream point it will need go through a period where companies compete to reduce the sizes of their displays, much like phones did in the eighties and nineties. While mobile phones were able to gather mainstream popularity while they were still quite big, due to the wearable nature of virtual reality devices they will need to be reduced in size to almost the size of a pair of glasses in order to be inobtrusive enough to wear for extended periods and be comfortable enough to carry around all day.

As a conclusion, in the end we feel that we have succeeded in discussing the topic of Virtual Reality. We examined the mechanics of Virtual Reality, and their impact on current generation VR systems. We then discussed these systems, carefully laying out their specifications as to give a detailed oversight of the topic. Then, we discussed some of the cornerstone games of VR, the ones that contributed hugely to VR as a system and viable future for PC gaming. Finally, we investigated the future of VR and made our predictions as to how it would look. We hope you agree that we covered the four major aspects of VR as a topic, discussing them thoroughly and concisely. Thank you for reading.

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