Virtual Reality for the Web: Oculus Rift

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ABSTRACT
Virtual Reality (VR) is a technology for experiencing three dimensional computer graphics, since September 2012 the Oculus Rift gave VR a new boost. Through open source development and an enthusiastic active community many new opportunities have arisen, for example graphic interfaces aimed for browser based immersive experiences. We introduce VR for the web using the Oculus Rift with Oculus Bridge.

1. PURPOSE, CONTEXT AND HISTORY

1.1 Purpose
Virtual Reality has been defined as an "interactive immersive experience generated by a computer" [1] and provides and natural, intuitive way of human-computer interaction. Most web pages and applications already have two of these three properties and only miss the immersive quality or sense of presence in a virtual space. To accomplish this, a total field of view in the Virtual Reality (VR) world is needed, and sensor data on head behavior and body movements are desirable.

We browse the World Wide Web today in two dimensions, we click through pages and create bookmarks and taps as if we are handling physical books. Not all digital web content is meant to experience as flat two dimensional pages, and loose impact or important information due to the 3D to 2D conversion. The Oculus Rift is a head mounted device that enables a user to interact with 3D virtual environments in a natural way, and is for this reason suitable for experiencing virtual reality content in a web browser.

Oculus Bridge is a WebSocket based plugin to access tracking data provided by the Oculus Rift and manage the display configuration to view virtual reality online content. It is easy to install and implement in your own JavaScript code. [2]

1.2 Context
The Oculus Rift is a head mounted display (HMD) (see Figure 1) for experiencing virtual reality environments. It is founded by Palmer Luckey. He is moderator of Meant to Be Seen 3D forum and developed, with the help of this forum the first inexpensive Virtual Reality headset. The first Oculus Rift developers kit was financed by Kickstarter, backers of 300 dollar or more received this developers kit. The campaign raised 2.4 million dollar, and was bought by Facebook earlier this year, this gave the large VR content developers the confidence to invest in the upcoming medium according to Oculus' CEO Brendan Iribe. Mark Zuckerberg posted on Facebook in March when he announced the acquisition: "Imagine enjoying a courtside seat at a game, studying in a classroom of students and teachers all over the world, or consulting with a doctor face-to-face—just by putting on goggles in your home." [3]

Some people think of the Oculus Rift as a hype that will pass by like other VR systems have done in the past, others believe this device is the breakthrough for consumer Virtual Reality. But the fact that an influential company such as Facebook is willing to invest in this device and Sony is working on a similar VR HMD called project Morpheus, are signs of the technology finally having reached a level that allows comfortable, exciting VR experiences at home. Next to new immersive games, VR applications beyond our imagination for many different industries ranging from art to healthcare and military to education could come into being in the next few years. And because the level of our inseparability with the internet will only increase in years to come, it is important that online content can handle these new VR technology devices or are even coded intended for this medium. We think browsers in the future will be programmed to support VR devices, but for now we can use software like Oculus Bridge for experiencing virtual worlds and applications in our browsers.

Figure 1. Person wearing the Oculus Rift HMD

1.3 History of Virtual Reality Technology
Virtual Reality Technology has a rich history with the first head mounted display experiments dating from the 1960's

and the first immersive virtual CAVE environments in the 1990's. A lot of these seemingly promising inventions failed on not being good enough to fool our senses in being present in a simulated world [4]. Fortunately, the extensive research done in this field has brought the medium to the point of today where the technology has become affordable for consumers and thus attractive for developers to design applications for.

Below are some important milestones for the development of VR technology:

- David Brewster invented the lenticular stereoscope in 1849
- Evans and Sutherland demonstrated the first head-mounted stereo display in 1985
- The term 'Virtual Reality' (VR) was initially coined by Jaron Lanier 1989
- VPL Research introduced a commercially available HMD, the famous "EyePhone" system 1989
- The first CAVE was built at the University of Illinois at Chicago and demonstrated in 1992
- September 2012: The Oculus Rift was successfully kickstarted through crowdfunding
- March 2012: Facebook acquired Oculus Rift

1.4 History of Virtual Reality for the Web

Development of VR for the web actually coincides with the development of three dimensional graphics for the web. One of the first attempts was VRML (Virtual Reality Modeling Language). VRML was a file format for three dimensional graphics designed specifically for the web. In order to view VRML files, you need a VRML viewer in the form of a plugin [5]. VRML did not contain any link to VR hardware but it was a tool to view, share and collaborate on three dimensional graphics in the browser. The main reason why almost no one is using VRML today, is probably because it could not run on Mac OS [6].

Below are some important milestones for the development of VR for the web:

- The first 3D graphical Massive Multiplayer Online Game (MMOG) was Air Warrior by Kesmai [], which first appeared in 1986.
- 1994: release of VRML (Virtual Reality Markup Language)
- Vladimir Vukićević first demonstrated a WebGL Canvas 3D prototype in 2006
- April 2010: Three.js was first released by Ricardo Cabello to GitHub
- February 2014: Ben Purdy releases Oculus Bridge
- Janus VR releases FireBox in 2014, a VR browser supporting the Oculus Rift.

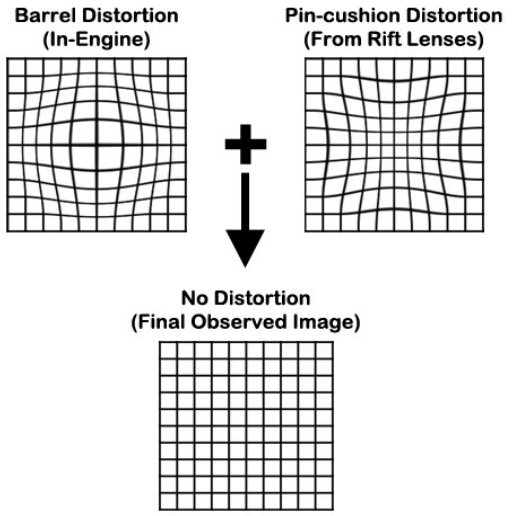

Figure 2. Barrel Distortion

2. OPERATING PRINCIPLES

This section provides an overview of the hardware, software and networking principles of VR for the web.

2.1 Oculus Rift

The Oculus Rift is today's most popular VR HMD. It is available to developers in the form of a developer kit (it is unclear when the consumer version will be available) [6]. The Oculus Rift uses stereoscopic vision technology, rendering a slightly different perspective of the 3D image for each eye. For this it uses AMOLED screens which can switch color 15 times faster than today's best LED screens in less than a millisecond. For a complete wide field of view the Oculus Rift uses optical lenses. The software running the image pre distorts the image to look natural to the user (see Figure 2) [7]. To track head movements the headset is integrated with a high-speed gyroscope, accelerometer, and magnetometer that take 1,000 readings a second, allowing it to predict motion and pre-render images to eliminate latency that caused motion sickness in previous VR HMD's. This enables the natural interaction of looking around while exploring a virtual three dimensional world. To 'predict' the user's motion the software makes use of 'Time warping', a technique developed to shorten the time between moving your head, and seeing the display update to the correct position [8]. The Oculus Rift has more pixels per eye and a wider field of view than most VR HMD's on the market today [9]. However, the current version still makes seeing details such as text difficult. The next generation (still in the form of a developer kit) will be equipped with a twin 1080p AMOLED display. The weight of the next generation is approximately 379 g, which is an increase of about 90 g in weight due to the increased screen size [10]. The Oculus Rift comes with DVI and HDMI input ports and does not include headphones.

Figure 3. Example of barrel distorted rendering

The Oculus Software Development Kit (SDK) is provided by Oculus to help developers start building VR content for the Oculus Rift using the development kit. The Oculus Developer Center has everything they need to get going including official Unreal and Unity engine integrations, samples, documentation, videos, developer wiki and community forums. However, all software that can read and interpret the Oculus Rift's sensor data can be used to programme for the device. This means many other applications are possible, for instance VR for the web.

2.2 Oculus Rift for the Web: Client-based Applications

In the case of a client-based application the Oculus Rift communicates with an application that is running on the computer (the client-side). The application in turn communicates with the web.

VR HMD's can be used in networked interactive multiplayer experiences such as Massively Multiplayer Online Games (MMOG). Most interactive multiplayer experiences are based on client-server architecture, this means the game runs on the server and the client sends inputs e.g. key events and Oculus Rift viewing angles [13]. To connect to the internet the application communicates to the server through internet sockets [14]. Recommended protocol for real time data is UDP.

2.3 Oculus Rift for the Web: Browser-based Applications

In the case of a browser-based application the Oculus Rift communicates with an application that is running in the browser, thus working on the base of the HTTP application protocol.

Communication between the Oculus Rift and the browser can be reached with the use of a WebSocket. Since HTML is a request/response protocol with no persistent connection, the WebSocket creates a permanent, bi-directional communication channel between a client and the server [15]. Benefit of this is that it takes place in the application layer via HTML, this way the vast existing HTML infrastructure working with existing browsers can be maintained. A WebSocket connection remains available until one of the parties disconnects from it. WebSocket connections are useful for games or websites that need to display live information with very low latency. This makes it ideal to use with the Oculus Rift because the web content can change real time according to the changing values of the the sensor data [16].

To communicate Oculus Rift data through WebSockets the computer needs to recognize the hardware. 'Oculus Bridge' is an application that recognizes the Oculus Rift hardware and sends its data to the browser via WebSockets [2]. A similar application is 'Webrift'. Where Oculus Bridge can run on all platforms, Webrift can only be used with a Windows or Linux Operating System [17]. Ben Vanik however proposes an alternative for communication between the Oculus Rift hardware and the browser namely with the use of an experimental NPAPI (Netscape Plugin Application Programming Interface) plugin [18]. Although this method promises even lower latencies than the Oculus Bridge, NPAPI support for Google Chrome will be phased out during 2014 because "NPAPI's 90s-era architecture has become a leading cause of hangs, crashes, security incidents, and code complexity." [19]

For the purpose of this paper we focus on the Oculus Bridge. Apart from acting as a bridge between the Oculus Rift hardware and the browser it is also a very simple javascript object that manages the WebSocket connection and messaging. The result is a simple solution to make use of the Oculus Rift head tracking data for any web based experience. One way to develop three dimensional graphics for the browser is with the use of the aforementioned JavaScript library 'Three.js'. Most of the example code of Bridge is based on Three.js, however the library has no dependencies and can be used with any other javascript framework just as easily.

3. STRENGTHS AND WEAKNESSES

3.1 Browser-based VR applications versus Client-based VR Applications

This section assesses the strengths and weaknesses of browser-based VR applications compared to client-based VR applications.

Strenghts

- Browser-based applications run in the browser and, in case of the Oculus Bridge, with the use of WebSockets. WebSockets are supported by all major browsers; Google Chrome, Firefox, Safari, Internet Explorer and Opera [16]. Additionally WebGL is supported by all major browsers.
- Applications running in the browser do not need extra extensions or custom drivers.
- Browser-based applications are easily updated; updates are pushed from the server side, thus no patches or expansions are required and all updates happen unnoticed.
- A browser-based application requires only a single

code base for all operating systems e.g. HTML and JavaScript.

- Applications running in the browser are not fixed to one machine, this way they can be run in any location.
- The same browser functions as platform for many different applications (games, social networking etc.).

Weaknesses

- The Oculus Bridge still requires a client-based application.
- The Oculus Bridge only works if other applications using the Oculus Rift are turned off. This seems to be a problem of the Oculus Rift SDK [18].
- In general applications tend to run faster on the client-side. Although JavaScript, with its possibility to run on the client-side, has some benefits, a client-based application will perform better.
- Browsers will still need updates and browsers will not provide support

3.2 Natural browsing versus VR browsing

This section assesses the strengths and weaknesses of natural browsing (the way we are used to 'browse' today) compared to VR browsing. VR browsing being the use of a HMD and VR for internet browsing.

Strengths

- 'Browsing' the web is one of the main activities of the internet today. This activity however is completely two dimensional and screen based, also three dimensional information is communicated through this two dimensional medium. The advent of VR for the web enables this activity to become three dimensional; it enables three dimensional information to be communicated in three dimensions
- Websites become three dimensional environments instead of two dimensional pages.
- VR browsing enables the viewer to see connections between information sources in 3D which could make the connections more clear [20].

Weaknesses

- Naturally, VR for the web will require getting used to. We are not used to three dimensional web pages. Information is always displayed on a two dimensional display.
- Particularly the positioning of text will need some consideration since we are used to reading from two dimensional surfaces.
- We are not used to wearing a HMD while interacting with computers. Will we have to wear this all the time?

4. TYPICAL APPLICATIONS

Head mounted displays such as Oculus Rift offer an almost infinite number of possible applications in a wide variety of fields. This section discusses some of the typical applications of the Rift and possible future applications.

4.1 Entertainment

The Oculus Rift got his roots in the Game Industry. Therefor is not a surprise that the first applications for the Oculus Rift were designed in this field.

'Team Fortress 2', developed by Valve Corporation, was announced in March 2013 to be the first game to officially support the Oculus Rift. It's a team-based first-person shooter multiplayer video game, and is available to play with the Oculus Rift dev kit by use of a command line option. A patch is made to the client to include a "VR Mode" that can be used with the headset on any public server. In this case the game is only adding Rift support to an existing game.

Many existing games use features that do not translate well to VR, such as a HUD, cutscenes, menus, third person sections, fast movement speeds, not being able to see one's own body, etc.

The first announced game being designed specifically for the Oculus Rift and Virtual Reality, rather than adding Rift support to an existing game is The Gallery: Six Elements. It's a first-person adventure game developed by Cloud Head Games. Special attention is given to the so-called VR Comfort Mode. The VR comfort mode solves several fundamental issues with virtual reality locomotion and a system is created that probably will be adopted by other games in this space. Another special issue in this game is the experience of Body Persistence, the ability to ground ones self within a virtual body. This grounding will make the user feels a part of the world, gives a stable orientation and a sense of context to the experience. Next to this another feature is an important aspect of the game, namely the Sense of Presence. A broad number of perceptual cues are needed to deliver an immersive experience and understand what drives that sense of truly being there. The environmental design, sound design, GFX design and locomotive design all work together to create the sense of presence which is so crucial to the VR experience.

Figure 4. The Gallery: Six Elements

Notch, developer of Minecraft, while initially stating that their games would likely support the Rift, announced soon after the company's acquisition by Facebook that those plans were cancelled. But the fan-made mod "Minecraft," lets you play Minecraft on the Rift. Created by modders known as "mabrowning" and "StellaArtois," the mod supports Minecraft version 1.6.4, and is compatible with Minecraft Forge, a popular mod-loader that is useful and often required for running other mods for the game. The base mod tracks your head's rotation via the Oculus Rift headset. [21]

4.2 Informational Purposes

The Oculus Rift can be used to travel around the world and experience known and unknown places in Google Street View. Oculus Google Street View is using the plug-in vr.js for Chrome or Firefox, Google unveiled a totally new version of Maps in May 2013. It has become a platform capable of evolving into a virtual reality version of the real world. The visible part of Maps is augmented by invisible data. For instance, it includes information about posted speed limits, which streets are one-way and where the stops signs are. These kinds of data can be used for accurate turn-by-turn directions, estimating trip times and other uses. The head-tracking is working due to the plug-in, but experience mostly depends on how good the captured images from Google are. Most big cities around the world looks stunning, like New York and London. This really enhances the Street View experience exponentially.

Firebox is a 3D VR internet browser supporting the Oculus Rift, developed by Janus VR. In this browser webpages are represented as boxy rooms and links connect rooms as doorways. Pictures embedded in the webpages hang on the room's walls. The environment is dynamically generated, using a portal-based system. The project is still young, but is under very active development. Additionally, Firebox Room HTML has been created, which allows website owners to add special markup to their websites in order to create an optimized Firebox experience. [22]

Figure 5. Oculus Google Street View

Figure 6. Second Life Viewer

4.3 Communication

In April 2014, Linden Lab developed a limited beta test of a version of the Second Life Viewer that made it easy to use an Oculus Rift headset with Second Life for a fully immersive, VR experience. A few weeks later Linden Lab announced that the Oculus Rift integration is available as a Project Viewer, the first step toward becoming a part of the default Second Life Viewer.

One of the features of The Project Viewer is the Full Oculus Rift Hardware Support, including automatic hardware detection and display calibration for quick and easy setup. Another important aspect is the Avatar Head Motion, in which the Oculus Rift head-tracking data is mapped to the avatar, and enables that users' avatars look where they do.

5. SURPRISING APPLICATIONS

Some more unexpected use of the Oculus Rift is described in this section.

5.1 Healthcare

Virtual Reality Exposure Therapy is a therapy in which a patient – guided by a trained therapist – is confronted by their trauma memories through a retelling of the experience. This kind of therapy is now endorsed as an "evidence-based" treatment for post-traumatic stress (PTS). ICT researchers added to this therapy by leveraging virtual art assets that were originally built for the commercially successful X-Box game. With the Rift, it can become even more effective, and be provided at a lower cost.

'Virtual Iraque' developed by Virtually Better, is a program to treat soldiers with PTSD (post-traumatic stress disorder). It has been adopted by several military medical centers and veterans affairs clinics in the United States. Having real-time control over every aspect of the simulation, from time of day, weather conditions, and even ambient sound, allows clinicians to o create simulations for a variety of experiences be it driving a Humvee down a desert road or mountain pass or even re-creating an IED explosion or insurgent attack. By pacing the exposure in a much more controlled fashion and in a way that engages the user, clinicians can control the progression of therapy. [23]

Figure 6. Virtual Iraque

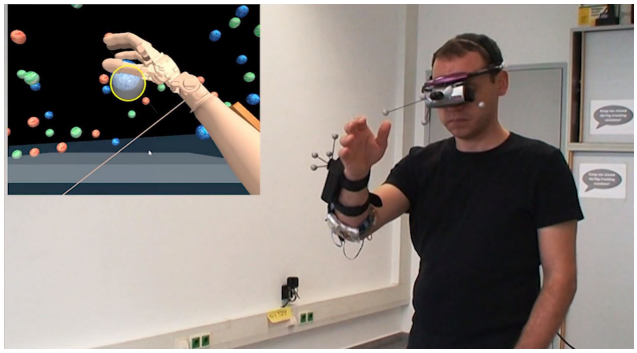

Figure 7. Virtual Reality Training for Upper Limb Prosthesis Patients

Annette Mossel, a PhD candidate, research assistant, and lecturer at the Interactive Media Systems (IMS) Group at Vienna University of Technology in Vienna, Austria works extensively in VR and augmented reality (AR) research. In 2012, her research group published a paper, "Virtual Reality Training for Upper Limb Prosthesis Patients" [24] which explains how VR/AR technology can be used to train and rehabilitate amputee patients receiving prosthesis. IMS developed a motion capture system that tracks an amputee's arm and head movement in three dimensions within a virtual environment. By combining this tracking data with electromyography to generate input for grasping controls for a virtual prosthesis, researchers can create a realistic training simulating for familiarizing patients with their prosthesis.

Another VR application is the virtual classroom project, developed by the University of Southern California's Institute for Creative Technologies (a research group Palmer Luckey was once a member of). This project creates a simulated classroom experience for testing children with ADHD and monitoring how well they can pay attention.

Phantom Limb Syndrom Rehabilitation is an application developed by the University of Manchester and a small company named Section 9. The general idea is simple. The patient places their remaining limb (their left arm, say) into the mirror box. They can then see a reflection of their arm where their missing right arm should be. By performing a set of exercises, studies have shown this can have a beneficial effect. [25]

5.2 Education

Virtual Labs, developed by Labster is an application to teach life science and medicine. In the laboratory, students get to perform experiments that are otherwise too expensive, time consuming, need sophisticated equipment and are unsafe to perform in the school environment. To overcome the above problems, the application has been introduced to enable users to perform experiments.

6. GETTING STARTED

This section illustrates how to get started with VR for the web in 10 minutes. Through a series of simple steps you will be able to set up a three dimensional environment for a webpage in which you can load three dimensional geometry to show the world via the Oculus Rift HMD. We assume a basic understanding of HTML and JavaScript.

6.1 Test the 'Oculus Bridge'

First, download the full Oculus Bridge package through: https://github.com/Instrument/oculus-bridge (Download ZIP). Unzip the files to a desired location and run the Oculus Bridge applications corresponding to your system found at oculus-bridge-master/app/build. The app shows a window with two squares, one for the WebSocket and one for the Oculus (see Figure 8). The squares show the connection status; filled means connected. Next run the 'First Person' example found at oculus-bridge-master/examples/first_person.html. This is just a normal HTML file so when double clicked it should automatically run in your preferred browser. Now connect the Oculus Rift to your computer through HDMI or DVI and be amazed!

Although we could entirely script this three dimensional world ourselves, parts of this example are very valuable and highly recommended for re-use i.e. the OrbitControls and RiftCamera JavaScript libraries. For this reason we continue with this example and add the model loader on top of it.

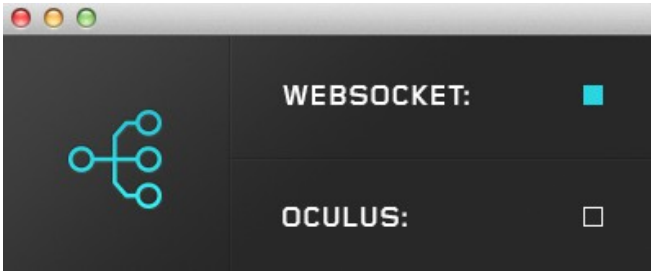

Figure 8. Oculus Bridge application window

6.2 Add an OBJ importer

Three.js offers many ways of generating and importing three dimensional geometry. One way is by importing .obj files. OBJ is a for the most part universally accepted 3D geometry file format; you can export .obj files out of most 3D modeling software. In order for the OBJ import to work we will need to add the OBJLoader library to the HTML file. This library can be found here: http://threejs.org/examples/js/loaders/OBJLoader.js. Save OBJLoader.js to the oculus-bridge-master/examples/lib/ folder and add this line to first_person.html:

```
<script src="lib/OBJLoader.js"></script>
```

Next we will need to add a 'models' folder to oculus-bridge-master/examples/ and add a .obj file (in this case name it: "helloOBJLoader.obj"). Finally we will need to add a couple of lines to the first_person.js JavaScript file found at oculus-bridge-master/examples/js/first_person.js. Inside the initGeometry() function add these lines:

```
var loader = new THREE.OBJLoader();
loader.load( 'models/helloOBJLoader.obj', function ( object ) {
    object.traverse( function ( child ) {
        if ( child instanceof THREE.Mesh ) {
            child.material.color.setRGB (1, 0, 0);
        }
    } );
    scene.add( object );
} );
```

This imports a red colored version of your OBJ model! Now you can import any object file into your browser-based three dimensional world.

7. FINAL THOUGHTS

Since the advent of the Oculus Rift, Virtual Reality is popular again. The open and very active community behind the Oculus Rift have ensured many new application opportunities, among which the development of three dimensional graphics for the browser and special applications for healthcare. According to Mark Zuckerberg, founder and CEO of Facebook after the acquisition in March 2014: "Oculus has the chance to create the most social platform ever, and change the way we work, play and communicate." [26] A critic is Jaron Lanier, who founded the first VR company, VPL Research, in 1983. Lanier warned that the acquisition could have a stultifying effect: "I have seen a lot of cases where big ticket acquisitions seem to actually slow innovative startups down". [27]

We are looking forward to experience applications using the Oculus Rift together with other intuitive input devices such as the Microsoft Kinect and the Motion Leap, we think this will make a big difference for the ease of use and enjoyability of VR systems.

The future of VR will be literally limited by our imagination, what the implications of this new medium will exactly be for our (social) lives is uncertain at this point, but the least we can do is see how it can improve our current communication technology and media use.

REFERENCES

1.Pimentel K. and Teixeira K. 1993, Virtual Reality through the New Looking Glass, Windcrest, NY

2.Oculus Bridge, A utility and javascript library to link the Oculus Rift with the web. https://github.com/Instrument/oculus-bridge

3. Rubin, Peter. "The Inside Story of Oculus Rift and How Virtual Reality Became Reality", blog post on wired.com. May 20th 2014. http://www.wired.com/2014/05/oculus-rift-4/?mbid=social_fb

4.Mazuryk, Tomasz, and Michael Gervautz. "Virtual reality-history, applications, technology and future." (1996).

5.VRML (Virtual Reality Markup Language), WhatIs.com. http://whatis.techtarget.com/definition/VRML-Virtual-Reality-Modeling-Language

6."Why VRML Failed and What That Means for OpenOffice" http://cafe.elharo.com/ui/why-vrml-failed-and-what-that-means-for-openoffice/

7.Kesmai, Wikipedia. http://en.wikipedia.org/wiki/Kesmai

8.Oculus VR. http://www.oculusvr.com/

9.Whiting, Nick. "Integrating the Oculus Rift into Unreal Engine 4", blog post on gamasutra.com. June 11th 2013. http://gamasutra.com/blogs/NickWhiting/20130611/194007/Integrating_the_Oculus_Rift_into_Unreal_Engine_4.php

10.Brunner, Grant. "Oculus Rift's time warping feature will make VR easier on your stomach", blog post on extremetech.com. April 23rd 2014. http://www.extremetech.com/gaming/181093-oculus-rifts-time-warping-feature-will-make-vr-easier-on-your-stomach

11."HMD Specs Comparison: Oculus Rift vs. Silicon Micro Display ST1080 vs. Sony HMZ-T1". August 11th 2012. http://www.roadtovr.com/hmd-specs-comparison-oculus-rift-vs-silicon-micro-display-st1080-vs-sony-hmz-t1/

12.Hollister, Sean. "Inside Oculus: a tour of virtual reality's would-be savior", blog post on theverge.com. March 19th 2013. http://www.theverge.com/2013/3/19/4122388/can-oculus-rift-save-virtual-reality

13.Massively Multiplayer Online Role Playing Game, Wikipedia. http://en.wikipedia.org/wiki/Massively_multiplayer_online_role-playing_game

14. Network Socket, Wikipedia. http://en.wikipedia.org/wiki/Network_socket

15. Lubbers, P and Greco, F. HTML5 Web Sockets: A Quantum Leap in Scalability for the Web. http://blog.chinaunix.net/attachment/attach/24/78/92/5524789255ee40d274b8cf0a98fa6d470b73a945ee.doc

16. WebSocket, Wikipedia. http://en.wikipedia.org/wiki/WebSocket

17. Webrift. http://wwwtyro.github.io/webrift/

18. VR.js. https://github.com/benvanik/vr.js/tree/master

19. Protalinski, Emil. "Google looks to drop Netscape Plugin API support in Chrome, starting with blocking most plugins in January 2014", blog post on thenextweb.com. September 23rd 2013. http://thenextweb.com/google/2013/09/23/google-chrome-drops-netscape-plugin-api-support-to-improve-stability-will-block-most-plugins-in-january-2014/

20. Semantic Web. http://www.ebremer.com/semantic_web

21. Moore, Bo. "Minecraft for Oculus Is Dead. Here's How to Play It Anyway", blog post on wired.com. March 31st 2014. http://www.wired.com/2014/03/minecraft-oculus/

22. "Firebox: A 3D Internet Browser for Oculus Rift" http://vrmonkey.com/firebox-a-3d-internet-browser-for-oculus-rift/#sthash.t5sT341G.dpuf

23. Wiltz, Chris. "The Oculus Rift – Changing Virtual Reality for Healthcare". July 17th 2013. http://www.mddionline.com/article/oculus-rift-—-changing-virtual-reality-healthcare?page=1

24. Mossel, Annette. "Virtual Reality Training for Upper Limb Prosthesis Patients" https://www.ims.tuwien.ac.at/publications/tuw-210234

25. Proceedings of the 6th international conference on disability, virtual reality and associated technologies, 2006. http://centaur.reading.ac.uk/15050/1/ICDVRAT2006_Full_Proceedings_6th_Conf.pdf

26. "Facebook to Acquire Oculus" March 25 2014. http://newsroom.fb.com/news/2014/03/facebook-to-acquire-oculus/

27. Strange, Adario. "Virtual Reality Pioneer Jaron Lanier Talks Facebook's Oculus Deal", blog post on mashable.com. March 28 2014. http://mashable.com/2014/03/27/virtual-reality-pioneer-jaron-lanier-reacts-to-facebooks-oculus-acquisition/