DEVELOPMENT OF VIRTUAL REALITY APPLICATIONS FOR THE CONSTRUCTION INDUSTRY USING THE OCULUS RIFT™ HEAD MOUNTED DISPLAY

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ABSTRACT: *3D visuals are a fundamental part of virtual reality that we often take for granted. Yet when we simulate 3D we often neglect to accurately reproduce the basic concept of depth perception. This document discusses possible applications for stereoscopic head mounted displays within the context of the construction industry and seeks to highlight the technical considerations of using such technologies.*

KEYWORDS: *Oculus Rift, Construction, Simulation, Stereoscopic, 3D, Head Mounted Display, Virtual Reality*

1. INTRODUCTION

3D visuals are a fundamental part of virtual reality that we often take for granted. Yet when we visualise 3D we often neglect to consider binocular disparity. Binocular disparity refers to the difference in image location of an object seen by the left and right eyes, resulting from the eyes' horizontal separation. This is an important factor of depth perception that helps us to truly perceive an environment (**Anderson,** 2000). So it follows that it is the use of stereoscopic display technologies that provides the final piece of the puzzle needed to exploit virtual reality to its fullest potential.

The basic technique of stereoscopic displays involves the presentation of two offset images that are displayed to the left and right eyes. The offset between the two images accounts for the IDP (the interpupillary distance) so that the human brain is provided with the additional information needed to combine the images and thus enhance the perception of depth (Anderson, 2000).

Whilst stereoscopic technologies have been used for some time in virtual reality, they have traditionally been confined to the realm of very high-end and expensive simulation applications. However, in recent years there has been a consumer led desire for such products in entertainment markets such as television, film and gaming. This has significantly driven down the cost of the necessary core display technologies and, just as we have witnessed in the last few decades with mass market 3D gaming products, these technologies will inevitably trickle down to be adopted more widely in professional virtual reality applications.

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Fig. 1: The Oculus Rift at Makemedia, Brighton

The latest consumer product that is sure to influence professional virtual reality applications is the Oculus Rift™. The Oculus Rift is a high field of view (FOV), low-latency, consumer-priced virtual reality head-mounted display (HMD) (Figure 1).

The Oculus Rift has not yet been launched as a commercial product. However, a small number of developer kits have been made available, which has facilitated some early software prototyping, enabling us to explore its potential within the context of virtual reality for construction applications.

For development of such applications, we are using a number of different visualisation toolkits. The Oculus Rift development kit is supplied with an out-of-the-box integration module for Unity 3D™, which is facilitating rapid prototyping. However, we have also successfully developed custom integrations of the Oculus Rift with visual solutions such as Presagis Vega Prime™.

Here at Makemedia, our team has a varied background in military aircraft simulation, games, architecture and construction simulation. This provides us with the perfect set of skills to develop complex immersive environments using advanced stereoscopic visual technologies such as the Oculus Rift.

2. USES FOR CONSTRUCTION APPLICATIONS

Using Unity 3D we have already converted many of our virtual environments to integrate with the Oculus Rift. Figure 2 shows an image from one of our 3D environments, which demonstrates the stereoscopic projection required for the Oculus Rift. The environment depicts one of five 'time-slices' of a construction project that were modeled to aid training scenarios used at the ACT-UK simulation centre.

Fig. 2: Makemedia have produced 3D models of construction sites for ACT-UK and BLSC Australia.

Practically any 3D virtual reality application can be modified to work with the Oculus Rift. Below we discuss specific areas where the Oculus Rift offers an advantage for visualising an environment over traditional display methods.

2.1 Health and Safety Training

Health and safety training provides an ability to 'fly' through a virtual construction site, inspecting building work in close detail in order to provide an opportunity to make decisions in a safe and controlled environment, supported by individual observation, evaluation and feedback.

The enhanced perception of depth provided by the Oculus Rift facilities a heightened awareness of a scene that can benefit the inspection of building work in a virtual environment. Visual cues that were once less apparent on a 2D display are perceived to the same extent that they would be on a real construction site, which should lead to a better correlation between virtual and real world training methods.

2.2 Virtual Maintenance Training

Virtual Maintenance Training (VMT) is a training method that includes computer-based interactive 3D simulations of virtual equipment that replicates the actual real life vehicle or device. Its aim is to safely teach workers to correctly service, repair and maintain equipment.

The accuracy of stereoscopic vision offered by Oculus Rift is particularly beneficial for VMT applications, since it provides a true sense of depth and scale to the virtual representation of the simulated device and its subsidiary components.

As depicted in Figure 3, which shows a VMT application for a junction box repair exercise, this type of application is generally heavily reliant on a 'point-and-click' interface design to select appropriate tools and interact with the 3D objects. From our research it is apparent that such an interface does not translate particularly well to HMDs. However, solutions to such problems are conceivable and are discussed in this document under the heading 'Technical Challenges'.

Fig. 3: A Virtual Maintenance Trainer Application for a Junction Box Repair Exercise

2.3 Cost Effective Alternative to Large Multi-Projector Displays

Large multi-projector curved display solutions are used throughout the construction industry to provide the wide field of view necessary to immerse the user. Such displays can often be extremely expensive to purchase and maintain, with a single projector that is bright enough for large displays costing at least fifty times more than a single Oculus Rift head set (Projector Central, 2013). Furthermore, unlike large display solutions, this hardware can be used in conjunction with a laptop to become fully portable.

The horizontal field of view offered by the Oculus Rift is over 90 degrees, almost completely filling the user's field of view (Land, 2012). This, combined with the head tracking sensor capability, gives an effective 360 degree field of view.

It must be noted that an area where the Oculus Rift does not currently compare to existing multi-projector solutions is resolution. When released the Oculus Rift will support a resolution of 1080p (Oculus VR, 2013). This resolution shared between both eyes equates to an overall resolution of 960x1080 pixels. In comparison, a multi-projector display will often use two to four 1080p projectors within a comparable field of view. However, with the advent of 4K HD display screen technology already coming to market (Bell, 2013), this is an area that is likely to equalize over the next few years (Hopping, 2013).

2.4 Visualization of BIM Data

Building Information Modeling (BIM) is the process of generating and managing data about a building during its life cycle. We are currently in the process of developing applications to visualize BIM data and we see real advantages to using stereoscopic visualization for this purpose.

The Oculus Rift provides a portable solution to a visualization tool for designers, architects, town planners, sales/marketing personnel and construction workers to see a construction at any stage of the build process.

Whilst BIM data 3D models are often geometrically complex, they generally lack important visual features such as surface textures (O'Brien, 1997) that are key in simulating the perception of depth and parallax (the difference in the apparent position of an object viewed from multiple viewpoints) on a 2D display. The use of the Oculus Rift has the potential to minimize some of these deficiencies, due to its realistic representation of depth perception.

3. TECHNICAL CHALLENGES

From our initial prototyping with the Oculus Rift we have uncovered a number of technical challenges that are associated with HMDs in general. These are discussed below.

3.1 Human-Machine Interface (HMI) Considerations

Traditional virtual reality applications generally rely on a conventional user interface design that incorporates a 2D overlay (or Head-Up Display) to provide feedback to the user in text form or to provide additional methods of interacting with an environment. Many of these techniques do not translate well to HMDs for the reasons discussed below.

3.1.1 Decrease in Screen Space 'Real Estate'

User interface elements cannot be positioned near the edges of the screen; once wearing the Oculus Rift these areas are very much in the peripheral vision of the user.

Whilst it is possible to move such elements nearer the centre of the image, this approach has the obvious drawback of obscuring the user's vision of the 3D environment.

We are therefore required to utilize a more creative approach to convey information to the user. An increased usage of recorded speech is a good first step. But in addition, more of the user interface elements need to be integrated into the 3D environment. For example, a virtual smart phone could be utilized so that in the event that a certain piece of information needs to be conveyed to the user, the phone will ring and the user can then take the call in order to be presented with images and text on the virtual smart phone's display.

In summary, whilst user interface design is a challenge, it does bring about some exciting possibilities which could compel us to develop our applications in a way that is actually more intuitive to the user.

3.1.2 No Visibility of the Outside World

A drawback of total visual immersion is the lack of visibility of the external world. An obvious implication of this is that it is impossible to see one's own hands with the HMD on. Conventional VR applications rely on complicated user input devices with many buttons and inputs, such as keyboards, mice or joysticks, and these inevitably become difficult to operate whilst wearing the Oculus Rift.

One simple solution to this problem is to use the head tracking feature of the HMD as the pointing device. When the user wishes to select an object in the virtual environment, he/she can simply look directly at the object then combine this with a single button press or voice activation command to initiate the interaction.

Some more exotic solutions to a pointing device are feasible. For example the Razer Hydra™ is an inexpensive commercially available product that can provide a simplified representation of your own hands in 3D space (Figure 4).

Fig. 4: The Razer Hydra

Depth sensors such as the Microsoft Kinect™ are also possible inexpensive solutions to track hand movement and 3D gestures (Holloway, 2013). High-end products, such as the IGS Glove, are also available to provide full tracking of the hands and fingers (Figure 5).

Fig. 5: The IGS Glove

Currently, the Oculus Rift development kit does not provide an integrated camera. However, whilst at present unconfirmed, it is possible that the final commercial version will include this feature (Verry, 2013). This would certainly open up the possibility of using augmented reality (AR) to help solve the aforementioned challenges. *Augmented reality* is a technique to combine real-world environments with computer-generated sensory input.

Take, for example, an excavator trainer: a conventional simulator would normally use a real cabin combined with a panoramic display to simulate a virtual environment out of the window (Figure 6). With an HMD solution and augmented reality, the real image of the cabin as perceived by the integrated camera could be composited in real-time with the 3D virtual environment.

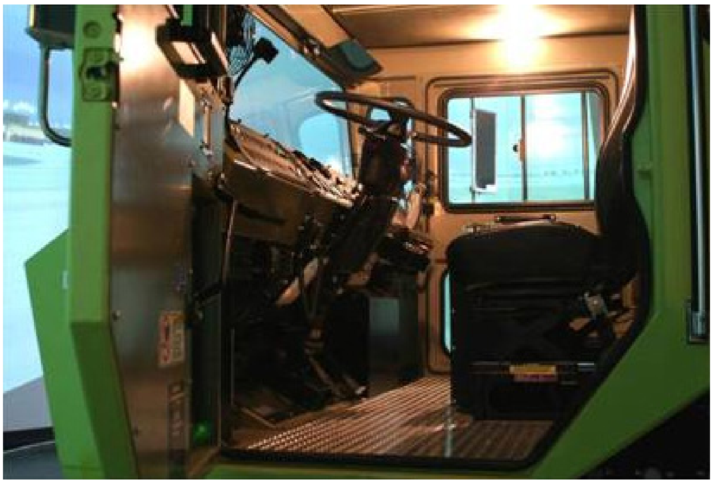

Fig. 6: Cabin with virtual environment projected out-the-window

It should be noted that HMD technologies specifically designed for AR are already available on the market, such as the Vuzix STAR 1200. However, as far as we are aware the field-of-view of this and other similar devices are far less than the Oculus Rift. For example the field-of-view of the Vuzix STAR 1200 is 23-degrees (Vuzix, 2013) compared to the Oculus's 90-degree field-of-view. Such narrow field-of-views will inevitably compromise immersion.

Another example of the use of AR in this context is to facilitate the combination of live trained actors and virtual reality as used by the ACT-UK simulation centre in Coventry (see Stockdale 2010 for more information on the ACT-UK centre).

By using a combination of the Oculus Rift and green screen technology it is conceivable that the user will experience a much more complete projection of the virtual world around the live actors than is practical with conventional curved screen technologies.

The photograph in Figure 7 was taken at the ACT-UK simulation centre and displays the projection screen used to depict the virtual environment. Whilst this current solution provides a wide field of view by the standards of traditional display technologies, it is quite apparent that much of the environment is either provided by a static backdrop or not represented at all. An HMD solution would provide the possibility of rendering much more of the environment as a dynamic virtual representation including the ground and the construction site environment at higher elevations.

Fig. 7: ACT-UK Simulation Centre

4. SUMMARY

Our experimentation with the Oculus Rift is certainly in the early stages, but already we have explored a number of interesting use cases via some initial prototyping.

We propose that the enhanced simulation of depth perception could benefit health and safety applications, virtual maintenance training and BIM data visualisation. In addition it is likely that the HMD can reduce costs by replacing expensive traditional multi projector display technologies with its inherently large field of view and head tracking technology.

There are challenges to user interface design. However, these could provide us with opportunities to enhance the user experience by challenging the software developer to create a more natural user interface than the traditional "point and click" design.

In the future we hope to see further improvements to the hardware specification of the Oculus Rift. Specifically we see the need for improved resolutions beyond HD in order to facilitate the replacement of all existing traditional high-end display technologies. With the advent of 4K Ultra HD displays already coming to the market coupled with the inevitable competition from rival HMD manufactures, this is something that is likely to take only a few years. In addition, we would like to see the inclusion of an integrated camera with the Oculus Rift to facilitate augmented reality application development.

Moving forward we are keen to explore how this technology can benefit the end user. To a large extent we are driven in this regard by the vision of our customers and so our hope is that this paper can spark further debate in order that other uses can be imagined.

5. ASSOCIATED TECHNOLOGIES

Oculus Rift by Oculus VR. http://www.oculusvr.com

Razer Hydra by Sixense Entertainment. http://www.razerzone.com/gb-en/gaming-controllers/razer-hydra

IGS Glove by Synertial. http://www.animazoo.com/content/igs-glove

Unity 3D by Unity Technologies. http://unity3d.com/

Vega Prime by Presagis. http://www.presagis.com/products_services/products/modeling-simulation/visualization/vega_prime/

6. REFERENCES

ACT-UK (2013) *ACT-UK Simulation Centre* [online]. Available at: http://www.act-uk.co.uk [Accessed 17 July 2013]

Anderson, B. L. (2000) 'Depth Perception' in Kazdin A.E (Ed.) *APA's Encyclopaedia of Psychology*, Washington, USA: APA

Bell, L. (2013) *Asus 4K UHD monitor goes on presale in US for $3,499* [online]. Available at: http://www.theinquirer.net/inquirer/news/2279303/asus-4k-uhd-monitor-goes-on-presale-in-us-for-usd3-499 [Accessed 9 August 2013]

BLSC (2013) *Building Leadership Simulation Centre* [online], Available at: http://www.blsc.com.au [Accessed 17 July 2013]

Gorman, M. (2013) *Oculus Rift HD prototype VR headset appears at E3* [online]. Available at: http://www.engadget.com/2013/06/11/oculus-rift-hd-prototype-vr-headset-hands/ [Accessed 15 July 2013]

Holloway, J. (2013) *Oculus Rift + Microsoft Kinect = full-on Virtual Reality?* [Online]. Available at: http://www.gizmag.com/inition-oculus-rift-vr/27701 [Accessed 17 July 2013]

Land, B. (2012) *HMD Specs Comparison: Oculus Rift vs. Silicon Micro Display ST1080 vs. Sony HMZ-T1* [online]. Available at: *http://www.roadtovr.com/2012/08/11/hmd-specs-comparison-oculus-rift-vs-silicon-micro-display-st1080-vs-sony-hmz-t1-937* [Accessed 17 July 2013]

O'Brien, J. M. D. (1997) *Texture and Motion Cues in Slant Perception*, PhD thesis, University College London, London

Oculus VR (2013) *Oculus at E3 2013* [online]. Available at: http://www.oculusvr.com/blog/oculus-at-e3-2013. [Accessed 10 August 2013]

Projector Central (2013) *Christie HD10K-M Projector* [online]. Available at: http://www.projectorcentral.com/Christie-HD10K-M.htm. [Accessed 10 August 2013].

Stockdale, L. (2010) *ACT-UK, Simulating Success* [online]. Available at: http://www.insidehousing.co.uk/simulating-success/6510432.article [Accessed 16 July 2013]

Hopping, C. (2013) *4K screens coming to Android smartphones and tablets?* [online]. Available at: http://www.knowyourmobile.com/google/20832/4k-screens-coming-android-smartphones-and-tablets [Accessed 10 August 2013].

Verry, T. (2013) *GTC Oculus VR Reveals Future of Oculus Rift at ECS* [online]. Available at: http://www.pcper.com/news/General-Tech/GTC-2013-Oculus-VR-Reveals-Future-Oculus-Rift-ECS [Accessed 16 July 2013].

Vuzix (2013) *Vuzix STAR 1200 Augmented Reality System* [online]. Available at: http://www.vuzix.com/augmented-reality/products_star1200.html#TechSpecs. [Accessed 10 August 2013].