# New Virtual Reality for Architectural Investigations

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*Visually decoding and evaluating digital 3D models in proper scale on screen from within 3D modelling software can be quite difficult due to random zoom-factors, Field of View (FOV) and eye height. Motion and interactive bodily grounded examinations are helpful factors that can be enhanced with the use of Virtual Reality (VR). The purpose of this phenomenological study is to address these difficulties of perception of scale by introducing a Virtual Reality Head Mounted Display (HMD) as an exploration tool and outlining possible ways of utilising this tool in architectural teaching. To achieve the purpose findings of perception of scale and distance; level of abstraction; navigation; and simulator sickness will be discussed in relation to architectural investigation in VR. This will be based on the experiences and findings during two workshops with architecture students qualifying their conceptual designs with the VR HMD.*

**Keywords:** *Virtual Reality, Level of Abstraction, Oculus Rift HMD, Perception of Scale, Simulator sickness*

## INTRODUCTION

New VR Head Mounted Displays like Oculus Rift and Sony's Morpheus aimed at the consumer market are presently in development and might result in VR finally succeeding as a wide spread medium. The incredible sense of presence and immersion in the Virtual Reality world will be made available for architectural simulations run on standard workstations and gaming consoles as opposed to previous very expensive setups like CAVEs. This expected availability makes it interesting to explore the potentials of (re)using VR in architectural education as well as for professionals communicating architectural designs to customers or community.

## BACKGROUND AND METHODOLOGY

First time experience with the Oculus Rift VR setup can be very overwhelming and immersive although the model immersed in might not be very photo-realistic or "real". Occluding the real world makes the viewer surrounded completely by the VR environment. This is emphasized when turning the head and the vision doesn't reach the edge of any screen or visual device - the model is all around.

First reactions by most students were expressions like: "Wow this is amazing". The fact that they could actually see large square pixels on the screen due to low resolution on the display screen did not seem to distract or ruin the overall experience.

## *Workshops, exhibition, video recordings and survey*

When dealing with the architectural and bodily experience of the city, VR makes it possible to realise the city's perspectival and spatial reality in real scale 1:1. During the initial workshop with 10 3rd year architecture students (Bohn, Kreutzberg 2014), the VR setup was used to familiarise the students with a route through their newly constructed imaginary city. A few students used the equipment extensively to test different means of navigation and representational abstractions while exploring the 3D city model. An exhibition finalised the workshop, and the resulting 3D city model was available for the public to explore in VR with the Oculus HMD in several sessions during a 14 days period, see figure 1.

Figure 1
Visitor at the exhibition exploring the tower in the imaginary city in VR.

The second workshop, part of a 'Hybrid Villa' semester project with 11 2nd year architecture students, focused on interior space perception. The participants used VR to confirm space and volumes in the initial design phase of a housing project. Students were video recorded while using the VR equipment and interviewed at the same time about experiences and findings.

A survey (made with Survey Monkey) was sent out to participants of the workshops as well as other students who were testing the VR equipment during the same period. 20 respondents answered all or part of the 40 questions regarding perception of scale; abstraction; navigation and simulator sickness.

## *Technical and Practical Setup*

After previous workshops introducing game engines as investigation tools for architectural design (Kreutzberg 2011) we experienced the contradiction of students being very open to learning new digital tools but then not having the time, commitment or support to keep using these new tools in projects after the workshops. It was therefore mandatory to keep the setup and use of the equipment as simple as possible.

The Oculus Rift Development Kit 1 (DK1) HMD was used directly together with SketchUp 3d modelling software through the WalkAbout3D plug-in. The ease of use in connection with SketchUp was really appreciated - no programming was needed, and everything worked plug-and-play. 3D models were investigated directly from within the 3D modelling software or from the stand-alone application.

Practical issues arose during the workshops since only one HMD was available. Moving the equipment between student workstations turned out to be quite cumbersome and instead a laptop was set up as "common investigation station" collecting the necessary files from the central school server and thereby supporting the iterative creative design process, see figure 2.

This setup also solved a problem with screen resolution: When the Oculus Rift HMD is connected to a workstation, it is recommended to duplicate the screens (the HMD and the computer screen) - and as a consequence the computer screen resolution was reduced to 1280 x 800 pixels, making it difficult for students to continue working with their 3D models.

A protected environment was established to avoid unwanted interference: The mouse was locked (right click) and navigating controls were restricted to an Xbox360 controller. Fellow student observers were asked to keep at a distance and not to touch either the person wearing the VR HMD or the equipment. Spoken communication was used extensively during the VR sessions taking the form of interview and was recorded for later reference.

Figure 2
The 'common investigation station' with a chair in front to help stabilize viewing direction.

Figure 3
The Oculus VR DK1 HMD.


Figure 4
Oculus Rift head tracking.

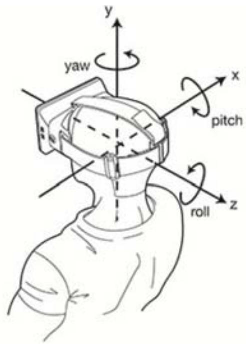


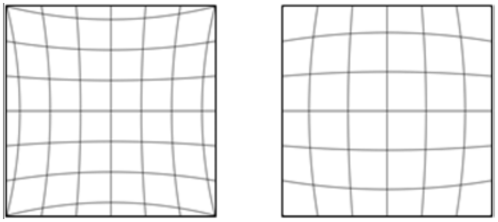

Figure 5
Pinch and barrel distortion.

The Oculus Rift DK1 includes 3 sets of lenses, the "A" lenses for normal to farsighted persons, "B" lenses for moderately near-sighted persons and "C" lenses for very near-sighted persons, see figure 3. Only one student required a change of lenses from A to C. The setup and calibration of the Oculus Rift to fit individual inter-pupillary distances was easy and the resulting distance as well as the eye height was stored in a personal profile. The head mounted devise was easy to adjust for different head sizes but was not very comfortable to wear. To obtain best stereoscopic effect the lenses were often felt to be too close to the eyes. With a display screen resolution of only 1280 x 800 pixels shared between the two eyes the virtual world was very rough and jagged.

The Oculus Rift DK1 hardware included a gyroscope, accelerometer, and magnetometer, see figure 4. The information from these sensors is combined to determine the orientation of the user's head in the real world, and to synchronize the user's virtual perspective in real-time.

WalkAbout3d is an interactive 3d content viewer capable of showing stereoscopic views, working as a standalone program or as a SketchUp plug-in. The plug-in distorts the visible area on the display screen compensating the pinching error created by the lenses, see figure 5.

For the general setup we selected: Controller type (Xbox), screen size (Oculus = 1280x800) and side by side stereoscopy. With the general setup in place user input for each student could be limited to: First scene selection, personal height, inter-pupillary distance and gender (for the avatar).



## PERCEPTION OF SCALE AND DISTANCE IN VIRTUAL REALITY

The layout in most natural environments can be perceived through the use of nine or more sources of information (Cutting, Vishton 1995). These nine cues: occlusion, relative size, relative density, height in the visual field, aerial perspective, motion perspective, binocular disparities, convergence and accommodation have different impact depending on their distance from the spectator. Within close range or "personal and action space" motion perspective, height in the visual field, binocular disparities and relative size are important cues.

Several studies of perception of space and distance in VR have found the impact of the same cues, especially eye height (height in the visual field) and avatars (relative size) to be important influences on estimates of egocentric distances in VR (Leyrer, Linkenauger et al. 2011, Wartenberg, Wiborg 2003).

Our initial experiments with Oculus VR HMD were performed sitting at a table, but the perception of the precisely calibrated virtual eye height did not match the physical eye height and caused loss of immersion, whereas standing up while navigating the virtual world in walk mode felt more natural.The eye height and head movement (motion perspective) were used extensively by students evaluating sizes and distances, see figure 6.

"I remember standing next to a building and trying to assess if the height was appropriate, it worked really well with the HMD. In particular evaluating the tower in the virtual promenade, here I was sceptical about the size (especially the height), but with the Oculus VR HMD I could lean my head back to see the top in a natural movement, and with that movement I saw that the height was appropriate. It seems like you can use this notion of leaning your head back to assess the height of a building just like you do in the real world".

Another student stated: "It was quite amazing to see my 3D model in this way! It provided a completely different spatial understanding of the scale in the space I had created, in comparison to examining the model on the computer screen. And besides this, I believe that the ability to move around in the project makes my continued work much more tangible, since I now have a greater understanding of the project's scale and shape."

Experiments with avatars were dismissed after a few try outs because the sense of immersion in the virtual world was lost with a 3rd person view. Other means of establishing relative size were reference objects in the shape of human silhouettes and textures with recognizable patterns.


Figure 6
Pointing at issues in the 3D model.

Binocular disparities like stereopsis provides depth information when viewing a scene with both eyes and is achieved in VR by utilising 2 virtual cameras placed at the inter-pupillary distance of the user. According to Cutting (1997) stereoscopic depth cues are especially relevant for spatial perception in "personal" space. Students measured their inter-pupillary distance with a configuring utility provided from the Oculus Developer site [1] for accurate stereoscopic viewing.

13 respondents answered questions in the survey about perception of scale in their own model. 11 students (84.62%) experienced different perception of heights and distances viewing their model with Oculus VR HMD compared to on screen in their 3d modelling software. Only 2 students (15.38%) did not experience any difference in heights and distances. One student commented in the survey: "I have discovered many things in my model, which I had never seen otherwise. It was a really good tool to confirm or dismiss ideas - if for example I was in doubt whether my room sizes and ceiling heights were optimal."

11 respondents placed reference objects in the shape of human silhouettes in their model and all of them ascribed these reference objects to have some or great impact of perception of scale.

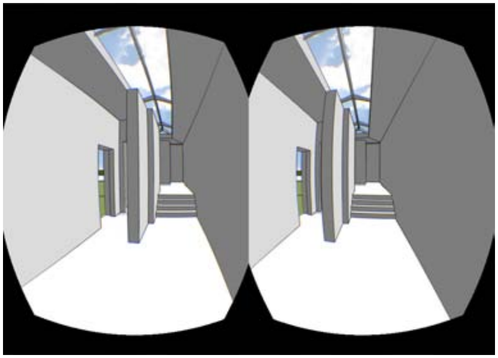


Figure 7
First iteration of a 3D model without coloured texture.

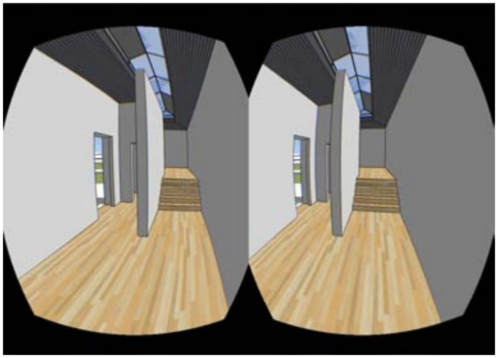


Figure 8
Second iteration of a 3D model with coloured texture.

## LEVEL OF ABSTRACTION

Architects are trained in reading 3D volumes from lines only. Walking inside a 3D drawing, a model without surface detail proved to be sufficient for general observations and the flat coloured white surfaces with hidden line shading worked really well with the low resolution display screen. Several students were inclined to clean up their models to remove unnecessary and disturbing lines from the surfaces.

Shadows would definitely have been helpful in defining volumes and voids, but they were not stable in motion producing heavy flickering and were therefore dismissed. Texture or colour on selected surfaces provided better means of understanding complicated spaces, see figures 7 & 8.

16 respondents answered questions about abstraction in VR. 6 respondents (37.5%) applied colour or textures on selected surfaces of their model and 5 of these claimed that texture or colour on selected surfaces provided better means of understanding complicated spaces. Only one respondent didn't experience any difference in level of abstraction with or without textures.

"It enables a really good understanding of distances, heights and depth and with improvements in future versions we will probably be able to sense emotions and expressions in the model as well."

## NAVIGATION

Navigating in VR with a head mounted display occluding the real world proved to be quite difficult; only experienced gamers felt comfortable with keyboard and mouse navigation blindfolded, figure 9.

Other means of interacting with the VR environment like game controllers, joy-sticks or body interaction with Kinect were initially dismissed, since our setup was planned to be as simple as possible. As described earlier we started out using the equipment sitting at a table. This was reconsidered after a student tried to stand up while navigating, to mimic his own eye height. The benefits of immersion, by matching the physical eye height to the VR eye height and avoiding double horizon confusion (Messing, Durgin 2005), compensated for the slight uneasiness or rather instability of standing up, but made the keyboard and mouse navigation even more difficult. A wireless Xbox360 controller was mapped with all available functions. Holding the navigation device blindfolded in a standing pose worked very well compared to handle keyboard and mouse but using multiple buttons without vision did not. Gamers used to hand held controllers could easily use many buttons for different tasks blindfolded, whereas non-gamers accidently pressed buttons and activated unwanted features.

Initially translation and rotation was mapped separately using one button for each movement, operated with left and right thumbs as in the default controller setup. To make navigation more predictable for non-gamers, the Xbox360 controller was remapped to only support very basic functions, simplifying the navigation to only forward motion and left/right rotation, mapped to one single movable button operated with the right thumb, see figure 10.

Some students then missed the possibility to jump, strafe and move backwards, but accepted the argument of trying to simulate real world movement rather than first person shooter computer game navigation.

18 respondents answered questions about navigation in VR. 10 respondents tried to navigate with keyboard and mouse. 2 (20%) of these respondents had no difficulties at all navigating blindfolded, they also considered themselves as experienced gamers. 7 (70%) respondents experienced some difficulties navigating, they considered themselves as casual gamers. 1 (10%) respondent had great difficulties navigating with the mouse and keyboard blindfolded, and had no prior knowledge of gaming.

13 respondents tried to navigate with the Xbox360 controller. All 13 (100%) respondents were comfortable with using the right thumb for controlling the single button mapped for navigation. Only 2 (15.39%) respondents experienced difficulties controlling rotation and forward movement.

Our experiments show that navigating VR space blindfolded with a fully mapped game controller requires practice, and with improved skills more functions can probably be mapped to the available buttons successfully extending navigation and interaction possibilities.

Figure 9
First tryouts navigating with keyboard and mouse blindfolded.

Figure 10
Navigating the Xbox360 controller with one button.

## SIMULATOR SICKNESS

All benefits of Virtual Reality with HMD set aside, the issues of simulator sickness with the current Oculus Rift DK1 need to be addressed.

Several theories of simulator sickness exist although none of them have highly predictable values as to why it occurs or what triggers it. The most widely accepted theory of simulator sickness is the sensory conflict theory, according to which passive movement creates a mismatch between information relating to orientation and movement supplied by the visual and the vestibular systems, and it is this mismatch that induces feelings of nausea (Reason, Brand 1975).

Figure 11
Extreme and fast head rotation provoked simulator sickness.

Figure 12
The Tuscan World Demo with vivid colours and patterns.

Three categories of factors which are potentially involved with simulator sickness in virtual environments are those associated with the individual, the simulator, and the simulated task (Kolasinski 1995). Some of the sensory conflict issues we encountered during the experiments were hardware or software related (the simulator) and could not be changed or eliminated, they involved latency and lag, see figure 11, binocular display, flicker, distortion correction and screen resolution (Yao, Heath et al. 2014).

The provided Tuscan World Demo, see figure 12, was dropped as an introduction and first try-out after several students experienced severe simulator sickness, probably due to extreme head movements, ascending stairs at high speed and vivid patterns in the model. In the first workshop many of the students experienced simulator sickness and they did not feel comfortable using the equipment and resisted to use it further.

We ensured that new users would be instructed in how to avoid the most obvious reasons we encountered for simulator sickness; keeping their head centred and still when moving forward and especially when moving and changing direction at the same time, only looking around when not moving and avoiding exaggerated, sudden and fast rotations of their head (the simulated task).

18 respondents answered questions regarding simulator sickness. 8 respondents explored the Tuscan World Demo. 5 (62.5%) of these respondents experienced severe simulator sickness, 2 (25%) experienced a little simulator sickness and only 1 (12.5%) respondent did not experience any simulator sickness.

10 respondents only explored their own models. 3 (30%) of these respondents experienced severe simulator sickness, 4 (40%) experienced a little simulator sickness and 3 (30%) respondents did not experience any simulator sickness.

9 (50%) of all respondents experienced less simulator sickness on subsequent sessions indicating adaption and a possibility to reduce simulator sickness by training.

Development Kit 2 (DK2), the newest development version (shipping July 2014) of the Oculus Rift HMD uses a low persistence OLED display to eliminate motion blur and judder, increasing the correspondence among the user's visual, proprioceptive, vestibular, and motor systems hopefully significantly reducing simulator sickness.

## CONCLUSION

The Oculus HMD is definitely a promising consumer market device for displaying and investigating architectural designs in VR. In our VR experiments students experienced a better understanding of room sizes and proportions than in their 3d modelling software on screen. Although plain models with flat shading were sufficient in many cases, applying textures to parts of the models increased the understanding of scale and dimension especially in models with untraditional designs. Human representations inset into the models also helped with reading the proper scale as did other well-known artefacts. Navigation was not intuitive and had to be trained. Finally issues of simulator sickness were partly overcome by restricting the movement and by keeping the sessions to a limited time of approximately 5 minutes.

Our experiments with the Oculus Rift VR head mounted display show great potential even with the low resolution screen and latency problems in the Development version 1 Kit used. Further studies should focus on navigation and interaction as well as integration with different design software. The possibility of simulating natural human movement walking in a 360° tread mill seems promising and could possibly limit cognitive efforts used for navigation. At the same time this would free the use of handheld devices for navigation to only pointing and other interactions with the model.

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