VR or Not VR - No Longer a Question?

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Virtual Reality (VR) software has developed to the point where, for the architect who is averagely technically adept, it can be incorporated into the design process with reasonable effort and costs. For VR to be an effective design tool, it must add value to the design process and should give insights and opportunities not available by other methods. Previous research by the authors reported on the results of an international student workshop which focused both on the workflow (to prepare the architectural models for the new VR systems) and the spatial perception that users experienced. In this paper, we continue to explore the question: "Can low cost VR be an effective addition to the architects' design toolbox, or does it still remain a "far-fetched, high-tech expensive folly?" To do this we are working with a larger group of students, a more developed workflow and we are also expanding this to architects in practice. We will be assessing both the practicality of integrating VR into the design workflow and the spatial perception of the designer when interacting with the model. We are experimenting with additional interface tools.

Keywords: *Virtual Reality, Google Cardboard, Low Cost Interfaces*

INTRODUCTION

2016 has the potential to become a turning point for architects in the use of VR and/or Augmented Reality (AR) in the design process. VR has been on the agenda for a very long time but has never really managed to have a significant impact on the design workflow of a "normal" sized architectural practice. The reasons are quite clear: up to now, a substantial amount investment, both financial for the equipment, complex workflows that are necessary to bring the geometry into the systems together with complex technical settings with a lot of technical issues (e.g. synchronisation of different PC's, projectors etc.) which needs a lot of preparation to get it working reliably. And after all this work, the main benefits were still unclear - at least outside of academia and the Global companies. There has been a considerable amount of research done which is concerned with high cost and large VR installations such as Powerwalls and CAVEs but, for the 'average' small architectural practice these have been of little practical use.

So, until now VR has never been a viable option for 99.9% (or even less) of architectural firms. Most of them would not have considered using VR for even for final project presentations and even less for using it during the design process - mainly because of the reasons mentioned above. Recent advances and developments in low cost VR hardware and software, in particular those that use mobile phones as a computational device, have given all architects and design-

ers the opportunity to use VR as an effective part of the design process. The new changes in the whole system are driven by the interests of the gaming industry and today, this a powerful and economically flourishing industry with a great deal of available resources.

With the new devices that are already available or will be available very soon the "game" is changing and we think that architects should finally make use of this opportunity. With the Oculus Rift Consumer Version, Sony's Morpheus, HTC's Vive, Samsung's Gear and the improved Google Cardboard among others, there is a wide range of extremely low to very low cost VR devices available for the general public. Microsoft Hololens is now available for developers in the US and Canada and also seems to have a lot of potential. In our opinion it is now the right time for architects to rekindle an interest in these systems because they have the potential to add a new level to the design as well as the presentation process. Together with free or low cost software and an easy to use workflow there is the opportunity for everyone who is interested. As in many areas, the car industry leads the way. Car manufactures have been using expensive and complex VR systems as an integral part in the design process for decades and now start to use the low cost VR versions for giving potential buyers an immersive experience in configuring their future car. But architecture is starting to catch up : The Prefabrication - Housing industry is starting to show an interest in these new devices and there are some examples how they make use of the low cost VR and AR systems. The APP Roomle from an Austrian producer is a good example. (www.variohaus.at). Also the new Zaha Hadid project for Graz already uses VR and AR technologies for smartphones - see the "Argos Graz" App to visit the unbuilt project

THE 2016 SYSTEMS

The current research focuses on the use of smartphones with Google Cardboard and the Oculus Rift systems. We used two approaches to bring the 3D geometry models into the VR systems. The first was

to use the game engine software 'Unity3D' to prepare the 3D geometry for the Oculus Rift systems. We also used Unity3D to create Google Cardboard versions for Android phones. Unfortunately, we could not create iOS versions due to Apple requiring (paid) developer registration.

The second approach was to use the 'Kubity'(www.kubity.com). This provides a cloud based service where 3D models are uploaded to a server and prepared automatically for the use in combination of Android smartphones in 2D panorama form and Google Cardboard devices for full 3D. This is a straightforward process where the geometry is uploaded; a QR code is displayed on the PC screen as a link to your own model in VR. The QR code is scanned from the smartphone app and the model is downloaded. That sounds perfect and in some ways it is, but it comes with a number of disadvantages. There is no collision detection implemented yet and there are some problems with the movement inside the models - we will discuss this problem in more details later.

However, development in this field is very fast and we can assume that there will be updates to 'Kubity' that will resolve some of the known issues - e.g. a recent update adds the possibility to use the open wavefront obj file format. Currently the service is free, but it might be expected to be monetised at some point. There are probably also some issues of data security when architects plan to use this app in the design process that are more important. We assume that there will be a certain reluctance to upload preliminary designs to an unknown server when you work as an architect on a project or a competition. This time it was no issue for the models we used.

THE TASK FOR THE STUDENTS

As last year, we wanted the students to model their own flat using either SketchUp or other modelling software; the assumption being they would have a good knowledge of their own living environment. Because of that they are very good candidates for experiencing these "real world" environments in the VR

systems and give feedback about their experience using them.

To give an extra 'virtual' dimension to the research process we added two small architectural built projects that we had received from an architectural practice so the students could also experience projects unknown to them. These projects were two houses in rural locations in the UK (see Figure 1). To keep the scale similar to the student's flats, only part of the houses were modelled. Unfortunately the designers themselves could not be part of the workshop but provided feedback on the spatial experience that it gave them.

Figure 1
Modelled interior of unfamiliar house (Design by Darren Ward).

THE WORKSHOP THIS YEAR

The workshop was structured similar to last year and was again taken by Masters and undergraduate students from TU Graz (Austria) and the University of Liverpool (UK). During the first phase in Graz students modelled their own flats using SketchUp. During the second phase in Liverpool, students developed their models further and then tested them using the VR equipment. They completed a questionnaire which recorded their experience and accuracy of spatial perception. One difference this year was that the VR software/Google Cardboard integration had developed rapidly since last year. This resolved some, but not all of the problems encountered.

PROBLEMS, POSSIBLE SOLUTIONS AND THE QUESTIONNAIRE

We experienced some of the same problems as last year (see "New Interfaces - Old Models" Dokonal, Knight, Dengg, 2015) together with some new ones.

One of the main problems we encountered last year was the import and translation of the SketchUp models into Unity3D. We were looking at the use of Okinos Nugraf as a means of translating/preparing the files, but this has been superseded by the inclusion of a direct SketchUp importer in Unity itself. This meant we had far fewer problems in bringing the geometry into the systems, both with Unity and 'Kubity' which also directly translated for Cardboard. The need for a well disciplined and constructed 3D model remains which some of the students found to be a greater challenge than VR itself. Itself, but all students quite quickly were able to experience their models virtually.

The problems this year were not in the model import, but in navigating around the models in VR. This was partly hardware caused by the first generation Google Cardboard's unreliable magnet switch and partly software when using Kubity. To move forward inside "Kubity" you have to use a tab on the screen of the smartphone - rather complicated with the first versions of Google cardboard we had available for the workshop. To use the apps produced by Unity3D we had to use the magnetic switch to move inside the VR model. The magnetic switch turned out to be very unreliable - with different Smartphones we had different results. The original plan was that everyone should use her or his own phone. (Kubity is also available for iOS)

It is worth restating that one of the main goals of the exercise is that students can use the workflow we developed during these workshops to use the VR app as a design tool for their own projects in the future. Having a lot of problems to move inside a VR model is not very helpful in terms of immersion and leaves the user with an experience of frustration rather than immersion.

We had a great deal of discussions how to overcome these kind of problems. One of the possible solutions we called the mechanical finger because we discussed that the simplest way would be to have a mechanical finger which does the tapping on the screen when you have the VR device on your head - ideally connected to the feet. It was not possible during the short workshop to get all the necessary parts for our ideas to build it. The workaround for the limited time available during the workshop was to use only the smartphones that were working more reliably with the magnetic switch.

The result of the questionnaire is not significantly different to previous results and might also have been influenced by the fact that we severely struggled with navigation problems. Therefore we could directly compare results with last year's workshop, the same questions were asked again; the results were almost identical (2015 figures in brackets):

- Viewing in a VR system helped to understand the design better 95% (94%)
- Spatial perception was much clearer and closer to reality than a 3D CAD model 96% (94%)
- They could easily orientate themselves in the flats 92% (90%)

Where the survey differed was in two areas. Firstly, the question about the 'atmosphere' created was much more positive. This is due to being able to create much more realistically rendered models than the 'white card' materials that we used last year and the need for more detail/materials was again reduced as a requested improvement. However, the lack of realism in the movement methods in Kubity (i.e. lack of collision detection and gravity) meant that some respondents felt that this affected the degree of immersion in the experience.
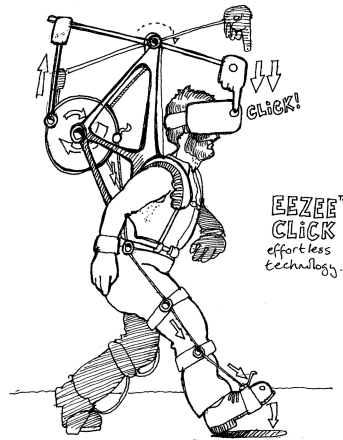

Figure 2
Eezzee click concept (with apologies to Heath Robinson).

EEZEE CLICK - THE "MECHANICAL FINGER"

The discussions during the workshop inspired the thought that the Cardboard VR device would gain a lot in terms of immersion (besides all those other aspects like level of detail etc) if a naturalistic navigation methods could be devised - i.e. moving freely inside the virtual world just by walking.

As we wanted to have it as a low cost / DIY version within our 'workflow for everyone' all the sophisticated systems using cameras and other tracking devices were not an option. We wanted a solution available on a student's budget and within their capability to construct. Moreover, we didn't want to limit our walking range like the Oculus Rift (Tracking area 1.75m x 4m) and the HTC Vive (5m x 5m) and the physical cage of CAVES, respectively. This is one of the biggest advantages of our system.

Thankfully also Google seemed to have realised that the magnetic switch was not reliable enough and the second version of the Cardboard viewer replaced the magnetic switch with a simple kind of mechanical finger extension to make it possible to tap on the screen with the device on.

Our mechanical finger only had to synchronise feet movement to a tap on Cardboard and not on the

smartphone itself which reduced the risk of the infamous Spiderweb App (broken screen) significantly. The solution was to equip Cardboard with a solenoid and connect it to switches on both feet. To keep it simple we started with a wired version.

At the moment the solenoid is mounted to the Google Cardboard with cardboard and Gaffa tape and the switches are pinned to the soles of both shoes of the person using the device. A 12 Volt battery pack produces the energy for the solenoid. The circuit is wired in such a way that the solenoid is pushing the cardboard tab whenever the person puts both feet on the ground. That was the easiest way to manage the movement without any additional electronics - there are other options in rewiring that we will discuss later. One of the problems with that circuit is that if the person stand with both feet on the ground the tab is pressed constantly. This is no problem for the Virtual world - you simply stop and stand like in the real world. But it is a slight problem in the real world because the solenoid is working constantly and therefore overheating.

FIRST TESTS WITH THE "EEZEE CLICK"
The result of our mechanical finger is quite stunning - it simply works. It makes a big difference to be able to move in the virtual world by just walking in the real world. But you should make sure that the real world is big enough to move inside without banging your head.

Still there are some problems in movement using the Kubity app. First of all there is the problem of a lack of real gravity or physics. This means that you cannot fix the eye level to a constant height that equates to eye level. So if you look up or down during walking you end up either flying up in the direction that you are looking or digging in the ground. Whereas flying is sometimes quite useful it is not so nice to end up underneath your model. Another issue is that there is no calibration for the width of any step inside the VR model when you use Kubity at the moment. It worked quite well with all the models we tested but at the moment we would have to rescale

the model and re-upload it to Kubity if we would want to do any changes. This should be no problem when we use Unity3D to produce cardboard apps out of the geometry but this has yet not been tested fully.
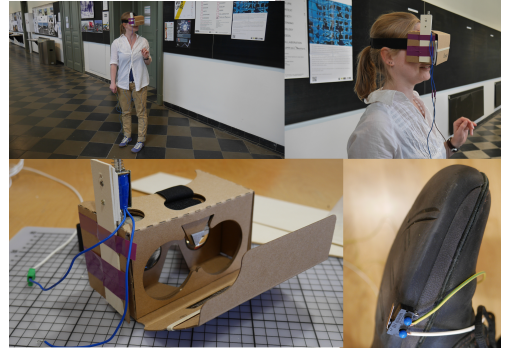
OUTLOOK FOR "EEZEE CLICK"
We discussed several ideas what new possibilities our enhanced device could have with different settings - some of them are not really within architecture.

At the moment with our serial circuit we can only walk not run. Whilst this is no problem to experience a house or a flat in VR for normal purposes - normally you do not run in a flat - it might be interesting for special tasks inside houses. For example, if you would want to test the design of an escape route in the Virtual world you should be able to run. Nobody walks away from a fire. Being a software for the gaming industry Unity3D offers many opportunities for fire and explosions that you can script as events into the geometry. So this could be an opportunity to test the ability of different groups to escape a certain geometry in a certain time (But make sure that you have enough space in the real world...)

Another situation for the use of running in the Virtual Model would be the experience of a city model like a jogger which also gives a different experience

For all these cases we would need to be able to switch the circuit to parallel mode which should

Figure 3
Eezzee click test set on Google Cardboard second edition.

also be possible within our low cost approach. This switching of navigation modes is possible by creating on onscreen interface that would allow the choice of walk/run/Superman modes. This is planned for the next version.

A DIFFERENT INTERFACE APPROACH - XBOX CONTROLLER

The second interface method used a standard Microsoft Xbox controller. Whilst this removes the common problem of the user being able to move the head though 360 degrees whilst using a static keyboard, it required modification to allow a natural walking movement.

The controller is supported by the Unity Interface controller and by Android smartphones, so it was a simple matter to map two buttons to a script which moved the camera one step per activation. Two push buttons were installed on the heels of the users' shoes, and the wires extended to the Xbox controller. The Xbox controller was attached to the Android smartphone with a USB OTG cable. If the user wants to move by 'walking on the spot', this 'walking' movement is achieved by alternatively raising and lowing each heel in turn. Turning is a matter of swivelling on the balls of the feet. It is also possible to walk naturally, but a 'second' is required to prevent accidents such as walking into physical objects.

COMPARISON - 'EEZZEE CLICK'(TM) AND XBOX CONTROLLER

There is no doubt that the simplicity and almost low-tech approach of 'eezzee click' enables anyone to view their designs in a VR environment with a minimum of both time and financial investment. There are currently limitations to Kubity, but this is to be expected in a new application. Of more concern is the data security issue of sending (and possible storage) of potentially sensitive design data on a remote server. However, as 'eezzee click' can also be used with Unity (by creating a native Cardboard app) there is also

The Xbox controller method allows for more flex-ibility and adaptability that 'eezzee click'(TM), but is more complex to initially setup. The advantage of using Unity is that it has a full physics engine that allows more natural movement and interaction with the virtual objects, but again, these require setting up

BACK TO THE OLD DAYS - THE EXERCISE BIKE WITH HMD DEVICES

In working on this project it was also decided to revisit the early VR work, particularly the exercise bike. Some of the problems encountered on this can now be resolved because of advances both in the flexibility and capability of the software and the lower (or free) cost of professional quality game authoring. One of the main problems with original bike was the handlebar movement which was achieved by adapting an old Microsoft mouse using gear wheels designed for radio controlled models. The problems arose not in the physical side, but in a lack of flexibility in configuring the software. Small movements were fine, but anything more than 45degrees meant rotating the handlebars a full 360 degrees - not a natural movement. With the flexibility of Unity3D, it is now possible to correct these and, when coupled with the use of a HMD, produce a much more natural and immersive experience.

To use the exercise bike as an interface would be especially be great for experiencing city models by cycling through them in the Virtual environment - and you don't have to be afraid to crash into a wall in the real world. We are still working on that and will be able to give you an update in August.

CONCLUSIONS

Although we still experienced several problems during our workshop and the following experimental sessions the potential of the use of especially the lowest cost smartphone based HMD is very obvious to us. Smartphones are ubiquitous today and the costs for the HMD devices very low - sometimes they are given away with the phone. Companies already see the potential for clever presentations - see introduction. Students took to the creation of VR and use of the VR

models with comparative ease. All produced models and were able to see how it could be easily integrated into the design workflow. Some tried this by revising and re-visiting their models in the classic circular design>test>revise scenario. This was largely achieved on their own laptops with their smartphones and it was only when the Oculus Rift was used that a higher end computer was required. Most of the participants indicated that they would at least try this on their next design project and a smaller number were very enthusiastic.

Bringing together free or low cost software, some carefully selected cheap components, some ingenuity and an easy to follow workflow VR bring added value in the design process. In our opinion VR in the design process will be no longer a question, it will be a reality soon - for students and for the average architectural firm, VR will be a valid tool in the designers toolbox.

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