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The Right Bike at The Right Time : a brand new (old) interface for VR

Introduction

Recent advances and developments in low cost VR hardware (e.g. Head mounted displays HMD), in particular those that use mobile phones as a computational head mounted device together with recent software developments, have given architects and designers new opportunities to use VR as part of their toolbox. With the continuing rise in interest and availability of VR seemingly in all sectors of life, low cost VR interfaces start to be of increasing relevance to architecture. 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. This paper combines a reappraisal of an older project and revises/updates it with the findings of more recent work and tries to address the old problem of "using the right tool at the right time".

Developments in display and tracking technologies continue to draw headlines, but for architectural use, the way we interact and interface with the virtual space is of equal, if not greater importance. Our conjecture is that to experience a virtual space in a believably immersive way, we should be able to navigate it in as natural manner as possible - using a mouse or proprietary controller to experience architecture is only a partial and often unnatural solution. Ideally, users should be able to replicate their natural movements in the virtual world.

The project to use a "mechanical finger" (Dokonal, Knight, Dengg 2015) to translate the movement of feet walking in the real space into the virtual world turned out to deliver very promising results.

Figure 1 : eeZee Click concept diagram

The main advantages of this very low tech version was that it was completely independent in space – there was no setup with a limited tracking area necessary – the system can be used everywhere the limits are only the available real space and the possibilities of the smartphones. Neither the limitation of cables tethering the user to a fixed computer nor the rather limited tracking areas of other HMD systems are an issue here. Additionally, eeZee click used only the basic sensors in the smartphone so the problem of different smartphones behaving differently was overcome. Gaze determines direction of navigation i.e. whilst wearing the Google Cardboard headset, the direction of travel is determined by where the user is looking. The sensors for the movement were attached to the users' shoes. It was really striking that this very low cost idea gave a much better feeling of immersion then walking by pressing a button on your HMD device or being transported by staring into a corner. We used the system mainly for interior spaces but we discussed the possibility to use it also in an urban setting. During our first attempts, we found out that walking a city is very effective but sometimes it would be good to be able to move a little faster – such as using a bicycle.

It seemed appropriate to revisit the nAVRgate project from 1999. (Knight and Brown 1999-2001) The Project was an attempt to use a modified exercise bike to be able to cycle round urban environments in front of a projected screen. It took inspiration from Jeffrey Shaw and the Legible Cities project (1988), but constructed in the spirit of low cost/home brew computing. Users used a familiar metaphor and 'rode' the bike whilst sitting in front of a large projected image which extended beyond their field of view. They were, within the restrictions of the screen size, able to move their heads to alter their view, but it was a 2D image which naturally reduced the immersive effect. More seriously, due to physical movement scaling problems (caused by a lack of configurability in software drivers) the handlebars in a rather less than natural manner requiring 90 degrees of movement for only 45 degrees on screen. The system used the proprietary games engine 'Unreal' to generate the environments which was good for the time (and exceeded user expectations), but current software has advanced significantly not only in terms of quality of real-time rendered graphics, but also in the degree of flexibility and customisation options. Despite these problems, it was very successful in terms of the overall degree of immersion that users experienced compared to other methods.

So, the idea was to combine the mechanical finger idea with the idea to use an exercise bike, taking advantage of more recent software configurability and more recent technology. The idea of riding a real bike in real space with HDM devices was quickly abandoned – we already experienced with our original mechanical finger test that the real world can have rather hard boundaries. The exercise bike idea was much safer idea. So the main problem was to bring the micro switches from the shoes to the bike and to define the speed of movement triggered by the switches. To give a natural feeling we wanted the bike to move at a rather leisurely pace through the cityscape.

Additionally, we wanted to attempt to establish a gear shift possibility so that we can change the pace of movement in the virtual world but still keep the same speed of pedal movement in the real world, however time constraints meant that this has been deferred to the next (fine tuning) stage of the project. So our interest in natural interfaces at a low cost price continues. Whilst there are commercial devices such as the Virtuix Omni, these are priced at a level which falls outside the definition of low-cost. We have revisited nAVRgate and used our experience of more recent work with an ultra-low cost walking interface that has proved successful. This again was in the spirit of DIY/homebrew computing. This paper reports on the updating of the original bike with the newer technology that allows some of original problems to be overcome. Rather than using a projected image, the revised system is designed for use both with Google Cardboard and more high-end devices in the form of the HTC Vive. In combining these projects, our aim remains the same – the creation of an accessible, low cost VR environment in the spirit of the home-brew computing pioneers. The advantage we have today is that it is relatively easy to ‘upgrade’ this with the use of commercially available HMDs.

The eeZee click system

The system presented here comprises of two separate but linked modules. The first part developed was the walking interface which tested the natural, untethered walking metaphor. In its unmodified state, the Google Cardboard headset requires the user to repeatedly press a button to move. In reality, the button is a simple lever with a conductive end which simulates touching the smartphone screen. Our system added a 12v solenoid to the headset which is activated by micro switches mounted on the user’s shoes. Moving the feet in a natural way activates the solenoid, ‘tapping’ the screen and creating moving the virtual environment. In the spirit of the materials of the headset, first version used a cardboard mounting system and a less powerful solenoid that the second version. One problem encountered was the amount of heat generated by the 12v solenoid, so in the final version, a more rigid mounting system was used with a heat sink. The drawback of this was that it was considerably heavier and in reality the solenoid was too powerful.

image 2 : eeZee Click Cardboard HMD

The cycling interface is a development of the original NAVRgate system (Knight and Brown 1999-2001) which had some significant disadvantage largely caused by the lack of suitable low cost resources when originally developed. The original system used a modified optical mouse circuit board (modified with a hacksaw to separate the X and Y movement components) and the movement was achieved through a series of gear wheels which activated the optical sensors. The handlebars steered in the Left and right in the X axis and the pedals moved forwards and backwards in the Y axis. In eeZee click, the user moves in the direction in which they are looking, removing the need for the handlebar movement. In the spirit of eeZee click, the forward movement is activated by a micro switch mounted on the frame. A battery pack (also frame mounted) completes the system.

image 3: revised naVRgate bike

For the complete system, the user is fitted with the foot switches (using mapping pins to fix the switches to shoes), the battery pack is placed in a pocket and the headset is connected to a power connector on the headset allows a quick change between walking and cycling.

image 4 : user using eeZee Click

Unity3D was used to create the environment with two scenes containing the same 3D models. The only difference between them was the slower speed of movement to differentiate between ‘walking’ and ‘cycling’. Currently, the switch between the two modes is manual, in final system, it is planned to have an automatic switchover.

For testing, we used a mixed group of students from both TUGraz and University of Liverpool. They had created models of their own student accommodation – environments with which they are familiar. They used both the eeZee click system and Google Cardboard and propriety software on an HTC Vive which used teleporting as a navigation metaphor. For eeZee Click, Google Cardboard application files were created on Unity and the students used their own mobile phones as viewing devices. During the workshop, we had no time to experiment with different speeds of movement, but this is easily achieved in Unity.

HTC Vive system

The HTC Vive represents the high cost end on the VR headset market and is used here as comparator to Google Cardboard used with eeZee click. Having two tracked controllers, it uses a ‘teleport’ metaphor for navigation where users select a visible point to move to. The user moves to that point with the screen rapidly fading as the move happens to prevent motion-sickness. An application called Symmetry was used as it loaded SketchUp files natively which removed a level of complexity (i.e. a dedicated gaming environment such as Unity was not required). The students viewed their apartment models plus a larger scale urban environment.

Survey

We recorded their comments in a survey with questions relating to how their experience of the real apartment matched the virtual world, how realistic the navigation felt, degree of immersion and any motion sickness experienced.

The survey results confirmed that eeZee click gave an increased level of immersion and that the navigation metaphor was natural. Some of the comments were more related to other aspects of the system (e.g. the capabilities of a mobile phone to display a complex VR environment smoothly) whilst another “*It's difficult to suggest possible improvements as it would likely defy the idea of being a low-budget VR-System*.” is more accepting of the low-tech nature of the system.

The bike had slightly more critical results which suggest that more fine-tuning is required. Although the speed was increased over walking, movement was not sufficiently fluid to be considered natural. In the original nAVRgate system, the handlebars controlled the direction of travel – this was replaced here with fixed bars and gaze directed movement. Some users commented that this felt slightly unnatural and was a minor distraction in that they felt the bars should move. So, whilst the degree of immersion was still increased over the standard

Cardboard, one user commented *"during cycling the cardboard was shaking quite a bit, also the cycling speed is very slow which is giving the impression of not really moving forward, it is a bit strange to move your head and not be able to steer"*. So it is clear that the original naVRgate metaphor of steering is considered more natural. However, this would not be possible using the current eeZee click as it would require the adaption of a low cost Bluetooth games controller to add a third level of control (gaze for view direction, Cardboard click for forward movement and Bluetooth for direction control). This may form part of the next stage of development.

Discussion

The questionnaire confirmed informal feedback that walking in eeZee click was natural and easy to adapt to. Users could either walk using real steps (although a minder was required to prevent accidental collisions with the real world) or, more commonly, they walked on the spot. The exercise bike was not quite so successful and needs more work, but is fine tuning rather than a wholescale rethink. It is now clear that separate models are required for walking and cycling

With regards to the headset (which was common to both walking and cycling), some commented that the weight of the solenoid on just one side of the headset made for an uncomfortable experience particularly given the rather basic nature of the Cardboard headset with no padding. The noise of the solenoid activating was also commented on as being distracting by some and valued by others who found that the sound of the solenoid gave them an almost physical connection with the virtual movement.

Users quickly adapted to the teleport navigation of the Vive although the learning and familiarisation period was considerably longer than eeZee Click.

Conclusions

Given that eeZee click cost a total of £30 (excluding a mobile phone which nearly everyone has and the exercise bike from naVRgate which had originally recycled from a charity shop) and the Vive is nearly £900 and needs a very powerful computer, our faith in the effectiveness of ultra-low cost VR systems has been vindicated. There is no doubt that the Vive offered a much more 'luxury' experience (in the same way that an up-market car is more luxurious than a budget model), both get the job done but in different ways. System such as eeZee click democratise VR and make it a genuinely useful tool in the design process.

Outlook

There is still a lot of research necessary to fulfil the initial goal that we had in mind to provide a platform for every architect to use VR as an additional design tool in the design process. The idea is that using this kind of software should be as easy as using any other App on the smartphone – no need for special software skills. Having a template in unity with readymade scripts that produce the geometry as an App to be used in the smartphone seems to be very promising. Our students had no special software skills and most of them used Unity for the first time but it turned out to be no problem for them – they all managed rather quick to produce the app out of their geometry – although they had different filetypes for input. We had models from Archicad, Sketchup, Rhino and Revit. A bigger problem are software updates and software versions. For example, it turned out that different versions of the Android APK's behaved differently depending on the version of Android that was running on the smartphones and we spend a substantial amount of time to overcome these problems. The eeZee click system itself has still room for improvement. At the moment we are working with google cardboard systems and the solenoid mounted on top of them. A more customized version of cardboard tailored to the eeZee click system will be a possibility for the future. Then we can position the solenoid in the middle of the HMD and avoid having to much weight on one side. Additionally a customized belt that contains the battery pack and oversized overshoes that you can use with your normal shoes are concepts that will make eeZee click quicker and easier to use.

For the bike the problem of "the right speed at the right time "still has to be solved. On the one hand it will be quite easy to produce Unity templates with different sizes of movement on the other hand there is no solution yet to "change gear" in the virtual world – you would have to change to a different version of your geometry app. A combination of the eezee click movement and the teleporting feature sounds promising because sometimes you don't really want to cycle in real speed through the city – too much exercise….

So we still have several problems to solve but eeZee click and the bike has the potential to become a valuable tool for anyone designing in the field.

bibliography

Anette Kreutzberg (2014) *New Virtual Reality for Architectural Investigations*, Thompson, Emine Mine (ed.), Fusion - Proceedings of the 32nd eCAADe Conference - Volume 2, Department of Architecture and Built Environment, Faculty of Engineering and Environment, Newcastle upon Tyne, England, UK, 10-12 September 2014

Dokonal, Wolfgang; Knight, Michael W. and Dengg, Ernst Alexander (2015) *New Interfaces - Old Models*. Martens, B, Wurzer, G, Grasl T, Lorenz, WE and

Schaffranek, R (eds.), Real Time - Proceedings of the 33rd eCAADe Conference - Volume 1, Vienna University of Technology, Vienna, Austria, 16-18 September 2015, pp. 101-106

Freitas, Márcia Regina de and Regina Coeli Ruschel (2013) *What is Happening to Virtual and Augmented Reality Applied to Architecture?,* Open Systems: Proceedings of the 18th International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2013) / Singapore 15-18 May 2013, pp. 407-416

Knight, Michael and Brown, Andre (1999) *Working in Virtual Environments through appropriate Physical Interfaces*; Architectural Computing from Turing to 2000 [eCAADe Conference Proceedings / ISBN 0-9523687-5-7] Liverpool (UK) 15-17 September 1999, pp. 431-436

Knight, Michael and Brown, André (2001) *Towards a natural and appropriate Architectural Virtual Reality: the nAVRgate project*. Past, present, future. Proceedings of the Ninth International Conference on Computer Aided Architectural Design Futures [ISBN 0-7923-7023-6] Eindhoven, 8-11 July 2001, pp. 139-149

Dokonal, Wolfgang, Knight, Michael and Dengg, Ernst (2016) *VR or Not VR - No Longer a Question?* Herneoja, Aulikki; Toni Österlund and Piia Markkanen (eds.), Complexity & Simplicity - Proceedings of the 34th eCAADe Conference - Volume 2, University of Oulu, Oulu, Finland, 22-26 August 2016, pp. 573-579

Dokonal, Wolfgang; Knight, Mike; Dengg, Ernst; *VR or not VR – an eeZee question*, p. 831-837. In: XX Congreso de la Sociedad Iberoamericana de Gráfica Digital [=Blucher Design Proceedings, v.3 n.1]. São Paulo: Blucher, 2016. ISSN 2318-6968, DOI 10.5151/despro-sigradi2016-777