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Design Interfaces with VR

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Virtual Reality (VR) is maturing as a technology. Now that mainstream head-mounted displays (HMDs) are consumer-affordable, the space of application development has begun in earnest. Some of this development transitions existing applications (e.g. computer games) to work with a 3D tracked interface while others explore completely novel and innovative uses of VR.

The idea of using VR in architectural practice has a long history. As a tool with the potential to allow 3D visualisation at 1:1scale, the use-case for architectural visualisation has seemed natural and obvious since the early days of the technology.

However, the realisation of this idea was not initially straightforward. In 2000 UCL built a CAVE-like VR projection theatre – this is a 3m x 3m room where three of the four walls and the floor are stereo displays, viewed through tracked stereo glasses allowing perspective-correct stereo views. This was driven by a state-of-the-art SGI computer, many times more powerful than any standard PC (and about 20 times the size). However, despite this vast graphics processing power, most architectural models, could not easily be adapted to this new technology. These models had been designed for accurate renderings of detailed geometry. Twenty minutes of processing with standard computer graphics applications on a desktop PC could produce a beautiful rendering of a view into this model, but VR demands real-time frame rates (ideally at least 60 frames per second) and the models were simply too large and detailed for this.

These tensions between designs for single viewpoint renderings and designs for real-time rendering are now better understood, and advances in both graphics hardware and software have improved this situation. However recent trends in consumer VR towards standalone headsets means that simulations are now driven by the same graphics processors that drive the mobile devices in our pockets.

Aside from these technical hurdles, cost has been the main contributing factor to the relatively slow uptake of VR as a tool for exploring design, but now that we have affordable devices available, what are the factors that still hinder progress?

LOOKING BEYOND THE TECH

To examine this, it is important to consider the technological perspective; but it is not just the tech problems that need to be resolved. The design of useful VR tools will come as much from the designers who want to use VR as from the engineers who create that possibility. In the context of architectural design, the requirement is for VR interfaces that allow architects and designers to do useful work, and not just the walkthrough-type simulations that are most easily facilitated. This requires insight into the design process that both assists the intuitive performance of a range of "typical" tasks and does not stifle the ability to take novel and innovative approaches.

At DC/IO 2020, Aish [Aish 2020] discussed the technological transitions that have taken place in architectural practice over recent decades. Firstly, the transition from 2D drafting to BIM, then latterly to higher-level topology representations. While the former transition is considered positively, by eliminating many inconsistencies and ambiguities in interpretation of 2D drawings, it does so by constraining possibilities and channelling design decisions according to the implicit constraints of BIM. Topology modelling is presented as a less constrained tool that still maintains the advantages of BIM.

Similarly, VR is not a modelling tool in and of itself. Rather it provides a new means for the architect to interact with their design. How we design these interfaces is critical to their success as tools. Even with a perfect VR (or AR) display, how should we interact with it? It is necessary, but not sufficient, to understand the types of activities supported by, for example, BIM or topology modelling. However, designing interfaces that attempt only to translate existing software and methods to the VR domain will do a disservice to the creative potential that VR can offer.

APPEAL OF VR

What is it about VR that is useful to architectural practice? One of the benefits of VR over other interfaces is the ability to experience a space, whether this space represents a house, a railway station or a whole city. While architects are trained to both represent and interpret space through a variety of design media (e.g. sketches, engineering drawings, CAD models), VR adds the ability to directly experience that space. Additionally, as a means of communication with clients, who mostly lack the ability to interpret abstracted representations, VR allows the direct communication of ideas, and limits the scope for costly misunderstandings.

This is not to say that VR is a perfect solution. Even with the most powerful graphics processors, capable of rendering complex geometry with realistic lighting, there remain some fundamental challenges. Firstly, and most importantly, is the problem of navigation in VR. To experience a design, it is necessary to move through it and explore from multiple perspectives. However, navigation through space in VR can give rise to undesirable side-effects of disorientation, dizziness, and nausea, commonly referred to as simulator sickness [Dużmańska et al. 2018]. This phenomenon is principally caused by the disconnect between our visual and vestibular senses when we move *virtually*, that is using a controller or joystick to move rather than *actually* walking through the space. In other words, our eyes see that we are moving, but our body does not receive the corresponding vestibular signals that it is moving. In this respect we can think of simulator sickness as the converse of motion sickness (where we receive vestibular cues in the absence of visual cues).

To avoid this problem, many VR simulations allow a teleport navigation mechanism. This circumvents visuo-vestibular sensory conflict, but reduces our capacity for path integration (our ability to estimate our current position in relation to a starting point based on the sum of our accumulated movements). Path integration relies on the sensory inputs (e.g. optic flow) caused by our movements. Teleportation, in removing the conflicting cues that can cause simulator sickness, also reduces our capacity to know where we are. Furthermore, teleportation disrupts our experience of moving through a space, a critical aspect for an architectural evaluation.

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Of course, there is another obvious way to avoid both simulator sickness and the disruptive effects of teleportation: *actual* movement is also possible in VR. Consumer VR headsets will track users within spaces as large as 15m x 15m (if you have a space this big available). Provided that you walk and turn through your simulation without any virtual movement, then the vestibular and visual sensory flows will match, and you will have the full experience of moving through the space (notwithstanding staircases or other vertical movements).

HEADSET RELUCTANCE

While navigation problems derive from inconsistencies in perceptual inputs, social factors can be seen as the issue behind other problems. HMDs socially isolate the wearer from people around them. Indeed, people might reasonably maintain a distance from the HMD-wearer for fear of collisions. On the other hand, the HMD-wearer might experience a social pressure to remove the headset and engage with the real people around them. This is especially the case for new users of HMDs who, having donned a headset for the first time, are left surprised by how much this cuts them off from the real world and are therefore unsure what cues they should look for to stop exploring the virtual world they find themselves in. The overall effect is that a carefully designed VR experience can be cut-off much earlier than necessary.

In this respect, the situation with cave-like projection theatres is better. Here the users can see and interact with their colleagues in the room, while their colleagues can see what the main user sees, albeit from a slightly distorted perspective. This makes these interfaces more conducive to teamwork and less socially isolating. However, these types of system are both expensive to build and to maintain, as well as occupying significant space. Portable versions exist, but these have setup overheads and sacrifice elements of visual quality for the sake of portability.

AUGMENTED REALITY

The promise of Augmented Reality (AR) offers hope to resolve a number of these issues [Skarbez et al. 2021]. With AR we can still see the real world, augmented with whatever virtual elements we want to layer on top of this.

These elements might be proposed physical designs, showing us potential physical reconfigurations of an existing space; they might also show us hidden infrastructure - the networks of plumbing, cabling and ducting that are accommodated within floor and wall spaces. Alternatively, they might just be abstractions: codified design elements or instructions for service operations.

AR also offers a solution to headset reluctance. The wearer is no longer socially isolated, and groups can both see and manipulate the augmented elements. Unfortunately, AR is a much less advanced technology in comparison to VR. Hololens and Magic Leap have shown the potential of what AR can offer, but relatively high cost in combination with limited display qualities have hampered their roll-out as practical technologies.

COLLABORATIVE VR

Collaborative VR has been the preserve of research labs for decades e.g. [Carlsson and Hagsand 1993] and, in the age of commodity VR, has attracted increasing interest. Since 2015 there has been a proliferation of social VR platforms and applications. During the Covid lockdowns of the past 18 months, our VR research group at UCL has, like almost everyone, spent many hundreds of hours in online meetings and conferences. But we have frequently abandoned these forums in favour of exploring the range of collaborative VR apps on offer. These typically allow groups to meet in a private space that can be selected from an overwhelming variety of settings: conference rooms, mountain cabins, theme parks and futuristic cities.

Collaborative VR provides some advantages over the aforementioned setups. It can work with consumer-level devices, and so costs are low and the infrastructure is portable. Participants can see each other, eliminating problems of social isolation and headset reluctance (people typically spend much longer in VR when engaged in a team activity). On top of this, these team members can be in a natural spatial arrangement - standing in a circle, dividing into small groups, or sitting around a coffee table. The spatial arrangement allows for more naturalistic interaction – the conversational cues that are absent from a videoconference are reintroduced – nods, gestures or turning towards others provide powerful social cues that we intuitively respond to. It is the absence of these that can lead to the jarring disruption of conversational flow in videoconferences. For the moment at least, collaborative VR avoids more, but not all, of the obstacles that stand in the way of productive design activities.

CONCLUSION

VR and AR technologies have developed in many directions over the past few years. While technological advances have been significant, many fundamental issues remain to be resolved. Alternative technological approaches resolve different aspects of the overarching problems that are relevant to teamwork and design activities, such that there is no single correct approach. Navigating the possibilities afforded by these technologies is key to designing useful interfaces that do not constrain and frustrate users.

REFERENCES

AISH, R. 202. Representation in Transition. *DC I/O 2020*, Design Computation Ltd.

CARLSSON, C. AND HAGSAND, O. 1993. DIVE A multi-user virtual reality system. *Proceedings of IEEE Virtual Reality Annual International Symposium*, IEEE, 394–400.

DUŻMAŃSKA, N., STROJNY, P., AND STROJNY, A. 2018. Can Simulator Sickness Be Avoided? A Review on Temporal Aspects of Simulator Sickness. *Frontiers in Psychology 9*, 2132.

SKARBEZ, R., SMITH, M., AND WHITTON, M.C. 2021. Revisiting Milgram and Kishino's Reality-Virtuality Continuum. *Frontiers in Virtual Reality 2*, 647997.

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