

This is the full transcript of the recording from the AR and VR for Rhino 3D & Grasshopper User Group Meeting organised by Simply Rhino, featuring Softroom and Fologram. This meeting took place on the 11th February 2021 and the video can be found here on the Rhino3d.co.uk website.

Paul: Hello everybody. Welcome to our AR VR for Rhino User Group Meeting. Joining me is Steph from Simply Rhino who some of you know and also Oliver from [Softroom](#).

Now, I just want to say a few things other than welcoming you.

So, [Simply Rhino](#), I'm guessing most of you or all of you know what Simply Rhino do. We supply Rhino software, we provide [training around Rhino](#) and Rhino plugins and support. So, that really sums up what we do.

Now, just sound issues, occasionally people have a few sound issues. Please, if you do, type in the chat that you're having any issues with anything to do with the sound and we'll do our best to help you with that.

Also with questions, do please use the questions tab on the little icons that you should see there, rather than the chat. There's chat and there's questions. If you can put questions in questions rather than chat, that would be great. We will try and get to as many questions as possible, but feel free to ask your questions throughout all of this presentation and the second presentation. There'll be a Q and A after each presentation.

Just to mention as well that these sessions as always are being recorded, so these will appear on our YouTube channel a few days after, maybe a week maximum I guess, after the broadcast.

Anything else that I need to say at this point? I think it's just to introduce Oliver. We're going to hand over to him to begin his presentation.

Oliver is from his design and architecture studio based in Southbank in London, not too far from us, and I wanted to say Oliver, do you remember, you hosted the very first of this flavour of meetings, the AR and VR meeting, and I think to a certain extent part of it was your idea. Before that, everything had a Grasshopper singular focus, and we decided no, it needs to have something else, a new line. I just want to ask you, do you remember when that was when we had that first meeting, because I do?

Oliver: Oh gosh, well it must have been... was it 2017 or 2018?

Paul: Correct yes, October 2017. Anyway, thanks for the idea. So, here we are again. So, I'm going to hand over to you now Oliver and I'll see you again after your presentation.

Oliver: Cheers Paul, thank you very much.

Okay, so I'm Oliver Salway of Softroom and my own working history with virtual worlds extends back to the late 90s when Softroom were doing virtual projects for Wallpaper Magazine, and that led on to working with the BBC. Firstly, we created a virtual set for their flagship sport show, Grandstand. So, that is a green screen background with a dropped in video and then a physical desk. The desk was actually shared with Match of the Day, so we had to use that really nasty desk and stick a different vinyl graphic on the front of it. Then that led on to a long since extinct web review show for the BBC called Hot Links, and for Hot Links, we visualised spheres of data as the home of Nomy, a virtual assistant, a decade

ahead of Siri. Nomy could curate the findings in a library space and she had her own garden, green and pleasant land that she could never physically inhabit.

But the technology wasn't really there 20 years ago, and everything seemed like a pale simulation. So, we rather parked our interest in that while we began to build real spaces like the [Kielder Belvedere up in Kielder Forest](#) in Northumberland. It kind of sucks in nature through a slot, turning it in to a panoramic tableau viviant, where you focus on the beauty and complexity of the real world, water, wind and sky. It was really a blend. It's a very real project in a real space, but it creates a virtualised experience of the landscape.

Then we did a long collaboration with the Virgin Group, firstly designing the interiors of their fleet of 747's, with a bar that was frequented by none other than James Bond himself, and from there, we designed the Virgin Atlantic Clubhouse at Heathrow, which has to cater for incredibly fussy clientele and has spaces to suit every mood. We really learnt about hospitality through projects like that. It was also very photogenic and featured in a number of films itself.

Most recently, we shaped the design vision and key spaces onboard the new and as yet, unused group of cruise ships for Virgin Voyages, and we learnt the ways of museum world with the British Museum and the V and A, and again, back in the hospitality sphere, we created the signature lounge space for the Eurostar, which now sits on the Brexit border between the UK and Europe and they're making it more poignant a symbol than ever it was.

But in the time between, VR has evolved and really recently been emerged as a powerful tool in the architectural design world, and we used Rhino, Grasshopper and Prospect extensively when we built the centrepiece of the new Istanbul Airport, underneath [Grimshaw and Haptic's great roof](#).

Then, just before Covid, we started working with the NHS, bringing our lessons from hospitality design back to reimagine the GP practice of the future.

But I guess what is fascinating me right now, is to look forward and to try and work out what impact extended realities, AR, VR, XR could have on architecture and spatial design, and what the implications are going to be for how we think about the design spaces, and try and merge and meld those different worlds.

I mean I would say, I am a cautious evangelist for this technology, with significant caveats. Firstly, in terms of consumption, these are power hungry technologies. Though the energy could be provided by renewables and the data centres, could be located underseas for cooling. And they require yet more devices be manufactured and eventually disposed of.

In terms of resilience, is it wise to invest resources in a vulnerable high tech technology that would wither the second its complex infrastructure is turned off?

However, using holography, we could store the data we collect for 13.7 billion years. So, maybe that data ends up being the legacy of the species, the epitaph sent out into infinity, and it's unlikely to be a universally accessible experience. It may be commonplace in affluent societies, but it's less likely so across the drowning and drying nations.

So, with those caveats in mind, we also need to consider what behaviours are responsible uses of this technology. What I doubt we want is this kind of hellish vision of mass isolation. Our history with mobile devices so far doesn't bode particularly well. Interestingly, when they designed the first Walkman, they included sockets for two sets of headphones to allow for a social experience, and a hotline button that you could press to interrupt the playback when you had a conversation. Similarly, virtual reality headsets are now being made like

welders masks, so you can flip back to reality, or at least flip back to your phone. And there are positive initiatives like the [National Theatre see through Smart Glasses](#) that enable rather than destroy social experience.

All of which is fine in specialised circles. But if these technologies are going to go mainstream, there has to be a credible mode of mass consumption. There is the Holy Grail's holographic display, but that's mostly vapour ware, and in their absence, they can place the displays on the head, but they're going to need to be genuinely comfortable and not anti-social. It probably won't be a mass consumer hit until a player like Apple see that. What we need is some really sexy specs or contact lenses with built in displays, which are promising in terms of miniaturisation, consuming less and less volume of resources in their mass production.

In terms of a breakthrough, killer app, virtual telepresence has got a strong case, particularly in reducing the carbon footprint in the world of work, and back in the 90s again, we designed concept living with Motorola and we had a prediction you might have your own blue screen booth, allowing you to work from home but meet people anywhere.

But as Covid has taught us, all of that brings with it real risks of social isolation.

The latest generation of video conferencing is certainly adept at recreating the formality and tedium of a board room meeting. But emerging technologies and spatial computing mean that if you can stomach wearing the headsets, we can have much richer, more collaborative long distance experiences, perhaps using motion tracked cartoon versions of ourselves, which require a lot less data streaming than live video.

But how do you replace the hazy evening after the corporate meeting, spent in a basement bar, where the real relationships get forged?

Already, hoteliers have cottoned on to the fact that much collaboration takes place in the lobby with a beer in hand. So, as well as the technology, we need to be creating physical spaces for these virtual encounters to happen, to facilitate the nuance and the subtlety and the fun of rewarding human exchange. We may need a new set of social skills and get used to interacting with the mix and flesh and blood people and virtual ghosts, like some high tech séance.

So, my journey has led me back to the world of television to look for clues, and Covid certainly dragged telepresence in to the mainstream. Even our grannies have caught up with Zoom and its high end cousins are now perfectly acceptable for Oprah and Barack Obama.

What has helped drive all this and presumably will trickly down to consumer level, are developments made in core technologies like chroma keying. This demo is from a [Turkish company, Zero Density](#), showing how subtle you can now get in real time with things like hair, and also picking up shadows in a lot of detail. These all add to the feeling of immersion. Their algorithms can now even handle really tricky subjects. I think there is an example coming up, refractive transparency. So, that's the Chromakey version and then that's live put on to an Unreal back plate. Then you can also add AR elements into the front plate, on the mid plate and then have the virtual world back plate and all be seamlessly joined. Of course, this is thanks to technologies going upstream, up the food chain, with Epic's Unreal Engines now powering most of the sophisticated TV graphics we see today.

Here again is another example of Zero Density, where they're able to weld together the virtual and real worlds incredibly sophisticatedly. You've got a physical person on the green

screen, standing next to an LED video wall, and objects will come out from the virtual world through the LED video wall and become augmented overlays in the foreground, which is all a pretty neat trick, and it makes you wonder where this is going to go, what can be achieved with those sorts of technologies when they come back down from the broadcast level to the world of work, and then also to the domestic environment which I think is happening really as exciting as a prospect.

Of course, technologies like green screen and chroma keying in themselves, aren't anything particularly new, but it's gone to a point with real time broadcast graphics, where with right keying and colour correction, you can pretty convincingly bring remote guests in to the studio and enable a two way discussion with full body language, as if they were really in the room.

Then I guess, the next step on from that is to fully wrap the stage with a virtual environment as we've seen in the Star Wars Mandalorian, LED volume. Now the actors can feel they're really in a location and the parallax of the environment is perfectly tracked with camera's movements. It's not perfect yet though and even they're finding that sometimes you just have to use the old-school chroma key to get a useful shot out of an LED.

But the trickle down has already started to happen, with the rise of smaller scale extended reality stages like this one from [White Light](#), which has got LED video walls at the back left and right, and also an LED floor with matte service that is walkable, polishable and cleanable that you can then extend that space out with a technology like Unreal, using a disguise server, and that gives you really convincing impressions of a much larger space.

When you've got that kind of environment, you can then much more effectively teleport in remote participants and interact with them, not only interviewing them but also as I said, reading their body language and they can read yours via link up. You can almost, but not quite interact and touch with them, not quite high five, but good effort.

The thing is, for those on stage, and not appearing to the camera, what it actually looks like is rather different, and so here you see the legs of the person stretched over the floor. It works perfectly from the cameras point of view, but it does preserve eye contact.

I suppose streaming 3D volumetric capture of subjects is the next holy grail and the bones of it are all technically achievable, but it's got a little way to go yet, before it's a really workable solution, but not so far. The non-real time volumetric capture is certainly here and it's starting to show great potential. So, the broadcast and consumer versions can't be too far off. So, here, once you've got your capture then you can relight it because it's pulling in depth data as well as the RGB signal.

So, all of that makes me think, what will the foundation of these incredible looking technologies... what are they going to mean for tomorrow's augmented living room? The sort of spaces we might inhabit? Back in 98, we were asked by Time magazine to visualise the family den of the future and what we showed there were people consuming media in a variety of ways, all within one space, which has certainly come to pass. But we hadn't predicted augmented reality smart classes. And of course, if you've got money to burn, and lots of floor space, you'll probably just have a whole area dedicated to AR, but I'm more interested in how this technology is going to end up retrofitted in the mundane confined spaces which most of us actually inhabit. What changes might happen in the average living room?

So, my first prediction is that the next big thing in interior decoration will be the colour black, because for AR, black is the new green. Since AR headsets can't block out light, they can

just overlay imagery. It's only when you look at the black surface that they suddenly become very dense displays.

So, here is the average family living room, furniture typically arranged around a TV, but we might replace that TV with an empty expanse of black, and then forget 100 inch LED's, anyone with wide field AR glasses would be able to enjoy giant sized video for the cost of a can of paint. Once you've got that black surface, you can render it transparent and enjoy a 3D performance in a stage space extending beyond your wall. And geomapped black surfaces in the foreground, allowing performances in the round within a space which is going to significantly change the performance paradigm about how they interact with an audience and what level of intimacy you expect to have in that kind of performance when it comes out of the TV.

Next one is Empty Chair. This is the Polish Christmas tradition of leaving a space empty for the departed for a feast, and I can see how a space might be made in a family circle for remote guests so that granny can join you through AR for the evening and sit in the visitors chair, and that visitors chair might also be the go to place for intimate long distance chats with a dedicated little camera set up which is mapped to a twin location in another home, going to a quiet corner and having intimate experience against the black wall. Of course, there is a chance for full size telepresence, where two homes become one, which is going to radically change our social experiences and be a big move on from something like Zoom.

Of course, all of this only works if everyone in the room has their own headset, which brings us back to creating billions of new devices.

So, a slightly different use case is to transport out of ourselves just for fun, and I would say the tourism virtual realities is a first rate experience. This is nothing new and this film from the 1960's shows this lady who was a Maid in America, it says.

[PLAYS VIDEO]

Now, I was born in Oxford and that's one of the many Heritage sites worldwide that is overrun with tour parties, so instead of virtual guided tours, virtual guided tours would be a real blessing, but of course, as well as over-tourism, there's the fact that many sites can only be maintained if local economy is preserved thanks to tourist spending. On balance though, I think the potential is really great, and in some ways, the virtual is superior as you have the place to yourself and it can be enriched with interpretation and maybe the locals get the digital rights, like the Guggenheim Bilbao protective industry of photographic copyright. Then there is extreme consumption of bucket lists to try and tackle, and there is great potential for an extended reality to substitute. This is me landing the space shuttle which I know is not a terribly useful skill anymore but at least I can claim to land it when I'm drunk. Or how about if you wanted to virtually climb Everest. No airfare, not queues, no tents, no bags of waste, no frostbite, no frozen corpses. It's like reality, but nowhere near as cold. The copy sounds better in this case. And obviously you click straight to the summit. I've taken in the view from the virtual peak and it is impressive, bit small, and I was very happy not to blow my carbon footprint to be able to do that. And the best thing is, like a child with a bedtime story, when you're finished, you can just say "again".

So, I did laugh to see this corroboration in the Daily Mail. I'm sure those same snowflakes that claimed that it was too cold and windy would be more than happy to climb Snowden in their living room.

Ultimately, first hand experiences of reality are superior, but even as a copy or simulation, digital technologies are unparalleled at documenting what they're losing. Take this virtual

simulation of the Titanic which I'm sure many have seen. For a technology that's only just maturing, it's incredibly powerful to roam around the decks, wander up the infamous Kate Winslet staircase in all its pre-Iceberg Edwardian glory, and then even be able to inspect the menus in the first class dining room. The detail is that convincing. That's somewhere I could of course never have gone in reality.

Closer to home, the ScanLAB projects documented the transformation of my alma mater to the [Bartlett School of Architecture](#) and they beautifully captured the place I knew in the blurry days of Britpop, as well as the world leading institution that it has become since, and what particularly captivates me, is where they scanned the student workspaces, showing how this technology has the power to record even those most subtle and ephemeral traces of human activity.

So, as a result, I would argue that VR offers tremendous possibilities for the field of education and museums, and then as an alternative, to producing billions of devices. That's a maybe more democratic location for it. They've got now the most amazing medium for sharing stories, and there's the prospect of scanning our imperial loot, and sending it back home with virtual Elgin marbles might be as good as having the real thing.

So, perhaps like the seed banks, it's time to invest in a virtual museum of mankind. There was just such a museum once and for me, a powerful childhood memory was visiting the now sadly extinct but unforgettable museum of mankind which is now occupied by the Royal Academy and it was famous and rightly popular for its, As if You Were Nearly There shows where they employed set builders to create life size walkthroughs of exotic places, and I vividly remember turning a corner, and finding myself transported in to a Yemeni Suk. I could only find this one black and white picture, but from what I recall, there were these amazingly subtle effects of light and shadow that they created in Piccadilly that really made you feel like you were in the Yemen. It was quite amazing. The Museum of Mankind eventually got reabsorbed in to the British Museum, leaving a trace, but I would love to see it reanimated and given centre stage using virtual media. At the heart of the BM sits the problematic reading room, and it's restricted by its protected interior. But if you substitute the old readers desks with VR spaces, it makes sense again. So, I'm imagining the room with readers immersed in quiet, virtual reality study. Then there's the crypt below it, and I can see there being an expanded digital centre beneath the reading room, with a couple of virtual reality caves, like a load of magic carpet rides. Maybe this is the sort of data we get sent out to the cosmos, as our epitaph, as the history of mankind in a virtual sense.

So, little question, is this the end of architecture as we know it? I wonder if the climate imperative spells an end to architecture as we know it? Of course, there will still be construction protecting us against the hostile climate. But does it matter what it looks like? Designing for descent has to be the spirit of age. As we reach the end of the line of our exploitative mode of living, we're going to have to get a lot leaner and more efficient in terms of what we create.

So, a lot of the works of architecture we see today, to me seem increasingly like brilliant answers to the wrong questions. When I first saw this detail of [OMA CCTV building](#), I was excited to see the almost ugly raw expression that wasn't wasting the resources on pleasing humans but of course, in that case, all that raw decorative economy is actually to serve a ridiculously wasteful expressive purpose.

So, there is a recalibration for aesthetics that is yet to happen. It's unlikely to be pretty. Maybe you can make all the expressive bits out of recycled materials but even so, it reeks of tin eared, conspicuous consumption like the extravagant folds of fabric in the 15th Century

portrait. But where do you stop with this austerity? If you chop off those extravagant serifs you could save 10% of the world's ink.

Architecture seems to be converging on a solution where most human activity could be housed in an efficient shed, just slightly oversized enough to provide flexibility and accommodate change of use over time. It should be built to last, maybe not from concrete, but something renewable and low carbon like a timber grid shell, and then maybe have a cap in trade, where we collectively decide to blow some of the carbon budget on the occasional delightful hamster wheel in our sustainable habitat, which in turn raises the questions of whether there is going to be much work for architects at all. If efficiency becomes the sole driver, it's a task that's quite possibly beyond human. Quite a lot of the analytical and specification tasks could or maybe should be done by AI systems. So, far these tools appear to help us, human design does not replace this. But maybe not for long. Let's just hope we teach those algorithms a full range of positive human values when we do that.

If this is the end of the history of expressive architecture, could virtual realities become a legitimate, low carbon outlet for all that architectural imagination instead? If you unleash it from the burdens of environmental responsibility, there exists the potential for architects' pure emotion to emerge. Maybe architecture becomes a disembodied virtual art form. No one planned this in commodity but high in demand, or perhaps as has been argued, architects become the builders of extraordinary world entertainment industry. But can it transcend art and incorporate utility? For those who can do their augmented reality glasses, it's possible that architecture just becomes a decorative skin overlaid on the loose fit sheds, as a placebo effect. It doesn't need to be one size fits all. We can all wander around in our own personalised pleasure domes. There will be no more aesthetic battles with English Heritage. One individual might choose to overlay a parametric utopia while their companion experiences a rose tinted period of nostalgia.

Being careful what they wish for, it could all get pretty dystopian, like in this brilliant visualisation created by Keiichi Matsuda where a mundane urban world is overlaid with this decorative personalised skin, and it's a visual experience teeming with information and overload, advertising, statistics and digital cats the size of skyscrapers. When you land on the space shuttle, there's a particular moment called declutter down, where the head up display simplifies at 3000 feet. That raises the tantalising prospect, if we were able to shunt all disposable, human centric, ephemera of our surroundings on to a sustainable digital layer, as well as reducing consumption and waste, we also gain the option to be able to turn off all that visual noise with the blink of an eye. But perhaps we still need that layer for now as a bit of a crutch, an opiate that soothes our transition and the stratospheric level of consumption down to safer ground. I think in these times, it's hard to make the case for virtual and mixed realities as a luxury art form that's really worth indulging.

But as a tool for bringing us together to share our experience and to collaborate, I think they're potentially very compelling and having begun this journey, I'm really interested to see where it's going to lead and I'm fascinated to see that the new technologies, and particularly the ones coming out of broadcast, how they're going to influence us, what we're going to design, how we work in design and how we create spaces, particularly even at the domestic level that we're really going to enable those shared experiences.

Anyway, those are my thoughts for the evening, so thanks very much and I will hand back to our hosts.

Paul: Excellent, thank you Oliver.

Oliver: You are very welcome.

Paul: I'm just going to share my screen. Just one second. There. So, I enjoyed your presentation very much. Thank you. Some questions for you. Okay, so just start from here. In any sort of order, what software are you using within your practice at the moment? What combination of tools? From headsets down to the actual whatever software platforms?

Oliver: So, we've always had a bit of a mixed environment of Macs and PC's, partly because I started off as a Mac person and never really got my head around Windows. But with AR, VR, it kind of pushes you down the Windows route. So, for all that work, it's been a decent workstation with good NVIDIA video cards in them, and for viewing the VR, we've tended to... well, we've been using HTC Vive stuff. Interestingly, I did look at... we got hold of a wireless Vive at one point, but just the pain of battery packs and all of that, most of the time you're not moving that far, so just tend to use the wired, tethered version. That's fine. Also, the [Vive Pro](#), I was hoping for a massive jump in visual experience and it wasn't quite as grand as I thought it was going to be. Obviously there's some amazing headsets coming out, people like [Varjo who have got 4K](#) or whatever it is displays and I've actually not experienced one of those yet, but I'd love to get my hands on one of them. I slightly balk at the cost of them at the moment. On the software side, all of our modelling is Rhino and then obviously it's got its own VR tools now, but certainly back in the day we were shipping out to [Prospect](#) as a quick viewer and then we became aware of Unreal and the ability to jump first via datasmith and then the in built connectors into Unreal. But actually, what I've been using most recently, certainly for pre-visualisation of motion stuff is Twinmotion. I find the connectivity between Rhino and Twinmotion fantastic. I think that the simplified tool set in Twinmotion is really geared towards visualisation. It's going to frustrate some people who want the control that you get from all the millions of panels in Unreal, but in terms of, it's just amazing as a design tool, not just a presentation tool. Finally, you can actually design in real time. You can put a live move around and it works. That's just astonishing and had we had those tools 20 years ago, we could have been so much more productive than we are now. I'm pretty sold on that sort of technology at the moment.

Paul: Thank you. Would you say out of all of that, the most exciting recent developments, is there anything you would highlight?

Oliver: I think that when you look at the world of broadcast, it's one of those things where you're going to expect this to trickle down in to those worlds of design and home entertainment, but the loops that they've got going on of being able to bring a real time physical element in to a scene, but then loop it back so that it's composited in to real time, in to its virtual environment, that you're seeing with only a four frame delay. So, a fraction of a second delay but to go in through tracking and rendering and compositing, is kind of pretty amazing. At the moment, there's some boxes that is running on that are pretty... they're chunky pieces of kit and very noisy and you're not going to want one of those sitting in your studio at the moment. But you can see, there's just been this huge advance in the video cards in the last six months and it would be amazing to see that unleashed on to the desktop.

Paul: Which reminds me to thank one of our sponsors for this evening which is PNY, the distributors of popular graphics card in use by many of our customers, which of course are Quadro cards. So, thanks to PNY. Nice lead in to them there Oliver. Okay. Let's see, so another question for you. Do you imagine working with your clients, particularly with Virgin perhaps in mind here, on virtual travel experiences? Is that something that is ever being discussed?

Oliver: It's an interesting one. Obviously the travel sector is hugely challenged at the moment. I think taking a bit of a longer term view about it, but for traditional travel brands, who only have that channel, I can see how they're starting to... I think some of the hotel groups are starting to show virtual experiences, what it's like to go to the resort, as an advertising tool. But with a company like Virgin, because they're multi-channel, they're not just selling a cruise or a rail trip or an airline or whatever, but they have the whole Virgin experiences, and they have hot air balloons and whatever, I can imagine that a company like that might want to... if they saw the potential in it, of taking people in to virtual worlds as a branded experience, because they understand customer service and hospitality. Of course, they're going to take people in to space theoretically and not all of us are going to get there, so I can imagine that there might be some interesting virtualised experiences to be created out of things that the average person can't do. It's not going... and then there's a question, are you cannibalising your market, because if you offer the virtual experience to people, will they actually bother going? Well with space, it's only if you've got £125,000 a ticket, and those people are going to go anyway because they get the free falling environment. But for the rest of us, the best and most we're going to get is going to be a virtualised version. So, the question then becomes, is that enough? Do we all have to go to the Taj Mahal in our lifetime? Do we all have to go to Ayres Rock? Do we all have to go to Yosemite? Patently, we can't. So, I think in some ways, if the virtual things can get good enough, they ought to hopefully satisfy our need for some of these experiences. I certainly don't want to go up Everest. I have no desire to go up Everest, but it was great to see it virtually and so whether that becomes commoditised and owned by different places, that will be interesting to see. But I think it's definitely an interesting sector.

Paul: Just a question from a student here who I think is relatively new to the subject, but they've asked, from a low budget start, what would you recommend as a good investment from the hardware point of view in terms of the glasses? Is there anything you could say about a good starting point? Where would you start from?

Oliver: Good question. So, obviously the augmented reality glasses don't really exist yet. Okay, there's the Microsoft HoloLens, but nobody is going to shell out £5000 first out. The Magic Leap is going to happen, but now that's imploded on itself as a business sadly. In terms of being a student now in terms of augmented reality, I would hold my fire on that one, because to develop the experiences, you may as well just do those with a comparatively low end VR headset. I've actually not got much experience of using things like the Oculus products, having invested in the HTC food chain. But I'd say that I would go for a relatively cheap headset and spend your money on a decent graphics card at the moment.

Paul: Okay. So, thanks Jonathon for that question. Okay, from Kevin here, a question, can you speak a little on the haptic boundary, where it currently sits with available technology and where it might be going in the future? Could the future of architecture have an adaptable personal haptic focus?

Oliver: Right, well if I think I understand the question correctly, for me, what that means is about it becoming tactile and having feedback that is actually back to the user. One of the interesting things about the smart glasses is that it's going to be... you're going to have to have some input device because as well as... yes, it can track your eyeballs, but to actually be making gestures and detailed things, it's likely that you're going to end up wearing something and I don't know if you remember, there was a kids television programme in the 1970's called Fingerbobs, Fingermouse, these little things on your fingers. I can see, and I think there is evidence of Apple trying to patent this technology. So, I think it's going to be really interesting when it does not only affect our vision, but also things like our other senses,

like our sense of touch and that certainly in the augmented world, there's going to be different spheres in which it works in terms of proximity, because there will be a zone which is within your fingertip reach, where you're going to be able to augment the human experience in that sense, not just visually but also in terms of touch and I would imagine that within that sphere that's close to you, that's where you're going to have your widgets and your little stock trackers and your memos and stuff and they're going to travel around with you and they're going to be locked to your personal experience.

So, if we imagine that sphere of experience around you, and then beyond that, there's going to be stuff that is tracked to the environment, like a sign on a building or something like that. So, you're going to have these layers of different visual and tactile experience that are differently overlaid in depth and will all be moving against each other. Is it going to be a nice experience? I don't know. That's up to us collectively as a community I think to make sure that these sorts of developments end up being positive and enjoyable rather than a hellish vision of overload like that Japanese simulation of the person on the bus, which... who wants that?

Paul: Here is a question, are we headed... I'm not sure if this is a question of an either or, but the question is, are we headed to an AR or a VR future?

Oliver: I'm kind of with Tim Cook of Apple on this one, which is, I think it's AR, mainly because of the isolation factor of VR. It's very hard to sustain experiences of VR without going off into a very personalised, isolated environment whereas AR, by comparison, has amazing social potential. If you're in that living room and there's Rihanna dancing in the middle of your living room, you can all be watching her at the same time from your different eye point of view, and also, you can maintain contact with each other, just have a little conversation, do all of those things. That doesn't work with VR. With VR, you're in your own thing and you might see some representation of the other people around you but it's not the same, you don't get all the nuance of human experience. So, AR definitely. The techs not there yet.

Paul: Thanks for that question Edward. Right, Steph was going to help me out here if I miss any questions from anybody.

Steph: I'm here, I think there's been a few replies to some of the more conversational replies to some of the questions that we've had, but I think given the time, we should actually move on to Gwyll who is with us now, live from Australia, nice and early in the morning for him.

Paul: It must be very early. Sorry Gwyll

Gwyll: No worries, I've been up for a little while now, I've had a coffee. I'm ready to go.

Steph: So, we'll make Gwyll the presenter now and Gwyll can go on to present. Do you want to give Gwyll an introduction, Paul?

Paul: A very brief introduction. Thanks for joining us so early from Australia. Early morning in Australia. So, Gwyll is from [Fologram](#). Many of you will know, and I know there are some customers who use Fologram as well here with us at the webinar. And the developers of Fologram software. Fologram.com is their website. So, we'll have this presentation from Gwyll now and please type your questions as before in the Q and A panel and I'll see you all at the end. So, I'm going to hand over to you now Gwyll and I'll see you at the end.

Gwyll: Thanks Paul. So, what I thought I'd do today is... also, thanks very much Oliver for that presentation. I managed to catch most of it. I'm glad I got out of bed really early for that. That was really fascinating stuff. I really enjoyed it. Hopefully this presentation will be a nice counterpoint to it, because obviously we're working with the same technologies, with mixed reality, but really focusing on a visualisation experience, about how you can augment work. So, how the mixed reality experience is going to help you perform fabrication and construction tasks on things like construction sites or within workshops, rather than how it might help you perform design tasks or trying to communicate an as yet unrealised experience using these technologies. So, hopefully, that's a nice counterpoint.

I thought I'd talk about it with two examples of projects that we've done. So, Fologram is a tech start up. We make and sell software for viewing 3D content, viewing and interacting with 3D content on mixed reality devices. But we also have a fairly intensive research and development component or arm, where we use our own software to improve and evidence use cases for mixed reality within architecture, engineering, construction and fabrication spaces.

So, there are two projects that I want to show and talk about in a little bit more depth that have happened since our last presentation at the AR VR Meet Up Groups, and actually, when we were first invited to talk at this one, I thought we just did one just the other day. But actually, it was two years ago and a lot has happened since then. So, I'm excited to share a couple of projects.

One is a project with bricklayers that we've done in Tasmania, so it's comparatively speaking, fairly large scale augmented reality, constructed part of brickwork that was part of the Royal Hobart Hospital. So, using the mixed reality on real construction sites to do real work.

And the other project is the collaborative design and construction project that we did in Tallinn in 2019. It's a small pavilion that was both designed using mixed reality tools, prefabricated using mixed reality tools, constructed using mixed reality tools and then we did a whole load of post build analysis with mixed reality to try and minimise the risk lets say of that whole structure not coming together.

Then the last thing I want to talk about today is some work in progress that we've been doing at Fologram, specifically, every time we show these projects, we're always asked, well what's the precision of the HoloLens? How reliable are these holograms if I just want to throw away my measuring tape and start working entirely from a 3D holographic documentation set instead? And usually the answer to that is very complex. It depends on how patient are you in setting up the environment that you're in to make sure that headset can track really well and maintain precision.

Now, I've got a couple of videos to show you of some research work that we've been doing at Fologram to eliminate error essentially in how these HoloLens track on construction sites and get the precision down to construction tolerances which we're obviously super excited by.

Right, so we'll jump in to it. Now I think this slide is a really nice counterpoint to the things that Oliver was showing.

So, one of the first, if not the first use of the term augmented reality in published literature, is from a paper by two engineers at Boeing who used this term augmented reality to describe the system for assisting with the manufacturing of aircraft wings. So, ever since its conception as a technology, and these two engineers prototyped this system that they're

describing as well, which is pretty amazing, because it was back in 1992. But ever since its conception of a term, augmented reality has been intended to help with actually doing things. It's not about taking users out of their physical environment, putting them somewhere else, somewhere virtual. It's always... at least in the engineering space, been thought about as a way to assist with complex and tedious tasks by providing a minimal amount of digital information, when and where it's needed. So, overlaying a physical environment with some basic instructions like where to place a drill hole which is a really useful bit of information when the forms you are constructing are entirely in 3D. It's difficult to place these drill holes purely off a 2D measurement. They require a complex set up.

So, we've really run with this application of AR for assisting with manufacturing complex things and the big technological change that has facilitated a lot of the work that we do, is rather than needing to prototype everything ourselves... so back in 1992, these engineers had to generate their own custom headset, they had to build custom sensor arrays generating that headset. They had to build custom workbenches for constraining the movement of that headset. They had to write all their own custom software to display the models for workers in the right place. All of that work has been done for us now and it's been done for most, well for any creative who wants to work with mixed reality, and that's because devices like the HoloLens or more recently the HoloLens 2 have become accessible to consumers. So, I think Oliver mentioned, these are expensive devices relative to the cost of a VR headset, but the applications for them are quite different. So, it is quite feasible to purchase a [HoloLens 2](#) device and then basically remake the cost of that device on one job, because it's going to basically save you time performing work and that's the pitch that Microsoft is making with this headset. So, they're really targeting enterprise use cases, and specifically use cases by front line workers with the HoloLens 2, whereas with the HoloLens 1 when it first came out, you might have seen a whole lot of fancy marketing videos where people were playing Minecraft or shoot em up games and things like that with the headset, which is really what this technology is not ready for yet. I strongly agree with Oliver there. It's just very early days. But for work, for creating experiences which are a lot like the Boeing image from the last slide. You're just showing the location of a drill hole, or you're just showing some geometry that you need to check has been installed or been built. They're fantastic for that, they work really, really well.

So, the issue with the HoloLens really is for most of the people who have the exciting use cases for the HoloLens, so broadly speaking, that's front line workers but at Fologram we focus more specifically on creatives and people who fabricate complex things like art fabricators, sculptors, trades people and what have you. There's a real, very steep learning curve to using HoloLens 2, and that's because, there aren't a lot of off the shelf applications for headsets. It's not as if you can buy one, jump on an app store and download a thousand different apps to do a thousand different things. Most development on the HoloLens is custom development on Unreal and Unity and these front line workers, or creatives, often don't have that skill set and so, what Fologram's software does, it just makes it really straightforward lets say, to build mixed experiences off the top of Rhino and Grasshopper.

The main advantage of Fologram we think, is it just reduces the time that it takes to prototype an idea in mixed reality. So, rather than having to jump in to Unity and pull in all of your assets and build all these user interfaces and get everything running, and then build it for the HoloLens which is also a pretty time consuming exercise. All of that can just happen instantly within Rhino and Grasshopper directly. So, the time it takes to explore an idea is radically reduced and we think that's really important because mixed reality for making things is very much uncharted territory. So, there's a lot of exciting things that you could

use mixed reality for, no one has quite figured out how you would use mixed reality to do those things.

So, my hope today is I can show you two examples specifically of how we've used Fologram to prototype a whole lot of different tools for assisting with various aspects of design and construction, and all entirely out of Rhino and Grasshopper.

I'm showing this image as just a screen grab from our website. Fologram runs on HoloLens as well as [Oculus Quest](#), if you've got one, and on IOS and Android. But the use cases for those different devices are very different. While you can build one app let's say with Fologram in Grasshopper that will run on the HoloLens, will run on Quest and will run on Android and run on IOS, what you might use that for is really different on each of those devices and that's largely because, with the HoloLens, you have much more precise tracking and you have good depth perception when you're experiencing 3D content in a physical space that you just don't have with all the other devices. So, we're often thinking about using mobile phones more as a way of capturing and recording experiences that are taking place in the HoloLens, or as teaching and learning tools for just learning the toolkit, getting started with mixed reality. There's a really good free version of them, so it doesn't take much to get started, but it's maybe not a good idea to build extremely complex brick walls with mobile phones just yet. We've had some people try and it hasn't been that unsuccessful, so maybe I'll stand corrected on that one.

So, the two projects really quickly. The first one is this idea of using mixed reality for non-standard, holographic brickwork, and I think last time we presented at one of these AR VR Meet Up Groups, we had done quite a few projects with brickwork already, and that's because it lends itself really well to mixed reality instructions. So, the idea is that if you want to build a masonry structure where each brick is in a unique position, relative to the other bricks in the wall, which make them complex to set out, what you can do is just have a holographic representation of each brick that you see through the HoloLens and you make sure that the holographic representation is positioned in the correct location relative to the physical site that you're building it in using one of these markers that are accurately placed on site with traditional surveying techniques. Then whenever you see a virtual holographic brick, you just place a physical brick in its place, and when the two line up, you know it's right. So, it's a really simple, straightforward experience. So, if we've done this with lightweight materials, so things like foam in workshops, with several thousand bricks constructed by a couple of teams in an afternoon in Germany, and after doing it with foam, we were really keen to try doing it with mortar, with real skilled bricklayers and on a real construction site, just because a lot of the constraints and challenges there just don't exist when you're working with foam and we wanted to essentially prove this technology was ready for these sorts of industrial applications.

So, we found a bricklayer, his name is Colin Barrett from a company called All Brick, who is definitely really keen to try out working with mixed reality on this job like the Royal Hobart Hospital, mostly because there's just a huge amount of set up that's going to be required to build... I think it was a few dozen of these individual structures. So, they're benches that go inside outside spaces within the hospital. The longest of these benches, they're about 12 metres. The bounding box is about 12 metres on the longest edge, but the brick walls themselves are much longer than that. This gives you a sense of sort of the limit of scale that you can work with using holographic constructions on the HoloLens, if you are only positioning models with a single marker. So, you're placing model once on site, and then you're able to walk from that placement point to any point in the structure, and you won't get

too much drift. You can still rely on that holographic information to show you precisely where the brick would be.

In order to build the wall, we had a slightly more sophisticated parametric model that was required in order to fully document this. You end up having to produce shop drawings for brickwork, where you model every single brick in the wall. These are cut bricks in order to have a smooth curve with consistent bonds between each of the bricks. So, we were showing as a hologram, cutting templates for the bricklayers, as well as where those cut bricks would need to go in the structure. This was extremely efficient for the brickies, because of well, several reasons. One is, they never really needed to worry about labelling any bricks. Whenever they needed a cut brick, they could just pick up a brick, pick up that holographic template and cut it until it matched the template. So, it was extremely fast for them. They were also able to reuse a lot of offcut bricks. They were always able to just pick them up, see if they fit one of those templates, cut them a little bit more, put them in to the structure. And they could just pre-prepare them as well, so they cut bricks and they just pile them up in piles and you could have apprentices or really anyone on site grabbing one of those bricks and doing a visual check to make sure it was the correct one. So, just minimised error as well.

But the main advantage of working with the HoloLens, is that the bricklayers were able to construct this fairly complex brick wall in parallel. So, they could have an arbitrary number of guys wearing headsets. We only had four on site. I think the most we ever had was four people wearing headsets building these segments of wall. But they could put on a headset and all see the same holographic construction information in the same place and they could keep building these brick structures from any point along the wall which is a completely new process for masonry. You would never normally do that because you would never be able to have consistent bonds if you just arbitrarily placed bricks along these curves and hoped everything matched up later on. So, that really increased the efficiency of this construction process, just allowing several guys to work from anywhere, and then come together and have a perfect millimetre precise bond at the end of it, without worrying about introducing error. So, there is low risk while improving the productivity, basically.

So, this is what the benches start looking like once they are closer to being finished. It gives you an idea of the scale. I think there's a few guys just up in the corner of the screen. You can see them wearing HoloLens and laying bricks, and the HoloLens just disappears as a tool. It's no different to having a measuring tape on your tool belt or maybe to a lesser extent, having a stack of drawings sat on a construction site somewhere. This isn't something that the bricklayers really need to think about. It just provides the information, it's present, it's reliable. The headsets are, so long as they're fitted okay, you forget that you're wearing them after a little while. That's definitely the case, more the case with the HoloLens 2 which we think is really exciting, mostly because you're not trying to change what a bricklayer does, necessarily. We're not trying to turn bricklayers in to robots where they don't have to think. It's a very flexible, dextrous arm that can move around messy sites. Definitely not trying to do that. Instead, what we're trying to do, we're trying to extend their capability in terms of bricklaying. So, we're trying to make it so that it's easier to learn from skilled bricklayers. We're trying to make it so that there's less time doing rework, like fixing mistakes that didn't need to happen. We're trying to enable more ambitious structures that these guys can create and Colin, the CEO of All Brick has definitely put out a call to architects to push the limits of what they can design, because now there's a capability on there, and more feasibly build these structures.

So, this project was done in late 2019 now, so a little bit over a year ago, and we did do some LIDAR scans of some of the prototypes of this structure, just to measure the precision before we went on site. I just made a claim that this approach would reduce the bricklayers risk and we wanted to have some integrity and ensure that would be the case, that they wouldn't get on site and nothing would fit, and the precision just out of the box with the HoloLens is... on average, it's about 7mm of error, which is acceptable to the brickies for this project, but we think we can improve that more.

So, the brickies are happy because it brings some technological change to their industry, in an industry that hasn't really changed much since the invention of the laser level. It's like the next generation of bricklayers to that industry. It improves their capabilities, upskills their team, improves their ability to collaborate and just reduces rework for a better quality result. Then it also can save money on jobs. But all of those other things, it was really important to these guys.

Second project, I'll run through this one fairly quickly. So, this is a collaborative project that we did with SoomeenHahm and Igor Pantic both from the Bartlett at the time and then with [Format Engineers](#) on the engineering side who were really amazing, as well as the volunteers who donated their time to do this project, and the idea was just to combine an analogue craft technology. So, steam bending timber with really precise digital guards in order to reimagine what you could do with steam bent timber at low cost. So, we thought that we could have an augmented reality model for laying out formwork for the steam bending timber. That would be more efficient than having a CNC mould and things like that which are traditionally done and we did a little prototype in our studio. That worked. And then we jumped to this as a design proposal. So, really trying to push it to the limits of what was possible. We didn't actually expect to win the competition to be frank. We thought that... we along with pretty much everyone on art daily didn't really think that this could be built, this design, that the design would have to be very rationalised. But the jury believed in us and gave us a shot to try and build it. So, we spent a few weeks prototyping with the HoloLens. I'm not sure how well these videos are going to play, so I'm going to pause them a couple of times. But essentially the idea that we ended up coming up with was having a very rudimentary formwork system attached to a false floor that you could place in a fairly ad hoc way until that formwork would let you recreate any arbitrary, three dimensional strip, and with that system, we were able to build quite complex sweeping curves, initially from short segments of timber and then from 12 metre long lengths of timber that you could almost tie in knots as you can see from this image on the right. We didn't need to rationalise the design very much at all. It turned out that it was possible to form these complex 3D curves. So, there was an enormous amount of rationalisation digitally going on just to make sure that all this would fit together, which I've talked about in longer talks if you're interested in it later.

Here's a little video of this happening with the 12 metre long strip. So, you can see that in this short video, I think we might have been placing the formwork using a holographic guide. But the main bit of information that you need to construct these strips is just the mesh of the strip from Rhino, so this red shape here. That just streams directly from Rhino. It's the exact same geometry as is in the design model. It's orientated flat on the floor in the physical space, and then you've got a big bit of timber in a bag and you're just trying to form that timber until it matches that red strip. So, it's a very simple approach to making things.

A couple of other little clips here that I'll show you. This is more what it looked like on the HoloLens generally speaking. So, we weren't documenting where these scrap pieces of timber, the supports, we weren't documenting where they were going digitally. It was too much work. Instead, we just figured that out intuitively by following only that 3D model of the

strip while we were forming things. We also used the HoloLens to fabricate all of the steel brackets in the structure at hand. So, this is something we have done with lots of other projects as well. It's adding a holographic overlay to an analogue tool, lets you fabricate very complex parts with virtual, that wouldn't otherwise be possible, because you always have a nice visual guide of what it is that you're trying to create. Then we had later in the video, we've got a hologram on site. So, showing you where those strips are supposed to go as well as where the steel brackets are supposed to go. So, because everything is pretty flexible, floppy material, this is what the strips look like when they arrive on site basically, you really need a 3D representation of the finished form of each of those strips when they're installed, because the parts aren't rigid. So, it's kind of an exciting way of making things from spaghetti, this project. You had extremely long flexible parts, that were formed accurately. They wanted to relax and form in to the correct geometry, but at the same time, they were deformed under gravity and it was easy to push them out of shape, and using a holographic guard, you could reliably massage these bits of spaghetti in to that correct shape.

So, what's interesting about this project we think, it enables very traditional craft based projects to making where you're intuitively responding to how material behaves while you're forming it. So, it's seen bending very much like that where you're always trying to accommodate the springback, or the grain of the board might change so some lengths bend easily and others don't. You're able to work with those techniques and those sorts of materials, whilst still realising some form which is inherently very digital. So, every part of this project was modelled. We knew exactly where each one of these pieces needed to go. That enabled us to offer James Solly from Format Engineers to do all of the engineering on the project and guarantee that it wasn't going to fall down, because this is a public building. So, it's not just a sculpture that is made up on the fly, because that just wouldn't make those things really realisable or feasible. But at the same time, it isn't something which is exactly right and perfect, because it just is an exact replica of the digital model. So, I think there is a lot of really exciting opportunities there for rethinking analogue craft with digital technologies like mixed reality.

Last thing that I want to show, because I'm pretty close to my time, is how we're working on trying to improve the precision of the HoloLens, because each of those projects that I've just shown then, the pavilion, it's about 8 x 8 x 5.5m or so. That's the bounding volume of that one, and that's at the limit of what you can achieve with the HoloLens precision before you just end up with a bit too much drift in the hologram for it to be reliable and the brick projects, they are sort of 12 metres long and the bounding volume, but they are largely 2D, so it's easier to maintain precision and drift.

What we really want to achieve is construction site tolerances. So, 5 to 10mm or less, depending on the application, over arbitrary scale. So, you can work with the HoloLens over a scale that is as large as you like, it doesn't make any difference, and still be able to be confident that what you see in the HoloLens is positioned in the right physical location.

Now, how we've started doing that is by essentially trying to minimise or account for the drift in the holograms, which are caused by the way, by just accumulative area in the slam tracking of the headsets. So, the headset is working out where it is in space, just by using its onboard cameras to detect features in the environment and calculating how those features change in the camera, and then inferring the position of the headset. That just introduces error, the more you move around generally speaking. So, what we're trying to do is just basically tell the HoloLens exactly where it is using fiducial markers that contain precise known 3D coordinates in space. So, the research that we've been doing at the moment is

we've taken, we've gone and produced some cloud scans, so some fairly reliable 3D models of large poorly tracking spaces, things like car parks which are just in the worst conditions tracking wise on a construction site, and used those scans as a ground truth for evaluating the precision of the HoloLens. So, if when you see the scan through the HoloLens and it matches up with the physical environment then you know you have reliable precision. We're developing systems for placing these fiducial markers. So, in this case it's literally just QR codes which arbitrarily are placed in 3D space. We're developing systems for essentially calculating their exact, precise known coordinates and then using those to adjust for the drift in the HoloLens. So, what you see here, some point clouds viewed through the HoloLens and those point clouds are pretty perfectly registering to their physical spaces, because we're managing to adjust for the drift.

So, this is really early days, but we're expecting that pretty soon, HoloLens applications are just going to be precise. They'll be precise and reliable, or as precise and reliable as just any old human error in taking any other form of measurement on a construction site. so, we're extremely excited by the implications for that.

Last thing that I wanted to make a quick plug for is we're doing some work with remote publishing from Rhino. So, being able to publish Rhino models to the web. If you're interested in that, just shoot me an email after this. We're looking for some Beta testers, so thank you very much for your time and I'll take some questions.

Paul: Thank you Gwyll. Just show my screen. Great presentation. So, first question up was, you're working with Rhino 7 now?

Gwyll: Yes, everything works with Rhino 7 which is exciting.

Paul: Great. So, how effectively could those brickies we saw, work as a team? There's a question about, what about them working independently and how well did they come together as a team? Perhaps you could foresee some issues there and how did that work practically and on site?

Gwyll: Yes, so there's two disclosures to make here. I never actually went on site, because while that project was happening, I was building the pavilion. Couldn't be in two places at once. But there is a video on our Vimeo page which has a whole load of footage captured through the headsets while the bricklayers are working, and there's a few really interesting insights there about exactly this question, how they worked together in mixed reality. I think it worked fantastically well. Because the brickies were able to use the mixed reality documentation as a ground truth, they were often doing things like just calling one another other saying, do you see what I see? Is this right to you? And they'd work through issues really quickly. So, rather than needing to call the one guy on site who did this set up and he might be on another job, call him up, get him to come over, check something, because all the brickies are arguing about whether it's right or not, everybody could just see whether it was right. So, that expertise became distributed across the whole team, and there are several examples of that being a good way to resolve issues pretty much before they came up. Another thing that happened which is really interesting was working with other trades on site. So, every other trade in the hospital wanted to have a go of the HoloLens to find out what these brickies were doing wearing this sci fi headset. That was a real draw card. What we found was that the other trades were often needing to change the brickwork basically. They put in a pipe in the wrong spot or something like that, and it was punching right through the brickwork that the brickies had done. They were able to resolve those issues really efficiently as well, because they could put on a headset, they would see where the brickwork was about to be built. They could see where the guy wanted to place his pipe, and then you

could see, that's going to punch through the brick wall again, so let's resolve that before we build a brick wall, rather than afterwards. So, that was really fantastic. Then the last thing that worked really well was this collaboration between guys wearing the headsets and not wearing the headset. So, you would have these impromptu hybrid teams of people doing fairly manual labour, pushing wheelbarrows around and things like that and whoever was wearing the headset at the time just doing brick placement. So, normally you would be doing a bit more of each of those tasks all the time on site. They were sort of specialising which was fascinating to see. So, it seemed like they just naturally worked together really well in mixed reality.

Paul: It sounds like there were some unforeseen benefits as well then. Okay. Can you talk a little bit about depth perception with the AR setting out markers? I am imagining it is a bit like trying to move something in 3D space, but only viewing it in one Rhino window?

Steph: I think Kevin meant timbers not markers.

Gwyll: If it's timbers or markers, they are two different things. It's a really good question. It would have been impossible to steam bend those pieces of timber using a mobile phone looking at the same thing. So, those videos that I showed of the steam bending process, they were all filmed through a mobile phone, but you can't use the mobile phone to form three dimensional curves precisely, because you don't have depth perception. So, it would look right from one view, and then as soon as you move the camera of the phone, you'll realise it's out in the depth axis.

With the HoloLens, you don't have that problem. It's far easier to just depth. It still isn't perfect because you only have one focal plane on the headset right now. So, this is one of the ways that the hardware is going to improve. So, it takes a little bit of skill and actually, it's much easier we found to use the HoloLens for correctly judging depth when things are a metre and a half away from you. If they're closer than that, it becomes more difficult to focus on the holograms, and if they're further away than that, it just becomes slightly harder to judge depth. But it's worlds away from the mobile phone experience. Hopefully that answers the question.

Paul: Yes, it sounded as if Kevin had some first hand experience of that perhaps. So, have you had any experience of Fologram being experienced outside of the AEC marketplace and if so, where and what industries?

Gwyll: Yes, we have. Our focus is on AEC, largely because that's a significant chunk of the Rhino database, is AEC. But anyone that uses Rhino can pretty easily work with Fologram. So, there's been... without wanting to name names, we've got clients from the automotive industry, or everything from naval architecture through to product design and development. You can probably imagine if someone is working with Rhino, then they might have tried Fologram. Our focus right now is definitely on, as I mentioned at the start of the presentation, it's on facilitating work. So, we're really interested in applications of mixed reality, where you're using the headset while doing some other tasks, some probably manual tasks and at the moment, that's really looking at trades like bricklaying or other trades like concrete formwork or rebar placement or things like that. But you know, it could extend to really anyone that is doing manufacturing.

Paul: Question from Edward. I believe the question is, when did all of this start for you? Was it a research project? Where did it first begin?

Gwyll: Good question. If you... you can probably find some longer talks we've done on YouTube and things like that, where we unpack that a little more. The really short answer is,

we were working a lot with robots at [RMIT](#) and we were trying to teach those robots to be like human crafts people. So, to see the material that they were working with and respond to it in real time, and then HoloLens came out and we realised that oh, hang on, we don't need robots anymore. We can build all of these really complex structures that we were interested in building. We can realise all our designs. We were designing things that were really complex, just by hand now, because we have access to these really precise floor models. So, it started as a research project at the university. We thought that research project was going to have far more impact in the industry than continuing on as lab based research. So, we realised, well now we own the IP and started a company.

Paul: Thank you. Another question from Viorelle. Are there other softwares that you're integrating with that assist with the calculations, for example with wind resistance? Now I suppose as you're working with Grasshopper, there's going to be many options within Grasshopper that could allow all sorts of different types of analysis, including wind resistance. Any particular experience there Gwyll?

Gwyll: Yes, it's a really good question. So, one of the most exciting things about supporting Grasshopper, is just the plug in ecosystem. So, like anything you can do in Grasshopper, you'll also be able to do well, integrate with mixed reality and Fologram. Fologram is a pattern. How it works, you can stream your geometry from Grasshopper, to the headset so you can see it, and then you can stream your gestures and how you interact with that geometry on the headset, back in to Grasshopper to affect your parametric models. So, if you're doing something with wind resistance or what have you, you could visualise that wind resistance in mixed reality, maybe it's scale on a desk or one to one on site somewhere, then you could also do things like building simple user interfaces. So, changing the various parameters in your simulation and immediately seeing the effect on the HoloLens. All of that is possible, definitely with Fologram. We always describe Fologram as a prototyping tool though. It's going to be really quick to set that up in Fologram, and really quick to check it out on the phone or the HoloLens. If this application then needs to be really high performance, like say you want to view things at 60 frames a second, because animation is really important, Grasshopper is not an animation software. It's like an overhead to recalculating a Grasshopper solution. So, you might do all the prototyping in Fologram, and then realise, there's a fantastic use case for this. Then you would go invest all the time in doing your own custom application in Unity for instance, so you can see those two things as being... or custom integration with some other wind resistance software or whatever it might be. So, Fologram is great for testing out ideas and it will just work with any plug in that works with Grasshopper.

Paul: Steph I was going to suggest, if Oliver is still there, can we bring him in? I imagine he may have questions for Gwyll? I'll carry on with the next question.

Oliver: I am still here.

Paul: So, next question, do you think improvement with the focal lens will improve accuracy and reduce tolerances?

Gwyll: With the focal length, you mean with regard to depth perception, if I understand the question correctly?

Paul: Yes, it is from the same person so it must be.

Gwyll: I think it will. Right now, a lot of the error we have with the HoloLens in terms of precision is caused by the hologram that you see drifting, moving relative to where it should be in physical space. So, you place it, initially it will be right and then as you walk further

away from where you placed it, the hologram will drift. You'll see the virtual and physical don't overlap anymore. It's unreliable. As we begin to just overcome that problem with marker based solutions like we've shown, then the only cause of imprecision is going to be human error. So, incorrectly perceiving where a hologram is and that actually will be much more difficult to overcome I think. It's probably going to be... as the resolutions of the screens get better, as you have variable focal length, so hopefully improve that as people just get better at using them, and I think Oliver has shown a lot of, or made a pretty good argument for more ubiquitous mixed reality technology. As people just wear their iPhones on their face, rather than having them in their pocket, it'll become a natural way of interfacing with 3D content. You won't look at it on a screen, that would be really weird. Instead you'll just see everything in 3D as it actually is. This idea of projecting 3D content back to 2D space, either in the form of a drawing, or building buildings or in the form of a screen for viewing models, is going to be really archaic.

Paul: There was one other question and then if there's any other conversation that can happen, that would be great. So, question from Mikail. If other big companies like Apple and Facebook come out with consumer AR glasses in a few years, how much of our tooling and scripting could survive or transfer to these other platforms?

Oliver: It's an interesting one in the sense that there's an inevitability that the key market players are going to end up dominating these industries and it will be interesting to see whether everything gets folded in to them through mergers and acquisitions or whether things do stay alive as standalone technologies as themselves. But I don't know. I think there's probably enough competition in the market that you'll have ubiquitous... a simple case and point, which is I've been interested in following what Epic and Unreal have been doing and thinking how that can be applied to Apple smart glasses, but then of course, Apple and Epic fall out and then where does that leave us? But, if the Epic stuff is actually being streamed via the web, and the Apple stuff is just the display device, then it ends up being quite agnostic. So, I think it's going to be a bit horses for courses. And also I don't think big companies like Microsoft and Apple, although they've got loads and loads of people doing loads and loads of stuff supposedly, I don't think they're really focused on anything other than mass consumer products. HoloLens is an interesting little offshoot of Microsoft, but obviously it's not a core technology for them. So, I think it does leave, most of the development gets done by third party independent developers. So, I would hope there is still space for those people to still operate and they don't get swallowed up, and even if they do, it's likely that the standards... a big company is going to buy a small company because they're interested in their IP and their standard and therefore, that then gets sucked in to the food chain of the larger market. But I don't know what it's like, and it's interesting to see what it's like in AEC. But in broadcast stuff I've been looking at, I don't think you can place your bet on any one tech being dominant or surviving in five to ten years. I think there's really not such a Wild West, but such a rapidly evolving market that it's almost impossible to say there's going to be a right horse to back.

Paul: Okay. I don't see any missed questions there. So, now it's a matter of thanking everybody. So, thank you Oliver. Thank you Gwyll, especially to Gwyll because I think he had to get up at something like 5am for us. Special thanks Will. Last time it was at Grimshaw's offices in London, just over two years ago, so that was a little while. So, I hope to see you back in London again at some point.

Gwyll: Yes, me too, when we're allowed.