xR StOries

WHAT IS VIRTUAL PRODUCTION?

AN EXPLAINER & RESEARCH AGENDA

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About XR Stories

XR Stories supports research and development for companies working in cutting-edge digital technologies in the Yorkshire and Humber region. We do this through a programme of funding, research collaboration and connection. We work across film, TV, games, media arts, heritage, advertising and technology to champion a new future in storytelling.

XR Stories is putting the innovative and dynamic digital storytelling community of our region at the front of the global creative and cultural landscape. We draw together the University of York's research excellence and a strong business focus. We are finding new ways to tell new stories to new audiences.

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1. INTRODUCTION

Virtual production harnesses the power of virtualising technologies to create digital environments in, and through which film and television can be made. In combination, these technologies offer more flexibility to filmmakers and the potential to cut carbon emissions. But while the technologies at the centre of virtual production are not new, their application in combination with each other is generating new approaches to production which are evolving fast.

In this report, we highlight the prominent technologies involved in virtual production and how these have been used in three approaches to virtual production: live action green/blue screen, entirely virtual worlds and LED volume virtual production. The report then goes on to examine the 'emergent orthodoxies' of virtual production: what the opportunities and challenges associated with virtual production are and how virtual production is changing established production workflows. We conclude by outlining a research agenda for further work on virtual production, posing questions about how the industry and its associated working practices may develop and how virtual production might address skills shortages and equality, diversity and inclusion.

How to define virtual production?

Neatly defining virtual production is not straightforward. The technologies used, the methods applied and uses of virtual production approaches are evolving rapidly. There have been many attempts to define virtual production, including:

'A game-changing development, VP combines virtual and augmented reality with computer generated imagery. All this is made possible by real-time game-engine technology.' (StoryFutures, 2019)

'Virtual production is a broad term referring to a spectrum of computer-aided production and visualization filmmaking methods.' (Kadner, 2019)

'Virtual production uses technology to join the digital world with the physical world in real-time. It enables filmmakers to interact with the digital process in the same ways they interact with live-action production.' (The Virtual Production Glossary, 2022)

Participants in our research defined virtual production as a way of making film and television which harnesses computer generated content that allows real-time visualisation and control of the digital environment in which you are shooting. Importantly, virtual environments are captured 'in camera', rather than added in post-production. Virtual production is made possible by an ecosystem of technologies and workflows which sit at the intersection of established film and TV visual effects and immersive media and technologies. It draws on a range of visualising systems including real-time game engine technology (such as Epic's Unreal Engine or Unity Technologies' Unity engine), virtual and augmented reality

a way of making film and television which harnesses computer generated content that allows real-time visualisation and control of the digital environment in which you are shooting.

systems, motion capture (mo-cap), camera tracking, dynamic lighting, green or blue screen, LED screens and in-camera visual effects.

Methods and Participant Recruitment

This report draws on a mix of secondary materials and primary data including analysis of over 440 secondary sources and interviews with 22 leading industry professionals from around the world. Secondary sources analysed for the project include promotional and educational materials from virtual production software developers and equipment manufacturers; behind-the-scenes featurettes of productions adopting virtual production techniques; written material by industry professionals and commentators in blogs and industry publications.

To get deeper insights into themes emerging in these secondary sources, and to cut through the hyperbole that is rife in promotional 'behind-the-scenes' looks at virtual production, we also undertook interviews with professionals using virtual production. We spoke to professionals working across the film and TV production chain, from R&D and facilities, through pre-production, production and post-production, to exhibition and distribution. Participants were predominantly drawn from the UK and US, plus other parts of Europe and thus reflect the current geography of the virtual production sector. Interviews were transcribed using Otter.ai, cleaned manually and coded in NVivo alongside written materials and notes from video content. A mix of inductive and deductive coding was used for all materials.

We also attended two industry events which had a focus on virtual production. Following in person networking at these events, follow up emails were sent to the companies and individuals who had been approached during the shows. From these two recruitment strategies, we then snowball sampled additional participants.

Image 1 - Production Park/Xplor's 'brain bar' and LED volume

2. VIRTUAL PRODUCTION TECHNOLOGIES

The range, application and combination of digital technologies used in virtual production marks a shift in the way film and television are made. We can trace the development of this shift through some of the key technologies (and their histories) that enable virtual production approaches.

Game Engines

A game engine is a software development programme which was originally developed to create video games. However, game engines are now being used for different forms of visualisation and collaboration including virtual production. Game engines work by laying a framework which allows the user to create something more easily than if they had to make something for scratch. This framework for creation varies across different game engine creators but typically includes a 2D or 3D rendering engine. The two market-leading game engines are Unreal Engine, which was created by Epic Games and Unity, which was created by Unity Technologies (Perforce, 2022).

Achieving Parallax

Virtual production involves connecting real time game engine technology to surrounding LED screens. Game engine plug-ins (such as Epic's nDisplay technology) distribute the rendering of each camera frame across a network of machines – allowing each machine to render just a small part of each frame. The rendered images are then displayed on a number of display machines via cluster nodes - which specify which 'windows' or viewpoints are assigned to each computer (Dalkian, 2019). A virtual camera updates to match the perspective and parallax which the physical camera records on set. Parallax is the perceptual difference in an object's position when it is seen from different points of view. For virtual production, trackers and computers calculate the correct relative position of an object to the position of the camera in the real world in order to create accurate parallax (Goossen, 2022). The game engine matches the physical camera coordinates to that of the internal virtual camera within the virtual environment allowing the viewpoint of the virtual camera to be rendered and displayed on the LED wall. This synchronisation is commonly referred to as 'Simulcam' (Kavakli and Cremona, 2022).

Motion Capture ('mo-cap')

LED volumes need to have a motion-capture (or 'mo-cap') system in order to be aware of where the physical camera is and how it is moving to ensure appropriate parallax on the volume (Kavakli and Cremona, 2022). The movements of the paired virtual and physical cameras are rendered in real time, allowing the perspective of the scene to move with the camera angles (Kavakli and Cremona, 2022). Seamlessly displaying high quality imagery in LED volumes and achieving a convincing parallax effect requires the combination of complementary technologies (Goossen, 2022). For example, the software used to synchronise multi-projector displays and auto-alignment systems used in the aviation industry and military flight simulation systems, have been adapted for use in virtual production motion capture systems (Dalkian, 2019).

Blue or Green Screen

Many film and TV productions utilise green

or blue screen backdrops that allow CGI (computer generated imagery) environments to be added in post-production (Giardina, 2017). In virtual production, green screens allow real-time rendering of virtual worlds as the live action occurs in a studio, rather than being added in post-production (Holben, 2020).

Live Action Green/Blue Screen

The Jungle Book (2016) was a massive step forward in testing virtual production technologies. Neel Sethi who played Mowgli was filmed on a blue-screen stage and the film was directed as if it were traditional live action, but the jungle was in fact, created in computer graphics (CG). The virtual world of the jungle was then combined with this live action, physical sets, motion capture and visual effects (VFX) to create what we see on screen in the film (Animatrik, 2017). Prior to shooting with actors, block animation for Mowgli and other characters was created along with a virtual environment. This allowed the filmmakers to prepare for shooting in the pre-visualised environments. Characters could then be played back in real-time, allowing cast and crew to see the combination of virtual worlds and human performers on monitors (Giardina, 2017).

LED Volumes

Major advancements in LED panel technology, developed in the live events field and combined with technologies from the aviation industry and military flight simulation systems, have enabled virtual production using large walls of LED screens called volumes (Image 2). Virtual environments are projected onto the LED screens in camera-ready quality. The often large size of these LED volumes allows the use of physical props and sets in conjunction with virtual environments, and are typically big enough for cast and crew to operate in.

LED volumes harness volumetric capture technologies which allow tracking and synchronisation of cameras, lights and the virtual environments displayed on the LED panels. Video games engines are used to control virtual sets and environments and can be combined with sections of greenscreen for compositing other elements if VFX work is required in post-production. The majority of the VFX work with LED screens is captured in final-pixel in-camera,

Image 2 - 'Icarus' by Northern Ballet using Production Park's LED volume (image courtesy of Northern Ballet)

however, thus reducing the amount of work which needs to be completed in post-production (Unreal Engine, 2019).

LED screens for virtual backgrounds

The Mandalorian (2019) was shot in an LED volume and has become the poster-child for LED based virtual production. The Mandalorian was filmed on one of the largest LED volumes in operation – ILM's 'The Volume' - a 20-foot-tall and 75-foot-long set of LED screens (Antunes, 2021). The Volume' spans 270 degrees and can immerse both the production crew and the cast in a moving CGI environment, mimicking the immersion facilitated by VR (Winter, 2021).

Virtual Reality (VR)

VR is typically experienced using a headset (such as Oculus Rift or Google Cardboard) with headphones and involves experiencing some degree of virtual realm or 'reality'. VR technologies enable filmmakers to be able to scout a digital version of a real place or construct a virtual location to visualise a scene to plan the filming process - allowing for real-time collaboration across the world. VR platforms have also been used to run virtual production systems, with trackers on cameras, props and real spaces used to provide the tracking needed to accurately combine movements and filming angles in the physical world with virtual environments (Winter, 2021).

Entirely Virtual Worlds

The Lion King (2019) was shot in a 100 mile-wide virtual world which the cast and crew were able to freely explore through the use of VR headsets. This virtual world was created using traditional animation and modelling tools, such as Maya and translated into a video game engine, Unity, to create the explorable virtual environment (Clarke, 2020). This pre-visualisation allowed the director, cinematographer and camera team to best understand where to shoot from. For final shooting, the crew used virtual cameras linked to tracker-enabled physical camera rigs to move around the virtual set. The 3D path of the camera was tracked and reflected inside the virtual world (Summers, 2019).

Augmented Reality (AR)

Augmented Reality (AR) enhances the user's view of their surroundings by overlaying it with digital objects in real time. Augmented Reality is different to Virtual Reality (VR) as AR adds to real world experiences rather than creating whole new 3D worlds - virtual information is simply placed on top of the real world to enhance the user's experience (Gillis, 2022). In AR, digital overlays are typically viewed through a device (such as a smartphone or glasses). Pokemon Go is perhaps the most well known application of augmented reality for smartphones. Users view and 'collect' digital Pokemon which are overlaid on real world locations through their phone (Wingfield and Isaac, 2016).

3. EMERGENT ORTHODOXIES

There are a series of emergent orthodoxies about what virtual production can be used for, what it can't do and what it might allow filmmakers to achieve in the future. This section of the report focuses on exploring these emergent orthodoxies and examines the opportunities and challenges professionals across the film and TV industry are discussing. We deliberately use the term emergent as the arguments for and against virtual production and the benefits of it, are contextual and dynamic.

Efficiencies and Practicalities

Lighting

When using LED volumes, LED panels can provide most or even all of the lighting needed for a set. The LED lighting can be controlled from a computer and doesn't require as many physical lights on stage (Bickerton, 2022). From a practical shooting standpoint then, crews are able to shoot environments with particular lighting (such as dusk or dawn) for as long as they need and alter the environment without needing to re-rig lights. Shooting in a volume also limits the interference from outside issues such as the changes in lighting or noise interference ruining a shot (Creamer, 2022).

"Sunset all day!"

Working with virtual environments running through game engines means scenery can also be modified relatively quickly (Slater, 2021). Entire virtual sets can be switched quickly and the composition of digital environments (e.g. rocks, trees, buildings, the position of light sources) can be altered, added, manipulated or removed. Computer control of LED panels also allows for reshooting at a later date as settings are recorded and can be recreated with ease (Grater, 2021).

Technical Breakdown

Virtual production technologies are still in their infancy and crew are still learning virtual production techniques. Running virtual production smoothly is not straightforward and it is likely that users of the technology will experience some form of technical breakdown during a virtual production shoot.

"I wouldn't feel comfortable taking a client into the volume at the moment due to the immaturity of the tech"

(Founder, film production company)

Technical Limitations of Lighting

"It will crash..."

LED panels are unable to capture all types of lighting. Hard directional lighting (such as the midday sun) is the most difficult to mimic. If required, additional practical lighting will have to be added into the set, or those shots will have to be captured away from the LED screen.

'What doesn't work so well is when the sun's right up top...midday sun...you can't get the sheer power of the sun. [That] will never quite look real, never quite look as good...it's better just go shoot outside in the middle of the day.'

(VP supervisor, international VFX company)

Technical Limitations of Display Effects

There are other technological issues associated with using virtual production technology. If the pixel pitch (the distance between the individual LED lights on the screen) is not dense enough, the image displayed on the LED volume may look low resolution or moire patterns may become visible (Kadnar, 2021).

Some LED panels are also not designed to act as lighting sources and they can cause issues such as metamerism (the effect of the visual appearance of an object changing as a result of the spectrum of light illuminating it). Metamerism can result in unrealistic flesh tones or unwanted colour shifts on costumes, which detracts from the believability of the in-camera effects (Kadner, 2021).

Interoperability

At present it is difficult for data to move across multiple platforms, limiting the amount of virtual production integration which can be achieved. Interoperability - that is the ability of computer products or systems to connect and exchange information between one another - is therefore a key challenge of virtual production at present (Burns, 2021).

Latency

Another challenge of virtual production is issues of latency. Latency is where there is a slight delay from moving the camera to the perspective updating on the volume. This is usually only noticeable with very fast camera movements.

'At one point, at the beginning of last year, when we started that project, you had the director in LA, you had a senior producer out in Hawaii, that one was quite challenging for latency'

(Virtual production engineer, immersive software company)

"...it's pricey"

Cost of LED Volumes

The cost of creating an LED studio or renting an LED studio space - especially when compared to traditional methods such as green screen or shooting on location - means that lower budget productions are less able to adopt LED based virtual production technology. This means that LED volumes and LED based virtual production studios are often built and owned by large corporations.

'We still have the whole LED wall, which is quite pricey. But I think it's pricey now because there are only a few players in the game but I know how much those things cost to produce. They don't cost that much, but I think they cost probably 800 bucks a panel, but it's selling for 2400 bucks a panel. So that's a, what is that? 300% markup?'

(Virtual art department supervisor, global streaming service)

Lowered Post-Production Cost

Displaying a real time set on LED walls removes the need for the majority of green screen required on set. This is a cost-saving opportunity because green screen tends to create reflections, with the actors and objects often 'spilled' with glare. The post-production team then has to invest time and effort into removing the 'green spill' glare, which can be a costly process (Business Matters, 2022).

Improved environmental sustainability through reduced need to travel on-location

Virtual production technology can reduce, or even remove, the need for travel associated with location scouting and for cast and crew to shoot on location.

'The numbers are pretty stark in how much the CO2 output is for sending maybe 1000 people [on] to set with all of the equipment that's needed to go and shoot on location. It's huge in comparison to what it takes to

run you know, even a large LED volume for six months and have maybe 100 people on location. I think that it will only improve as well, because of those efficiencies improving, right?'

(Dept head, graphics processing unit manufacturer)

This could create significant carbon savings given that "transport has the largest impact in terms of carbon emissions, accounting for just over 50% of total emissions for tentpole productions" (Arup, 2020: 6).

Improved environmental sustainability through reduced wastage of physical sets

"transport...account[s] for just over 50% of total emissions for tentpole productions"

Pre-visualisation tools allow the specifications for physical sets to be tested in virtual environments and positioning, size and interaction perfected. Doing so reduces the need for physical mock-ups before final construction starts. Virtual production also reduces the need for physical sets. Tangible set elements and props remain in use for LED volume and green screen virtual production, however, but there are fewer materials used overall.

Increased energy usage reducing environmental sustainability

Running virtual production set-ups require large amounts of energy usage - as energy is needed to power the LED volumes, the game engines and the media players. In addition to this, large amounts of energy is also used to store data in cloud servers and to power render farms. Yet, as articulated by this director of virtual production for a leading AV company, the sustainability claims of virtual production remain largely unclear and contested. This uncertainty is in part due to the lack of systematic evidence around the environmental impacts of virtual production.

'So there's this spinning of sustainability [claims] where some people will be like, "Yeah it's super sustainable, no more travel costs." And then you've got someone over there like, "Yeah, well, it's pumping out all that electricity, and we had to reshoot and...."'

(Director of virtual production, audio-visual technology company)

Issues of environmental sustainability along the virtual production supply chain

Issues around the potential environmental credentials of virtual production become even more stark when we focus on the potential environmental impacts along the virtual production supply chain. For example, the environmental costs of extracting the raw materials, manufacturing the equipment and then disposal once it is outdated. As one participant put it:

"I think we all need to be aware that it's like driving an electric car and still driving the same miles and thinking you save on energy. No, it's just a different type of energy. And if we're really concerned about our ecological system, we also should make these considerations. Start being really honest about the things you do."

(Head of marketing, LED screen manufacturer)

Disruption of Existing Production Pipelines and Workflows

Virtual production is fundamentally disrupting established production pipelines and workflows which have been long established across the film and television industry. This section of the report focuses on examining four key ways in which virtual

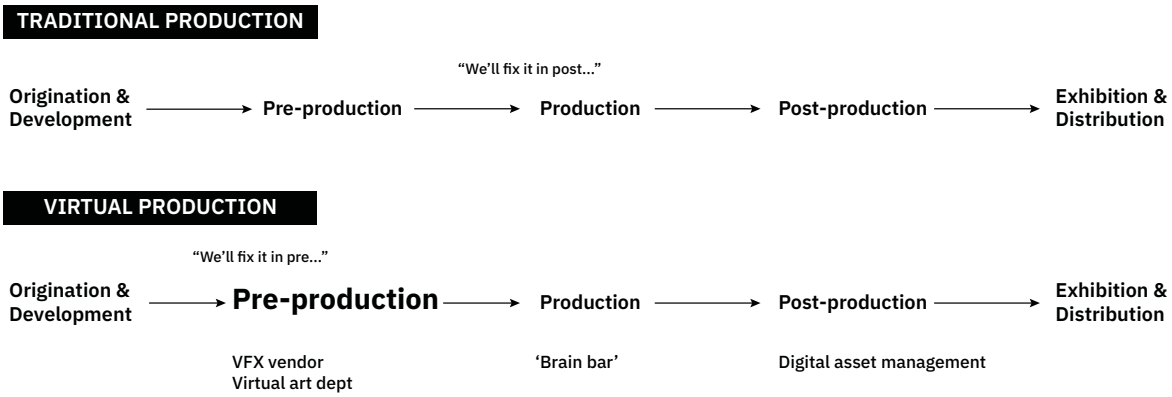

Image 3 - Traditional production and virtual production chains

production is creating change.

Enhanced focus on pre-production

Virtual production is placing enhanced focus on the pre-production stage of the production pipeline. This is because it is within the pre-production stage that virtual environments and characters are created that allow 'scouting' by the cast and crew before official shooting begins. The pre-visualisation of these virtual environments is a crucial stage of pre-production as it allows space for creative questions, ideas or changes. This can include testing shooting angles, safety checks for stunts, virtual lighting setups and prop/set arrangements. In traditional film-making workflows, these decisions would often be fixed after storyboarding or changes made in 'post-production'. Pre-visualisation, then, allows greater flexibility and choice for filmmakers. But this can be a costly process, particularly if crew are unfamiliar with virtual production methods and/or there is not a clear vision about what the production should look like.

Changing the organisation of departments

The greater emphasis on the pre-production - and therefore the shift of time, financial and human resources earlier in the production chain - is changing how departments are organised and at what point they become involved in the production. Within Image 4, we see how the pre-production phase is much longer in virtual production and involves bringing in additional departments (such as the VFX vendor) much earlier in the production process than compared to traditional film and TV production. We also see how virtual production is changing the organisation of traditional production with additional departments such as the virtual art department and the department of technical directors (often referred to as a 'brain bar' including LED panel and game engine operators) created for virtual production.

Enhanced opportunities for remote collaboration and remote working

Virtual production offers the potential for film production to be undertaken remotely, potentially from anywhere with a fast enough internet connection. This has been particularly useful in the context of the COVID-19 pandemic and even with more travel happening, some members of the crew do not need to be in the same room. This is easier for certain tasks (e.g. pre-visualisation in VR) and particular job roles (e.g. VFX artist).

This ethos has the potential to increase accessibility. For example, remote working facilitated through virtual production could bring new opportunities for those facing exclusions from film and TV work. Moreover, the choice to use virtual production rather than shooting on location has upsides those who cannot easily travel:

'In terms of you know, people are starting

Image 4 - Northern Ballet using an LED volume at Production Park, West Yorkshire (image courtesy of Northern Ballet)

young families and mums and getting back into work. I think that's a lot more achievable [with virtual production] because I completely get it if you're a young parent, you don't want to be travelling for three months leaving the baby at home doing all that kind of stuff. But if it's a [virtual production] studio 30 minutes down the road, that's just like going to work'

(Founder, film production company)

Skills shortages and New Entrants

The potentials of virtual production and its influence on established production pipelines and workflows, are limited by existing issues around skills shortages. A recent report by StoryFutures identified that ''hands-on' experience of virtual production and its associated technologies is still relatively rare, with demand for talent and training far outstripping supply' (2021: 3). Virtual production companies are therefore aiming to recruit individuals who have a mixture of on-set experience and game engine or computer programming skills. People from the videogames industry are being 'poached' to work on film and TV projects.

However, the different experiences and industry backgrounds of crew brought together for virtual production can create vocabulary problems and issues of communication. These communication issues are compounded by the newness of the industry and the novelness of the workflows, equipment, software and other technologies meaning new languages, ways of communicating and workflows are constantly being created and then evolving. As the game engine technology is being used to drive the creative vision and ambition of film crews, technical issues are arising from creatives demanding more and more from those in charge of the technology and the relatively new, unestablished virtual production pipelines.

'I think you have to remember that production designers, the director of photography, directors, this is all new to them this technology. So they obviously are excited about it. But there's, it's easy to get some misconceptions about how to use it, what's going to work really well, what's kind of going to work less well or going to be, you know, time consuming or something, and what's going to accelerate their shooting, and whatnot.'

(Virtual production supervisor, international VFX company)

4. THE MEANS OF VIRTUAL PRODUCTION A Research Agenda

The evolution of virtual production is happening quickly and the industry is shifting. We are already beginning to see uneven development between companies and centres of production, and for workers barriers to entry are rising.

Workflows, R+D and Technologies

The rapid development and application of virtual production approaches means there remains a high degree of uncertainty about its future trajectory. Participants in our work predicted the next iterations of what virtual production will look like. One of the key developments is the establishment of 'turnkey solutions' for virtual production: ready-to-go software stacks that can be purchased and implemented by the customer without the need to create bespoke patches to get systems communicating. Turnkey solutions for virtual production will probably involve the consumer paying a set fee to a vendor which covers all components, installation and support for a fully functioning LED volume.

'But there are companies...they have their own proprietary system, software, and hardware that has been very successful. Basically, what they're doing is they're making things a lot more solid, making things turnkey, so that if you want to open up a stage and run a production, you don't have to like go hire all these people who are extremely hard to find at the moment'

(Virtual art department supervisor, global streaming service)

In addition to the establishment of turnkey solutions for virtual production, a move towards more virtualised and/or cloud-based solutions for virtual production is also predicted in the next iteration of the technology. As discussed by this VAD supervisor, the possibilities are beginning to emerge and develop, but at present virtualised workflows remain in their infancy due to the time and expertise needed to create them:

'So, let's say if I'm a VAD [virtual art department] supervisor, I need to hire an artist. This artist is in, whatever, Australia. I would like the ability to easily go into my cloud computing VAD infrastructure and spin them up...So this person will just log into the cloud, the VAD team cloud, and then everything will be all set up for them. Ready to go. The file directory, the software of choice, source control, the right version of Unreal, all of these things will be already solved. That person will just only have to focus on the work. Because right now, if you're an independent studio, it's still very difficult to properly set up remote work for another VAD artist. It's not impossible, but you just have to have the know-how and the time'.

(Virtual art department supervisor, global streaming service)

A key area for researchers in thinking about an emerging research agenda for virtual production then relates to both R&D process and new and altered workflows in virtual production, and who has control over access to new solutions. Researchers need to ask which technologies are resources being focused on? Who is undertaking R&D? Where is R&D being done? How will workflows be integrated in the next iteration of virtual production technologies? How can people access it and what barriers are being erected/removed?

Market Structures - Spillovers, Mergers and Acquisitions

Virtual production has been made possible by mobilising and combining technologies from sectors such as gaming and live events. As these technologies are adapted for use in film and TV, and as these technologies are developed through a film and TV context, new workflows and innovations are being created that have potential use in other sectors. Exploring the spillovers between sectors will allow us to understand how the market structures for these sectors are shifting. Major players have already begun acquiring companies which complement or extend their production offering into the virtual sphere. In 2021, NEP Group acquired Prism Collective, Halon Entertainment and Lux Machina, who all operate different elements of the virtual production pipeline. In 2022, Sony Pictures acquired Pixomondo which operates three LED volumes and has worked on Game of Thrones, Star Trek: Strange New Worlds and House of the Dragon.

First, mergers and acquisitions are beginning to happen as a result of the pervasive skills shortage within the virtual production industry. Instead of waiting for the skills to be developed (i.e. through personal development or dedicated training initiatives), it is quicker for larger companies to simply buy up smaller companies which contain the staff with the skills which they need.

'It's prime for, you know, for startups to get acquired in that way, or even traditional companies, right. We've seen, you know, Lux Machina be acquired by NEP as well as, you know, Prism and the whole, you know, the three or four companies they acquired at the same time to build their virtual production capabilities.... And I think buying knowledge is one of the key parts there, right, because it's an area that for a long time, and still today, we talk about the skills gap in virtual production, right....I think from a commercial point of view, if you see an opportunity for this in your company, then it's going to be quicker for you to go and acquire that skill set than it is to develop it than try and compete with the people who have been doing it for 5- 10 years.'

(Dept head, graphics processing unit manufacturer)

Second, it is quicker for larger companies to acquire companies who have already developed virtual production infrastructure, such as virtual production stages.

'[Acquisitions are] maybe more widespread in virtual production because it's so challenging to upstart it. And so if you think about what's the time to make a stage ...if you look at ILM, and the way that they produce things for Stagecraft, they're averaging 12 to 18 months to make these stages. And so that's a long time, if you're going to start up a company and make four of them [stages], when you could just acquire this, you know, now you get four [stages] right off the bat.'

(Founder, virtual production studio network)

Future research to trace which companies are operating in which parts of the virtual production pipeline and who owns the means of virtual production will be important. Undertaking such research will help understand who has access to virtual production facilities and where monopolistic patterns are forming and where exclusions might occur.

Skills and Training

We highlighted above that new languages are emerging as virtual production techniques emerge and evolve, and because of the influx of workers from industries including gaming and live events. New communication skills and roles are required to manage and oversee the collaboration of these industries into the virtual production sphere. The

newness of virtual production workflows and languages (and the associated skills shortages resulting from the newness of the technology) may increase accessibility by enabling those who have previously been excluded from the film and TV industry to showcase their skills and develop their careers in the virtual production space.

'[Virtual Production] is where you're gonna see the democratisation...anytime you give more capability to creatives, the most creative people shine, that's the meritocracy... as far as you know, with gender equality, with racial discrepancies in the industry with those type of things, I think this is a really good reset, because the industry primarily has, you know, taken shape off of what's happened in the 40s and the 50s. And so you have these generational kind of families in the business that were privileged in many senses...And so now you have this new complex way of doing things. It's the people that hustle and just get after it, you know, they're gonna get ahead and that multiplies. There's a really good.'

(Founder, virtual production studio network)

This perspective was common among participants but it is crucial to acknowledge that undoing the structural inequalities in the screen industries is not a straightforward task, nor will virtual production solve issues overnight. Lack of privilege will remain a key barrier to getting in, and getting on in the sector. There was a genuine belief from participants, however, that we are in a moment where those with the right skills can take advantage of the virtual production skills shortages to get in and get ahead without the usual obstacles.

Mapping the emergence of new skills needs and upskilling of existing crew will be crucial as virtual production develops further. As part of this, it is important to understand who is in the best position to provide those skills and help remove barriers to entry, reduce skilled workers being left behind and closing the skills gap the industry faces.

Equality, Diversity and Inclusion

The remote working opportunities enabled by virtual production and the move towards virtualised processes may widen opportunities for participation in film and TV. ScreenSkills (2021) found that 54% of their survey respondents felt remote working practices would allow them to hire talent from a wider geographical pool domestically and internationally. In particular, the increasing shift towards remote working may enable the virtual production market to become more globalised - and therefore enable workers from marginalised groups and communities, who may have previously been excluded from the centres of film and TV production, to have their skills in virtual production recognised and valued.

'By making virtual production more virtual from a remote perspective, you can actually have like, state of the art talent from Brazil, Africa, wherever, so you're actually making the market more global than it's ever been, which is a beautiful thing. Rather than I have to move to LA for Hollywood, or Vancouver for VFX or the UK for post [production] or whatever. So yeah, it actually opens up, it makes it more accessible in terms of again, minority groups anywhere around the world.'

(Director of virtual production, audio-visual technology company)

This requires a concerted effort from those with the power to choose who gets work, how they are treated and whose work is promoted. We must not be naive and assume virtual production will solve longstanding issues, many of which are rooted in wider societal structures of discrimination and exclusion, but there are opportunities to make some change.

The reduced travel associated with virtual production could also provide better opportunities for people with caring responsibilities to retain their place within the film and TV industry. This is because

shooting in virtual production reduces the need to shoot on location and also reduces the pressure to capture all shoots whilst away as digital places can be created and re-shot within a virtual environment. This is just one barrier, however, and more must be done to address working practices which limit opportunities for people with caring responsibilities and for whom working on location is disabling.

With virtual production still in its infancy, research needs to be undertaken to test assertions about inclusivity and accessibility. Not least because despite the efficiencies virtual production can provide, companies may keep long hours cultures, which act to exclude people with caring responsibilities and disabled people, albeit without the travel (Swords et al., 2022).

Second, there have been repeated claims that virtual production may be 'democratising' because game engine software is open source and therefore free to use. However, the reality is much less simple than this as courses dedicated to learning these technologies are often extremely competitive and oversubscribed.

'You need to learn Maya and Notch as well, pay £1000 more for more education to learn. Well, then you're not making a skills gap accessible, are you? So you're saying there's 40,000 jobs we need to fill out this year or a year for production? And you got 6000 applicants for Unreal Academy and only 50 places? So who's also going to drive that change? How is that making it accessible?'

(Director of virtual production, audio-visual technology company)

In addition, although some of the technologies may be open source, this does not remove many of the barriers which already exist within the film and TV industry. Individuals still require the financial means to buy a powerful enough computer and need time opportunities to be able to upskill or re-skill themselves to levels which are deemed appropriate within the film and TV industries. Moreover, much of the software used in the screen industries is not compatible with screen readers.

Understanding the exclusions, exploitations and discriminations in the film and TV industries in different parts of the world is already a major task, with libraries of work already available on the causes and consequences of deep structural problems. Tracking the impacts of virtual production as it is more widely adopted will involve not only a research effort, but also timely interventions to help people seize the opportunities of a new way of working that might begin to address longstanding issues.

5. FURTHER READING

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