Orbital Virtual Productions - Los Angeles.

THE BROADCAST BRIDGE
Connecting IT to Broadcast

Virtual Production For Broadcast

Part 1 - The Foundations Of Virtual Production

A Themed Content Collection from The Broadcast Bridge

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Themed Content Collection

Contents

Series Overview

By Tony Orme. *Editor at The Broadcast Bridge.*

Virtual Production For Broadcast is a Themed Content Collection which serves as a reference resource for broadcast technologists. It covers the science and practical applications of all aspects of virtual production for broadcast.

Virtual Production is rapidly becoming the workflow of choice in cinematic and episodic TV production. With large-scale multi-location productions there are potential cost benefits but it is the versatility, creative scope and the improved efficiency it can bring to production spaces, that are the compelling forces driving adoption.

The basic principles of back projection and greenscreen have been with us for decades and are already commonplace in TV production, especially in news and sports, but the creative versatility of virtual production brings fundamental technical and creative differences. The technology and techniques of virtual production are also evolving very quickly and there is not yet a standard approach, with different teams establishing their own approach.

Virtual Production For Broadcast provides a deep exploration of the creative techniques, technology and workflow involved. It discusses what currently can and cannot be achieved, with a specific focus on the unique requirements of broadcast production.

It is essential reading for those evaluating incorporating virtual production technology into new studio design and exploring the creative benefits it can bring.

Virtual Production For Broadcast is a four part series:

Part 1. The Foundations Of Virtual Production

Future parts due in 2023:

Part 2. Planning, The Unreal Engine & Virtual Lighting
- Requirements For The Well-planned Virtual Production
- Designing The Virtual World
- Lighting Tools For The Virtual World

Part 3. Creative Image Capture
- Shooting Locations For Virtual Production
- Capturing Objects In 3D
- Motion Capture

Part 4. Uniting The Physical & The Virtual
- Image Based Lighting
- Emerging Technology
- Finishing

Principles, Terminology & Technology

By Phil Rhodes. The Broadcast Bridge.

The technology and techniques of virtual production, from the camera back through the video wall, processors, and rendering servers.

No matter how successful the big effects movies of the last few decades have been, almost nobody becomes involved in the film industry because of a desire to spend hours in a room with bright green walls. That might be why virtual production has become so popular; it might also be that it has contributed so visibly to creatively and financially successful shows. In the end, the draw is that it allows people to shoot as they always have, but with results limited only by imagination that previously took months of visual effects work to create – although there are a few practicalities to bear in mind.

Beginnings and fundamentals

Most new technologies change rapidly soon after introduction, and virtual production is fairly new. Properly displaying an image on a video wall in such a way that it looks right to the camera involves a lot of different disciplines. The camera's position and lens configuration must be tracked, along with any geometric distortion created by that lens. The simulated environment must be prepared, which might mean a matte painting or a fully three-dimensional virtual world with all the considerations of art direction and lighting common to CGI. That environment must be rendered, colour-corrected, and displayed with geometric corrections based on where the camera is and where it's looking.

The mechanical details may be handled by the facility rather than the production, and in many ways the workload is not dissimilar to conventional visual effects – it's just before shooting, as opposed to afterward, which greatly changes the planning process. From the camera crew's perspective, it's reasonable to think of virtual production as an evolution of back projection. That's a technique which goes back at least as far as synchronised sound on film, because the synchronisation technologies which made The Jazz Singer sing also made it possible to synchronise a projector and a camera.

Since then, some spectacular-looking films have used back projection. Kubrick's 2001: A Space Odyssey is a prime example. The back projection effects of Aliens' dropship crash and elevator ride through a huge sci-fi structure mostly hold up to this day. When the Wachowskis chose to use back projection to simulate car journeys through The Matrix's green-tinted faux cityscape, the intention was to create a sense of faint unreality intended to clue the audience into the fact that the characters lived in a faked world. In the end, the effect is so well done that very few people noticed.

Back Projection Becomes Virtual Production

More recent examples of projection cross over with virtual production. Oblivion used craftily front-projected video to create a backdrop around a science-fiction habitat atop an impossible spire. It also allowed that projection to light the scene, something that had only become possible in the modern world of cameras with huge sensitivity (the production was shot on the Sony F65). LED walls are much brighter than most projections, of course, but the benefits are similar.

Oblivion's set was a green screen compositor's nightmare, filled with gauzy, transparent textiles and specular reflections. The benefits of working with a backdrop that's actually visible to the camera can hardly be overstated. Things which would usually be anathema to green screen compositing become desirable ways to sell the effect. Smoke, mist, hair, water, and transparent objects integrate perfectly. Reflections – with some caveats – are effortless. The current interest in vintage lenses for their softness, aberration and distortion can make green screen hard work, but all of those things actively help a virtual production by blending the real and the not-so-real.

An LED wall has more sheer power than almost any other video display technology which has ever existed, and the light it casts on the scene is another huge boon to convincing composites. Tron: Legacy was possibly among the first to use video wall panels, albeit kept out of shot, as lighting devices. Gravity, likewise, used the same technique to depict the fall of light on George Clooney and Sandra Bullock. None of those productions put video wall panels in shot; the technology of the time lacked the resolution to create a convincing backdrop.

As well as being powerful, an LED wall is also far less subject to the problems suffered by either front or back projection when extraneous light falls on the projection screen. A projection screen is white, making stray light hard to deal with. Meanwhile, most of the surface of an LED wall is black, so contrast is much higher and problems harder to see.

The Challenges

That's a good point, though, to accept that there are some caveats to deal with. Despite the huge contrast and high brightness of an LED wall, it is not completely immune to the fall of light; a large proportion of the surface is made not of black paint but of reflective plastic LEDs. Other boundaries include frame rate limits. Nobody's shooting material at a thousand frames per second on a virtual production stage. Certain kinds of reflective surfaces, particularly hard mirrors, can also break the illusion by making it clear that the video wall is much closer than it realistically ought to be.

And while that much-vaunted interactive lighting is enormously effective, the light cast by an LED wall doesn't have the colour quality we would demand from production lighting tools. That means LED wall light is useful only as a way of integrating foreground and background; we must still light conventionally. Image-based lighting techniques allow us to control production lighting devices from individual units to arrays of pixel tubes. The result can be convincing, animated, interactive lighting effects with excellent colour quality.

All of this means that in early 2023 – it's inevitable that taking a new camera department onto a virtual production stage will involve spending some time in test and configuration to ensure things look right on the day, although that's getting easier as time goes by. Mostly, the technical solution on the day will involve a conversation between the camera crew and the video wall specialists. Creating content for the video wall, meanwhile, might have been going on for weeks. As we'll see, collaboration of exactly that kind is key to successful virtual production.

It's a mistake to think that it involves less work per se. It does involve different work, crucially, at different times; a post production workload becomes a pre production workload. Again, that's nothing new; the model unit on Aliens worked simultaneously with the rest of the production to create the background plates that the main unit would need. That's not a complicated requirement, but it is outside the experience of much of the film industry in 2023. The upside is that, in an ideal world, virtual production requires absolutely no special consideration in post production whatsoever.

It does, however, impose an absolutely cast-iron deadline on the people who are preparing the material which will be displayed on the video wall, whether that's footage or a 3D world or a hybrid of the two. Similar workloads exist; they simply exist in different disciplines, and at different times.

Scale And Budget

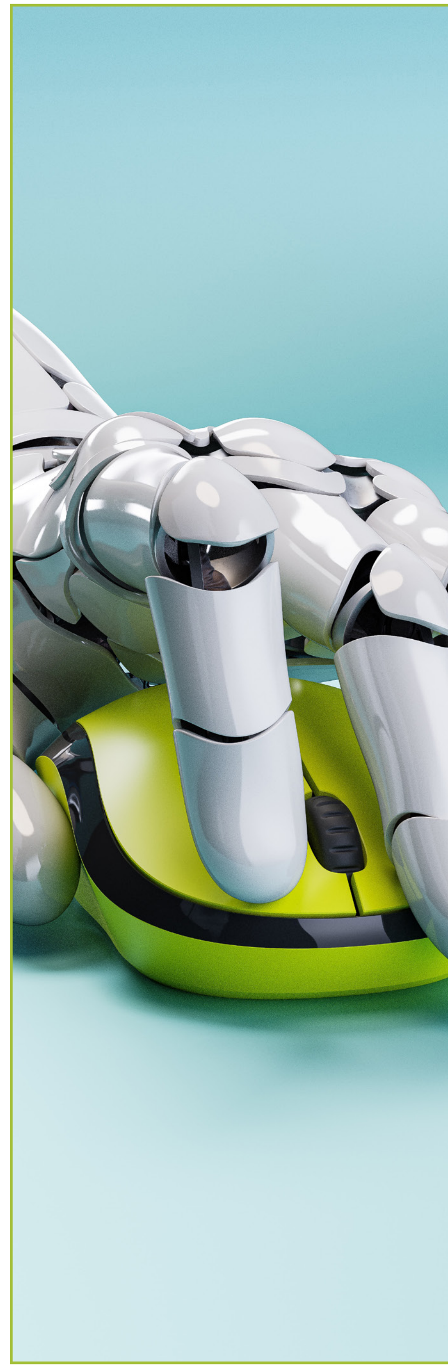
Whether virtual production seems expensive depends very much on the intent. It's perhaps safe to say that it can best save money for productions which were otherwise looking at a considerable spend on moving lots of people to lots of international destinations. It can make expensive things cheaper; whether it can make cheap things even cheaper is a more complicated question.

Still, it's a mistake to assume that every instance of virtual production involves a permanent facility with a vast video wall. Upscale facilities have huge capability, but it's just as possible to rent a small section of LED wall, the appropriate people and equipment to display images on it, and to wheel it into position in the background of a specific shot. The resulting setup has limited scope, though it enjoys all the advantages of virtual production in terms of handling difficult reflective and transparent subjects and avoids the expense of a big facility.

Stable Fundamentals

All of these things are becoming well-established as standard techniques available to film and TV productions. As with any newly emergent technology, though, advanced techniques are evolving almost daily. It's increasingly common to involve motion capture, 3D object scanning, and almost any of the things done by visual effects artists. That might include motion capture, for virtual characters that can react to a live actor in realtime, object scanning and recording, and virtual camera motion techniques which create almost limitless freedom in a 3D world.

There's still far too much variation in the way virtual productions are configured for anyone to create a point-by-point how-to. What flexibility that gives us, though, is fundamental to some of the most advanced tricks that virtual productions can pull off. Still, the fundamentals are likely to remain, and that's what we'll be discussing as the series continues.



Embracing Virtual Production: Unlocking The Power Of LED Screens

By Marina Prak. Marketing Manager at ROE Visual.

How the introduction of LED displays is transforming the creative possibilities of virtual production for broadcasters.

While the film industry has quickly adopted these techniques, broadcast producers and studio technicians seem hesitant to embrace them.

Broadcasters mainly work in a live environment, where the workflow and risks are different and must be addressed. In the current landscape, the broadcast sector is at the crossroads of a promising yet sometimes daunting future characterized by long-awaited media convergence in a genuinely impactful manner.

In this article, we aim to shed light on the benefits of virtual production for live broadcast productions, explicitly focusing on LED screens and the advantages of working with a LED volume.

Understanding Virtual Production

Virtual production combines physical, such as a LED volume, and virtual elements, like AR objects, to create seamless, immersive environments. It enables real-time visualization, which is crucial for live broadcast ecosystems, allowing the director to see all options in the previz. Furthermore, it revolutionizes how presenters interact with their surroundings on stage, providing numerous advantages.

Virtual production enhances the presenter's experience, as they can seamlessly interact with the content or AR elements in a natural way while on stage, improving storytelling and audience engagement. Virtual production enables quick changes to the virtual set design, providing presenters with versatile and customizable backgrounds that align with the delivered content.

Virtual production can also streamline the production workflow and make it more efficient. It enables production teams to make instant changes to the virtual environment, accelerating the turnaround time and allowing for quicker content delivery to the audience.

Virtual set design empowers production teams with endless possibilities, enabling them to create captivating, on-brand visuals that enhance their message.

Virtual production encourages creativity and innovation, allowing production teams to push boundaries and explore new ways of engaging with the audience through immersive technologies.

By embracing virtual production, live broadcasts can transcend traditional limitations and deliver captivating and dynamic content to audiences worldwide.

Future-ready Storytelling

At the heart of broadcasting lies the art of captivating audiences through compelling storytelling. The strength of your stories is paramount to captivate and enthrall viewers. Utilizing dynamic display solutions becomes an essential technological aspect in elevating the viewer experience. By integrating visuals and interactive content, programs are infused with life, enabling stories to unfold in a truly immersive manner. Recent studies show that graphics are increasingly crucial in how people consume sports and news shows. Specifically, the younger generation feels more engaged with additional visual elements, which helps them understand the content better.

Today's LED-based solutions are paving the way for exciting opportunities in live broadcast applications, revolutionizing how audiences engage with content. Broadcasters can create unforgettable moments that deeply resonate with their audiences, pushing the boundaries of what is possible in live broadcast entertainment.

The Power of LED Screens in Virtual Production

LED screens are used as the backdrop to display dynamic and realistic backgrounds that enhance the visual appeal of live broadcasts. Designed as modular units, they offer endless flexibility in the design and setup of your studio. While the semi-circular LED volume is more suited for film, the ecosystem of a studio requires a different approach. Elements such as a primary screen, side screens, a desk, or a decorative element, such as a totem, are common elements in any studio environment, delivering engaging and versatile broadcast productions.

During live television broadcasts, time is of the essence, making avoiding delays and downtime a paramount concern.

Display solutions with stable and reliable performance are indispensable for live broadcast applications to ensure seamless operations. An uninterrupted functionality of the LED display is essential as it allows broadcasters to focus on delivering content without disruptions.

Before You Start

Next to impeccable performance, there are key considerations to investigate and discuss with your team before selecting the right LED setup for any studio. While most high-resolution LED panels provide sharp imagery and vibrant colors, specifications, such as pixel pitch, refresh rate, and color depth, must be carefully considered for each setup to deliver the required on-camera output.

Pixel pitch: The move towards finer pixel pitches in LED displays for broadcast environments reflects the industry's pursuit of higher resolution and immersive experiences. While finer pixel pitches offer undeniable advantages in terms of visual clarity and detail, it is essential to assess the specific requirements of each broadcast scenario and strike a balance between the desired level of detail, practicality, viewing distance, content type, and budgetary considerations. By considering these factors, broadcasters can make informed decisions and select the most appropriate pixel pitch for their needs.

Viewing Angle: LED screens with a wide viewing angle ensure that the camera records accurate and consistent colors, matching the colors of the virtual set extension from various shooting positions.

Brightness and Contrast Ratio: These are crucial to maintaining image quality in well-lit studios, ensuring optimal visibility and clarity. High brightness ensures images remain vibrant and visible in high ambient light conditions, while a high contrast ratio preserves details and enhances the depth and richness of the displayed content.

Color accuracy and color gamut: Color accuracy refers to how accurately an LED screen reproduces colors compared to the source or reference. In broadcast productions, maintaining accurate color reproduction is crucial to ensure that the visuals presented to the audience align with the intended artistic vision. Precise color reproduction ensures that on-screen elements, including graphics, virtual sets, and talent appearances, appear natural and visually appealing. Color gamut refers to the range of colors that an LED screen can display, typically represented using color spaces such as RGB or DCI-P3. A wider color gamut expands the spectrum of colors that can be reproduced, resulting in more vibrant and lifelike visuals.

Bit depth, or color depth, describes the amount of information stored in each data pixel. As you increase bit depth, you also increase the number of colors represented, which is important if you want to achieve high color accuracy. In the case of an 8-bit image, each pixel has 8-bits of data per color (RGB), so for each color channel, the pixel has 28 = 256 possible variations. 10-bit would give 210 = 1024 colour variations and 12-bit 212 = 4096.

Genlock is the technique of synchronizing video signals from a signal generator or similar source to the other content resources. One of the most common Genlock applications is to synchronize cameras. Genlock syncs video signals or pixels to an external synchronization source while synchronizing the SDI output to an external source. The SDI refresh rate is determined with the help of a sync source.

A feature not often known is that a LED wall also can provide natural lighting integration. The ability to display virtual environments on LED screens allows for realistic lighting integration, ensuring that talent appears seamlessly integrated into the virtual set.

Refresh and scan rates are critical technical specifications when working with LED panels in broadcast productions. Refresh rate refers to how often an LED panel updates the displayed image per second, measured in Hertz (Hz). A higher refresh rate means the panel can update the image more frequently, resulting in smoother visuals with reduced motion blur. For (live) broadcast productions, a high refresh rate is crucial to maintain clarity, especially during fast-paced action sequences or camera movements. In contrast, a lower refresh rate can produce visible artifacts, such as ghosting or stuttering.

Scan rate, known as the scanning method, scan mux, or multiplexing, determines how an LED panel is addressed to display the image. One driver IC output pin drives multiple LEDs. This is done by completing the circuit for each LED one by one (multiplexing). During one refresh cycle, all the LEDs will light up once. Typical scan rates are 12:1 or 8:1. Where a lower scan rate will provide better results.

For broadcast productions, it's essential to understand the significance of refresh and scan rates:

- Clarity and Detail: A high refresh rate ensures that fast-moving objects or camera pans appear smooth and detailed, enhancing the visual quality of live broadcasts.
- Reduction of Motion Blur: A higher refresh rate minimizes motion blur, allowing for crisp, sharp visuals during dynamic scenes or camera movements.
- Camera Compatibility: It is essential to consider the compatibility of the camera's frame rate with the panel's refresh rate to avoid any synchronization issues or artifacts.
- Seamless Integration: LED panels with appropriate refresh rates and

scan methods ensure that the virtual elements seamlessly blend with the physical aspects, creating a cohesive and immersive visual experience.

- Enhanced Viewing Experience: By utilizing LED panels with optimal refresh rates and scan methods, broadcasters can deliver high-quality visuals to the audience, resulting in a more engaging and satisfying viewing experience.

Pain Points To Consider

Scan Lines: Virtual production workflows address scan line issues by utilizing high-resolution LED screens and advanced camera settings.

The color shift in a LED panel refers to the undesirable change in color accuracy and consistency that can occur when viewing the display from different angles. It deviates from the intended color reproduction, impacting the displayed content's overall visual quality and fidelity.

The larger your viewing angle, the more consistent the image quality will be.

Moiré in a LED panel refers to the unwanted interference pattern or shimmering effect that can occur when displaying certain patterns or textures on the screen. It is caused by the interaction between the LED panel's pixel structure and the displayed pattern, resulting in an undesirable distortion or visual artefact. You can reduce the moiré effect by using a smaller pixel pitch.

Latency issues can disrupt the real-time interaction between the virtual and physical elements. The delay between camera movement or actor action and the corresponding visual response on the LED wall can create a noticeable lag, impacting the overall synchronization. This latency can affect the immersion and responsiveness of the virtual environment, requiring careful optimization and synchronization techniques for seamless integration.

ROE Visual is a key enabling technology partner with industry innovators like GhostFrame, helping to bring about a transformative shift in utilizing multi-camera setups within virtual production for broadcast.

"When we first thought of using Multicam on a live broadcast virtual production, we thought it would be impossible. GhostFrame technology was the secret sauce to making the live broadcast happen." Zac Fileds – Senior VP Graphics Technology & Integration FOX Sports

Testing, Genlock, and Syncing: Successful virtual production productions integrate workflows and hardware seamlessly, emphasizing thorough testing, genlock, and syncing processes.

Achieving exceptional results in your application goes beyond simply assembling an LED screen. The harmonious interplay between the LED panel, processing, and camera brings breathtaking outcomes. The dynamic game engine drives the pixels on the LED wall in real-time, necessitating ample capacity in the driver IC to ensure optimal performance. Consequently, selecting the right LED panel for your specific application is paramount. Engaging in upfront discussions with specialists is highly recommended, allowing them to understand your unique needs and requirements. This collaboration ensures you receive expert advice on choosing the ideal LED panel tailored to your application.

Overcoming Challenges & Embracing The Future

Education, testing, and ways to familiarize yourself with virtual production technology's challenges and powerful possibilities are the best way forward. Many world-leading manufacturers involved in rolling out this technology, from media servers to camera tracking, to LED and LED processing, provide knowledge transfer through white papers, training, and demonstrations. Engage with technology providers and industry experts specializing in virtual production, and do not hesitate to seek guidance and support. Start small by gradually incorporating virtual production elements into your live broadcast production, experimenting with different setups, and refining your workflow.

Conclusion

The time is ripe for broadcast producers and studio technicians to embrace the incredible advantages of virtual production. Virtual production techniques, leveraging the power of LED screens and GhostFrame technology, hold immense potential for transforming live broadcast productions.

Broadcast producers and studio technicians can unlock new creative horizons and deliver visually stunning content by harnessing the power of LED screens.

Camera Setup, Tracking & Lens Data

By Phil Rhodes. The Broadcast Bridge.

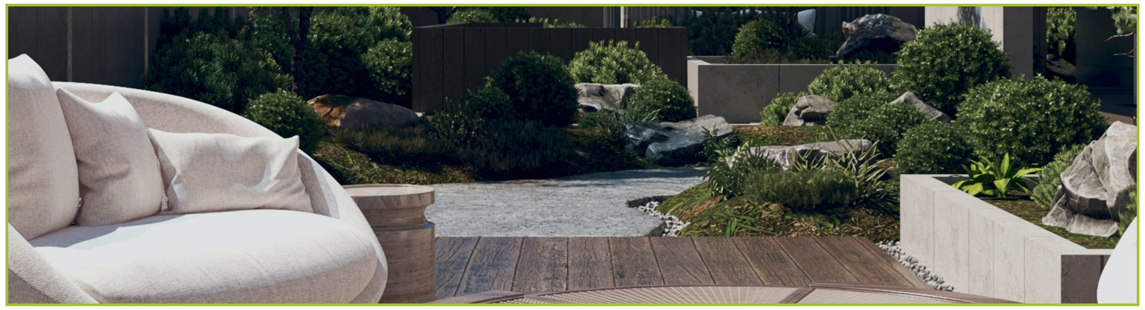
Although we're freer to use the camera and lens combination of our choice than we would be with traditional VFX techniques such as greenscreen, we discuss the changes that do need to happen around the camera, what information we generate, and how that informs the pictures rendered on the screen.

With the camera naturally at the centre of film and TV production work, a big priority for visual effects techniques is to create spectacular results without imposing too much technology on the camera department. At the same time, if there's a single, overwhelming advantage of virtual production, it's exactly that: cinematographers and their crews should be able to shoot advanced visual effects while working in exactly the same way they'd approach an everyday, real-world scene.

Some of the most interesting techniques, however, mean real-time rendering of three-dimensional environments, and displaying them on the video wall with correct perspective for the current camera position. To do that, the system needs to know where the camera is and how the lens is configured. Tracking that information might mean attaching things to the camera, and virtual production stages must make everything work without compromising the ease and convenience that virtual production can and should give us.

When There's No Need To Track

There are a many different ways to track a camera and lens, although one of the fundamental truths of virtual production is that not every setup actually requires a tracked camera. Depending on exactly what's being done, the phrase "virtual production" can cross over with "back projection" (or, similarly, front projection). Using video as part of a scene, whether it's projected or displayed on an LED wall, yields many of the advantages of virtual production even if it's nothing more than a static image. It's still an in-camera effect, ably handling most types of reflection, the fine details of smoke and hair, and other subjects that green screen may handle less well.



There are limits to how this sort of configuration can be shot – usually, the camera will need to be broadly in front of the video display. Some types of camera motion will reveal the trick, as will specific types of reflection (though that's true for fully three-dimensional, tracked-camera configurations, too). Material to be shown on the video display will need to have been shot in a manner that's suitable for the intended purpose, which can be complicated, and considerations such as colour correction and synchronisation still need to be right. Still, this approach to virtual production hybridised with front or back projection remains very effective, and requires no camera tracking at all.

Tracking Technologies

Sometimes, virtual productions will need the flexibility in camera position that's only provided by a fully three-dimensional scene, or even a partially three-dimensional scene, perhaps based on modified live-action footage, sometimes termed 2.5D. In that situation, we can rely on some fairly established techniques to create the necessary camera tracking data. Figuring out where something is in three-dimensional space is something that visual effects and games development people have been doing for years. It even appears in consumer technology, with virtual reality headsets capable of tracking their own position so that the wearer's point of view can appear to move through a virtual world (sometimes, those devices can even be pressed into service as virtual production tools).

There are other ways of knowing the position and rotation of the camera, particularly by mounting it on a motion control crane which will put it in a known position to begin with. Tracking the camera, meanwhile, allows for the use of any conventional camera support equipment. The image of an actor performing in a suit covered in reflective tracking markers is familiar to most people, and computer-generated productions have often tracked both the performers and an actual on-set camera to create a virtual camera position which might be used to frame the final shot once a visual effects sequence is rendered. Very similar – or even identical – devices can be used to track cameras, and maybe other objects, for virtual production.

Probably the most commonly-encountered approach to any sort of motion tracking is for an array of cameras – sometimes called witness cameras, to differentiate them from the taking camera – to observe markers. Markers might be simple reflective spheres or patterns such as circular or 2D barcodes. Cameras might be distributed around the outside of the studio to observe markers moving around on the studio floor, often termed 'outside-in' tracking, or mounted on the camera itself to view markers placed around the studio, called 'inside-out' tracking.

Established Technology

None of this technology is unique to virtual production, and many systems are sold as suitable for virtual studio, virtual production, and other 3D graphics work. Inside-out tracking has often been used in applications such as broadcast news studios, allowing virtual objects to appear in a real space. Studios with circular barcodes on the ceiling, often with upward-pointing witness cameras mounted on each studio camera, have been common for over a decade.

Variations include systems which display tracking markers on the virtual production display itself, using the time between frames, when the shutter of the taking camera (whether physical or electronic) is closed. In person, the tracking pattern appears superimposed on the virtual production image. Electronically, the witness cameras can see the tracking markers, while the taking camera can't. The benefit of this is that many virtual

production facilities have a large sweep of LED video wall which creates an area where it can be difficult to place physical tracking markers, potentially compromising the accuracy of the results.

Regardless the configuration, material from the witness cameras will be routed to a computer that's responsible for interpreting their images and calculating positions, which will then pass that position data on to the rendering system. Many purpose-built motion tracking cameras use Ethernet computer networking, to support a large number of cameras with minimal cabling; the image sent is sometimes nothing more than a cluster of black pixels representing markers on a white field. Cameras may have infra-red lighting distributed around the lens – a ring light – and an infra-red pass filter. That creates a clear reflection from markers with a retro-reflective coating, much as a car's headlights illuminate a road sign at night.

The more cameras which can see a marker, the better the track. Common systems can locate a marker in a space tens of metres across with a precision of less than a millimetre.

Lens Data

Knowing where the camera is and where it's pointing is only part of the information a rendering system needs to draw a three-dimensional screen and display it such that it looks correct to the taking camera. It's instinctive that a wider-angle lens, for instance, will mean displaying an image over a wider area of the wall. A zoom lens might mean that changes over time.

Similarly, the focus position of a lens, as well as its aperture setting, will change the way out-of-focus areas of the image are rendered depending on their distance from the camera. The rendering system must simulate that falloff of focus in the virtual world. All that data might be available from inbuilt encoding systems on some lenses (there are two principal standards), or from add-on devices such as a remote follow focus. Technical provisions for retrieving that information from the camera and passing it to the tracking system vary, although it has been common for this information to be used for conventional visual effects for some time.

Lens Geometry

Most people have seen an image produced by a fisheye lens, where straight lines appear bowed. While that's most associated with very wide angle lenses, most lenses have at least some geometric distortion. Often, that's described using terms such as spherical, barrel or pincushion distortion. Even lenses which don't show obvious signs of geometric distortion will generally have at least some; very few (formally, perhaps absolutely no) lenses are entirely rectilinear, or without distortion. That can sometimes be demonstrated by lining up a horizontal or vertical line with the edge of a monitor.

As with many types of visual effects photography, lens geometry can be adjusted-for by shooting test charts, which might mean a chequerboard or grid pattern, allowing a computer to characterise the lens's distortion and correct for it. While this is often effective, different software has different capabilities, and different lenses may create complex distortions that, while subtle, can make alignment difficult. Lens designers often try to correct for these distortions, and the residual distortion left after those corrections can be more complex than just continuous curves. That's especially true for anamorphic lenses, which will have different characteristics in the horizontal and vertical dimensions. Some lenses may exhibit geometric distortion which changes as the focus is altered.

Some lenses, in some circumstances, may have characteristics so complex that they're beyond the ability of the software to correct, potentially creating hard-to-solve alignment problems. Using those lenses in virtual production might be difficult. In general, though, one of the biggest advantages of virtual production is that vintage or unusual lenses with interesting optical characteristics are handled seamlessly. Unusual flares, glow, corner softness, or even optical filtration are a great way to tie the real and virtual parts of the scene together. So, where it's possible to take the time in prep to make difficult lenses work, there are benefits for both the effects and camera teams.

Video Wall Configuration

By Phil Rhodes. The Broadcast Bridge.

How video walls for VP are built in detail. We discuss the fundamentals of the underlying technology as well as techniques to ensure proper colour rendering and avoid flicker while maximising frame rate and dynamic range.

If there's a single enabling technology for virtual production, it's the LED video wall. While they aren't the only type of hardware we might use to create in-camera effects with video images, their performance is hard to beat.

No other type of large-scale display is as bright, and an LED display is not reliant on projecting light onto a screen, making it less subject to the foggy blacks which can be caused by extraneous lighting falling on a white screen surface. That combination of bright highlights and deep shadows minimises the problems common to historical projection techniques, and allows the display to cast meaningful amounts of light on the live-action foreground.

The design of LED walls used in virtual production is broadly similar to those used in advertising or large-scale video display at live events, although important details often vary. Also, the capability of an LED wall is not determined only by the panels. The video signal sent to the wall often uses a common standard such as SDI or HDMI, which is interpreted by a processor before being sent to a plug-in receiver in the panels. It's possible, with care, to rent general-purpose wall components and create temporary setups specific to particular scenes or locations, so long as the capabilities of the resulting video wall are appropriate to the project.

Resolution

With cinema cameras now capable of very high resolution, it's instinctive to assume that the display used for virtual production must have similar resolution. Often that isn't quite true, since the LED wall will often be slightly out of focus. Even so, depending on the situation, a certain minimum resolution will be necessary to avoid the individual emitters becoming visible. As a result, the resolution of larger, often permanently-installed virtual production stages can be very high - perhaps tens of thousands of pixels across the curve of a cove-shaped LED wall - placing a large workload on rendering servers.

The resolution of an LED wall will often be given as a pixel pitch, the distance between emitters in millimetres. Each emitter often includes red, green and blue elements, although alternative layouts exist. Compared to technologies such as LCD and OLED, as used in TVs and monitors, LED panels tend to have poor fill factor, with significant non-emitting black areas between the emitters. That exacerbates moire patterning, and LED panels may be chosen for high resolution not because of the demands for an ever sharper image, but to minimise the gaps between pixels. Even so, making much of the wall surface black helps reject extraneous lighting and maintain contrast; a compromise is inevitable.

Given a long enough lens and a deep enough depth of field, the pixels of any video wall might become visible, so there is no universal solution. Estimating the resolution requirements for a virtual production display depends on the resolution of the camera, the camera's distance from the wall, the focal length of the lens, the aperture, and where the focus is set, as well as the layout of the live action scene and its blocking and staging. As such there's no single ideal setup for every situation, although pixel pitches around one millimetre are available.

Refresh Rate

The term refresh rate applies slightly differently to LED walls than it does to conventional desktop and video monitors. Ordinarily, refresh rate and frame rate have been synonymous terms. Computer monitors, for instance, often show 60 or 72 individual images per second, while a video monitor for on-set use might show 24, with each pixel illuminated at the appropriate brightness to display a complete image. An LED wall operates differently, switching each individual emitter on and off rapidly to create the variable brightness required to show video, a technique called pulse width modulation.

For LED walls, "refresh rate" refers to the rate at which the pulse width modulation takes place. Typical refresh rates for LED walls are 3840 or 7680Hz (numbers which are only coincidentally related to the horizontal resolution of broadcast video resolutions). The refresh rate may vary so that the number of pulses per second divides evenly into the video frame rate, so each frame is displayed using exactly the same number of pulses. Refresh rate needs to be high enough to avoid flicker or visible segmentation, especially when the camera pans or tilts quickly.

Some special techniques may require higher video frame rates, and therefore higher refresh rates. One example is tracking systems which display markers in between the taking camera's exposures. Another is multi-camera broadcast applications which can handle several taking cameras simultaneously on a single set, displaying the appropriate background image for each camera in sequence.

Bit Depth

As with any other digital video application, the precision with which an LED wall can display brightness is limited by the number of bits of data used. A ten-bit system can display 1024 different levels of brightness between the darkest and brightest states of a pixel; an eight-bit system can display 256. Bit depth and refresh rate may interact based on the ability of the electronics in each LED panel to switch the individual LEDs on and off very quickly.

One complexity is that not all those brightness levels may be available to display video. For instance, a director of photography might request that the LED brightness be reduced one stop to accommodate other scene lighting. That's a reduction equal to one-half the total brightness. A ten-bit system (given certain assumptions) might originally have represented full brightness as a signal level of 1024; now it might only be at 512. Reduce another stop, and there are now only 256 levels between black and white, which might create banding (strictly, quantisation noise) depending on the type of content being shown, the camera system, and other specifics. Making colour and brightness changes may also reduce the available precision. Because of this, some systems use 12 or more bits.

Multiplex

The electronics in video wall panels are not usually capable of lighting every emitter at once. A 1920 by 1080 pixel HD display, for instance, would involve over two million pixels, each with red, green and blue emitters. Even if a single control chip could control 16 pixels, that display would require nearly 130,000 chips. Instead, multiplexing is used, where sets of emitters are lit in sequence, rapidly enough to seem constantly illuminated. Often, there are eight or sixteen sets of emitters in each group, so that only one-eighth or one-sixteenth of the emitters are actually lit at any time.

Lower multiplex numbers may mean higher brightness, since more of the lights are lit at any time, although many LED walls have more than enough brightness for many applications in any case. More crucially, lower multiplex numbers, like higher refresh rates, can reduce the incidence of interference patterns that limit certain combinations of frame rate, shutter angle and timing.

Processors And Receivers

The panels of LED emitters which make up the visible wall are often conceptually simple, dedicated to switching their arrays of LED emitters on and off very quickly. Each of them usually has a plug-in receiver card, several of which communicate with a compatible processor, generally made by the same company, installed near the rendering servers. A simple processor may not do much more than break the incoming image up into sections for each panel. More advanced models might perhaps perform scaling or translation, make colour corrections according to creative or technical requirements, and send the results section by section to the receiver in each panel.

The processor and receiver generally communicate using high-performance computer network hardware. Often, optical rather than copper connections are used for increased bandwidth per cable, reducing the number of cables required, though there's often a significant amount of cabling between the display and the server room. In principle, conventional computer networking equipment can be used, although certain processor manufacturers may require particular capabilities, or even specific firmware, for best performance, particularly concerning delay and latency.

Colorimetry And Calibration

When LED walls are used for advertising, the only requirement is that the result looks attractive to the eye and that corporate colours are reasonably well matched. Usually, those displays are configured to work in the same way as a conventional video monitor, perhaps with some modifications to appear correct in variable weather conditions and times of day in an outdoor configuration. Virtual production displays may need to fulfil other requirements, particularly with regard to colour matching, compatibility with other lighting, the colour presets selected in the taking camera, and any monitoring LUTs.

Colorimetry is a large subject which applies to all camera and display systems used for film and TV work. Two key factors include the colourspace of the system, which is determined by exactly which shades of red, green and blue are used to create colours, and brightness encoding, which controls how much light is emitted by the display for a given signal level. An in-depth discussion of this is more than we have room for, but for common camera setups, most virtual production facilities will quickly be able to configure the system to produce colour that's correct, or close to correct, with minor manual adjustments sometimes required to make the virtual world's colour and brightness look realistic compared to foreground action. The colour and brightness behaviour of virtual production displays, as well as their calibration and adjustment, is a rapidly evolving field.