BROADCAST
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Virtual Production For Broadcast

Part 2 - Production Planning, Virtual Worlds & Virtual Lighting

A Themed Content Collection from The Broadcast Bridge

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:

Available now:

Part 1. The Foundations Of Virtual Production

Part 2. Planning, Virtual Worlds & Virtual Lighting

Future parts due in 2023:

Part 3. Creative Image Capture

- Shooting Locations For Virtual Production
- Capturing Objects In 3D
- Motion Capture

Part 4. Uniting The Physical & The Virtual

- Moving Camera-side And Virtual Objects
- Image Based Lighting
- The Future Is Converging

Requirements For The Well Planned Virtual Production

By Phil Rhodes. *The Broadcast Bridge.*

Virtual production brings new technologies and techniques so thorough planning and great team communication are key to achieving smooth production and the best results.

The key benefit of virtual production is that it can allow a crew to operate very much as it would in a real location, with the benefits of reliable virtual weather and a short commute between locations that might be continents apart in reality - or non-existent. The trade-off is that virtual production involves some new technology, and moves quite a lot of what would have been conventional visual effects work into pre-production. Realising all those benefits while keeping the technology out of the way of the creativity is mainly a matter of preparation.

Defining The Production

Virtual production can be used to create huge, spectacular science-fiction or fantasy worlds. It could also be used to shoot - for instance - a dozen couch commercials in a dozen different lounges in less time than ever. The only thing that those productions might have in common is the desire to photograph in locations that don't exist (or don't conveniently exist) and for the in-camera results of virtual production. Given such a wide variety of applications, there's necessarily a lot of variation in the planning process.

As with any production technique, the starting point will be the preferred approach of senior creatives. Some directors work closely from storyboards; others prefer to be more reactive, walking onto a location and finding setups in the moment. Virtual production is often more capable of handling that kind of spontaneity than many visual effects techniques, if only because there are always real-time, in-camera previews of the finished shot. Nonetheless, even the most free form production will benefit from at least a broad plan for blocking, staging and camera work.

Many of those fundamentals arise from where cameras, people and objects are - the geometry of the scene. Whether that's the real world of the foreground, or the virtual world in the video display, things must be arranged to create a useful composition, reserve space for the foreground action to take place, and ensure enough LED wall coverage to occupy the proposed shots. Equally, the camera department must avoid photographing the LED wall in such a way that its individual pixels become visible, which may mean avoiding very deep depth of field, long lenses, close proximity to the wall or some combination of those factors.

Communication

Virtual production specialists consulted in the preparation of this piece agreed on many things, but particularly emphasised the need for communication. Virtual production is a new field, and technologies, capabilities and approaches vary widely between facilities. The people involved are very aware of the concerns of camera teams, and equally keen to engage in consultancy before a production has made a firm decision about what to do. Facilities will sometimes donate time and consultancy for testing and planning, and are generally very happy to discuss the right approach in order to avoid future problems.

Blocking & Framing

It's easy to think of the LED wall as a background in the same way as a traditional back-projection screen, and at the most basic level that can be perfectly valid. If a production chooses to use entirely two-dimensional background plates, that's exactly how it will work, albeit with the benefit of the high contrast and brightness of LED display technology. Where there's a three-dimensional world beyond the LED wall, though, it's more accurate to think of the wall as a window onto that world. From a distance, that might mean almost the same thing as a two-dimensional background plate, but as the taking camera approaches the video wall, more and more of the world beyond will be revealed.

In extremis, the taking camera could reveal almost a 360-degree view of the virtual environment by moving close to the LED wall and viewing it at extreme angles, just as someone might approach a normal window for a wider view of the outside world. Close range and extreme angles create the sort of setup that risks revealing the pixels of the LED wall, but it should be clear that in principle it's possible to reveal a huge amount of the virtual world outside that virtual window. What's crucial about this is that it generally won't be necessary - or practical - to define the entire virtual world in fine detail. Establishing approximate

blocking and framing lets productions choose what to put in the virtual world and where to concentrate the efforts of the virtual art department, which we'll discuss in more detail soon.

Where the geometry of the scene is very large, virtual production also makes it possible to move through that scene over much longer distances than are physically available. Techniques involving treadmills are an advanced topic, but can make it possible to create long, continuous walking or running shots over distances limited only by the size of the virtual world. More commonly, it's possible for a production to move an actor across a virtual production stage, cut, return to the start position, and adjust the apparent position of the virtual world to give the

impression of moving through a huge world in several edits. That, and related techniques, can make it easier to avoid having subjects too close to the LED wall.

Keeping The Wall Soft

Many virtual production setups rely on the LED wall being slightly out of focus. Traditional front- or back-projection might have more immunity to that as gaps between pixels are typically much smaller. As the resolution of an LED wall increases, there is less and less need to keep it out of focus. The specifics vary with different setups, but where a particularly huge, particularly high resolution LED wall is used, particularly with a wide lens, the need for it to be defocused will be minimised. Still, LED walls sometimes need to be out of focus to avoid the visibility of pixels and interference patterns.

That's easier to achieve if the geometry of the scene has been designed with that in mind. Story-relevant real world subjects, including people, which we want to see in sharp focus must be far enough away from the LED wall that when they are sharp, the wall is still soft. Wide lenses might reveal the edges of the wall or increase depth of field enough to make pixels or moire visible, while particularly long lenses might, again, enlarge the wall to the point where pixels become visible.

Larger-sensor cameras, with their reduced depth of field for a given field of view, can make it easier to keep the wall soft, especially where there's a demand for wide-angle lenses. The wall must be large enough to cover the shot, something that's a particular concern with wide angles, unless there's an intention to extend the shot in post (which will impose other requirements regarding characterisation of lenses, and perhaps other factors). Regardless, one of the challenges of blocking and staging for virtual production is to ensure enough physical separation between foreground objects and LED wall. The compromise is that the further a subject is from the wall, the less it receives the convincing interactive lighting the wall provides.

Test Sessions

Even before the design of the virtual world is finalised - or before background plates are shot, composited and prepared - a simple test shoot on a virtual production stage is likely to be helpful. Working with a stand-in, alongside the intended camera and lenses, setting up shots and evaluating the effects of focal length, camera position, framing and exposure on a good-quality display will help establish what's possible and where the limits are. If the facility in question hasn't worked with the intended camera package before, evaluating the camera and lenses for tracking, as well as colour matching and calibration, can also be addressed during a test session.

Where a production has created a new 3D virtual world, a test of that world, on the actual rendering servers to be used during the shoot, is a good idea. Lighting of the virtual world must match both the cinematographer's intent, and must match the lighting used for the real world, although that will inevitably only be finalised on the day. Tests are also important where the world contains complicated lighting or geometry. Often, simple changes to virtual worlds can massively increase rendering performance, but it's clearly preferable to avoid having to make those fixes while a full production waits.

On The Day

Well-planned productions will pre-empt as much of the technical preparation as possible, although in extremis it is possible (though very much not recommended) to arrive on the morning of the shoot with a full cast and crew and a virtual world on a hard disk. The virtual world data may be many gigabytes in size, and must be copied to all of the rendering servers; those servers must then do preparatory work before the real time rendering can begin. Meanwhile, lenses can be characterised for their focus behaviour, and the camera tracking system set up, with tracking markers attached to the camera and calibrated for position throughout the working space.

With those tasks complete, it will be possible to move the camera around inside the virtual production stage and view the results, at which point the conventional work of finalising the blocking, staging and lighting can begin. Approaches to lighting for virtual production - whether that's lighting of the virtual world, or interactive lighting in the real world - are a big subject for another time. Ideally, though, the well-planned virtual production makes most of the camera technique work in much the same way it always has, and that's one of the greatest benefits of working this way.

Designing The Virtual World

By Phil Rhodes. *The Broadcast Bridge.*

It is true that some of the key tools of virtual production are well-established in the world of computer entertainment, but the design constraints can be very different, demanding photorealism over smaller areas, as well as staging and layout that's suitable for the proposed scene.

The best-known virtual productions put people in enormous, spectacular environments full of imaginative production design. The least famous ones might recreate more everyday situations, albeit for equally important reasons. The work of creating those environments might employ artists in computer suites as opposed to construction workers in hard hats, but the virtual art department must do the same concept, design and construction effort that it always did.

Building The World

The specific usage details of various pieces of software are too huge a subject to cover here, although much of what we discuss will apply to Epic Games' Unreal Engine, which is commonly used for virtual production, as well as other real time rendering engines like Unity. Most of it also applies to visual effects software which are more usually used for offline rendering.

Creating an environment designed to be viewed through the virtual window of an LED wall, with both smooth performance and photographic realism, is a fairly new discipline. Design for virtual production will use some skills common to visual effects and game development, though the technical and creative considerations for a virtual art department are not the same as either. Several of those skills need more coverage than we can fit in this brief overview, and we'll cover them in detail later.

Scoping The Project

To the relief of producers everywhere, not every virtual production needs an elaborate three-dimensional environment built from scratch. The right approach will depend on exactly what the production needs to shoot, and that's a decision best made in consultation with senior creatives, experienced virtual production people, and the facilities that might be involved.

Using a live-action background plate shot on location can look convincing from a limited range of angles. Unlike a full 3D environment, using a plate will limit where the taking camera can go, but can be less work. Since some LED walls can be tens of thousands of pixels across, shooting and compositing adequate plates may not be trivial. The process of doing that is discussed in more detail separately.

What's perhaps more common than either a fully three-dimensional world or a two-dimensional background plate is a hybrid approach, where some live action material is used as part of a possibly simplified three-dimensional world. Sometimes that's referred to as "two-and-a-half D," combining some of the time and work benefits of a background plate with at least some of the freedom of movement as in a fully three-dimensional world.

The Construction Process

Many virtual productions will need at least some new 3D assets, whether that's a complete world and props to go in it, or simpler shapes to give a rough form to a live action plate. While there are crucial creative differences between the demands of virtual production environment creation and either VFX or games, many of the software tools are the same, ultimately building objects from meshes of triangular polygons and wrapping those meshes in images to define colour and texture.

There are many ways to model the shape - the geometry - and assign a material to 3D assets. Many of them will be familiar to anyone with a little experience of modern visual effects. Geometry might be based on manual assembly of simple shapes, scanning of real environments with laser scanners or by taking a series of photographs to be interpreted by a computer. Materials are often based on one or more images which might be painted manually, photographed from reality, or a combination of the two. Scanning real objects can be a quick and easy approach, though there are some caveats.

However an asset is created, the virtual production stage must reliably render its images at the frame rate of the taking camera, and the performance of the rendering servers has limits. So, assets must be designed for high performance, taking care that exactly the right amount of detail is included. Even though most virtual production facilities use the very best available hardware, there are still limits on the number of polygons and the resolution of textures in any scene.

Material Versus Geometry

Realistic objects are a combination of two things: realistic geometry with realistic materials. Both must have enough detail to look convincing to the taking camera, given the way they are used in the virtual environment - where they are, how large they are in frame, how sharply-focussed they are, how they're lit, and other factors.

Very often, the geometry of an object can be fairly rough if its materials are good enough. Texturing techniques such as bump mapping and normal mapping can

simulate fine surface detail on an object. Bump mapping, for instance, uses a black-and-white image to indicate small variations in the surface of an object, with white areas appearing raised. This can work well enough to reduce the need for fine geometry.

Recent developments in real time ray tracing, which was previously available mainly to non-real time rendering systems, have made more accurate materials and lighting possible, particularly where a material might need to reflect its environment.

Off-The-Shelf Assets

There are already libraries of environments and objects available very affordably for game development and visual effects. Geometry and materials may be packaged in a variety of different formats, often intended for use with different software. Some of those formats can be converted to others, although sometimes some manual intervention will be needed from experienced people.

Until now, game development has not routinely been able to target photorealism. Certain recent titles have been able to achieve it under some circumstances, and things change quickly, but many assets built for games won't have enough fidelity or even the right art style to work in virtual production. Equally, assets built for visual effects work may look good, but have too much detail to be rendered in real time. Again, qualified people may be able to work on an asset to make it more usable, although the practicality of that depends on the specifics of the asset and the intended use.

Lighting

Experience in visual effects makes it clear that lighting is key to making things look both realistic and appropriate to the production. Directors of photography are likely to become involved in planning and constructing virtual environments, both because layout will naturally affect blocking and framing, and because the lighting of the virtual world must be compatible with the live action scene.

For much of the history of video game technology, the lighting tools available to designers were limited, with restrictions on the type and character of light available and the way that light interacts with objects. For years, objects in virtual worlds didn't even cast shadows, or when they did, the shadow might not look entirely as it should. Soft light sources - even something as simple as overcast - could often only be approximated as a directionless ambient light. Sometimes, that sort of lighting might have been pre-calculated, or baked, which may take time and restrict the way that particular light source interacts with objects in the world.

Current systems are much more sophisticated, and many of the tools of real-world cinematography can be simulated. There may still be some restrictions on specific techniques, particularly around large, well-simulated soft lights and the total number of them, but in general there are equivalents for most of the types of lighting cinematographers might need.

Virtual Scouting & The Virtual Backlot

Even before a virtual environment has been finished, rough or approximate versions of the layout might be available for viewing. The pedigree of virtual production in the world of video games often makes it possible to explore that newly-created environment just like a game, perhaps with a virtual reality headset or on the LED wall itself, in a process that's sometimes called virtual location scouting. Often, that can take place using a personal laptop or workstation, or using video streamed from a remote location.

Once a virtual production environment has been finalised, its assets can potentially be stored for later use - whether the same production might need to return to a virtual location, or if the same assets might be useful for something else. That might even extend to scanning physical sets for later use in virtual production. Just as there are already commercial libraries of virtual assets, and just as there are already physical backlots and prop stores, anyone owning a particular set of virtual production assets might choose to create a virtual backlot, potentially making more sophisticated environments available to a wider range of productions.

Best Use Of The Virtual Art Department

Productions which might have enthusiastically adopted virtual production are sometimes concerned about the workload of creating a virtual environment. It should be clear that not every show will need a complete, from-scratch, three-dimensional environment, and that there are many valid approaches to virtual production that can keep the technology neatly out of the way of the creative process. Several of the subjects touched on here affect both the art and the science of virtual production, and we'll explore them in depth in upcoming chapters.

Virtual Lighting Fundamentals

By Phil Rhodes. *The Broadcast Bridge.*

When conventional VFX are produced, there's often a real-world lighting reference available. That approach can be used in virtual production, but increasingly, the director of photography might want or need to have some pre-production involvement in the development of a virtual world. The job may be familiar, but the tools are likely to be new.

Camera and lighting people who are used to lighting real sets are sometimes a put off by the idea of lighting a virtual one. After all, there's no such thing as an 18K HMI or a SkyPanel in the virtual world – although once we look a little closer, we discover that there are some pretty close equivalents.

Often, virtual production specialists – the computer people – will fill the role of a grip and electric team. Those terms vary somewhat in meaning on either side of the Atlantic, but either way, the software used to create virtual worlds is often capable of emulating most of the fundamentals of lighting equipment and procedure found on film and TV sets.

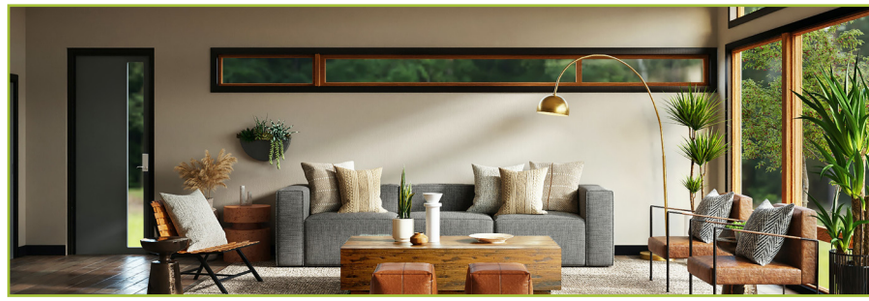
Not every production will use a large, complex, custom-built three-dimensional environment. Where live-action material is part of the virtual environment, a combination of both conventional camerawork, compositing and grading, and 3D world building might be involved. Either way, most virtual environments will need at least some lighting to create an appropriate look and match other live-action footage, such as the foreground elements of the virtual production studio shoot. Creatively, the people responsible for generating the virtual world will consult with the production's director of photography. It's understandable that might create some uncertainty for someone whose experience lies with practical, real-world lighting tools and, often, a particular team of people.

Fidelity & Performance

It would be a mistake for a director of photography to become too concerned with the mathematics underlying lighting in computer-generated imaging. The details are either handled automatically by the software or by the specialists involved; it's their job to work with a cinematographer on that cinematographer's own terms as much as possible. Even so, an understanding of the trade-offs between flexibility, realism and performance can make good results more accessible.

Rendering realistic three-dimensional scenes in real time tests the limits of what modern computers can do, and it's normal for software to use lighting simulations that look highly realistic without being a precise mathematical simulation of the real world. Recent developments have enormously improved the accuracy and flexibility of lighting, mitigating those compromises to some extent. The need for real-time performance still means some degree of approximation, and those approximations often come with requirements, such as a restriction on whether objects or lights can alter position, colour, or brightness in real time, how far each light projects across the world, the behaviour of reflected and refracted light, and special situations such as cloud, haze or smoke.

The Basics



Virtual production relies on technology developed for video games. Three-dimensional graphics of this type were possible from perhaps the 1970s onward, though real-time rendering only became possible in arcade games and home computers from the late 80s and early 90s. Real-time results good enough to look anything like real are mainly a phenomenon of the late 2010s, depending on the subject.

Most of these systems represent objects using triangular polygons, chosen because any shape defined by any three points can only ever be a flat plane (for the same reason a tripod is always stable, even on rough ground, while four-legged tables might need a wedge under one leg). Early systems assigned each triangle a colour and plotted it on screen, though simple lighting was quickly added. Designating a point in space as a light source allows the code to calculate the angle between any polygon and the light to control brightness – the surface looks brightest when it is pointing directly toward the light. Repeat that over the polygons describing an object, and the object reacts somewhat correctly to light.

That was cutting edge in the late 70s, but it doesn't allow objects to cast shadows unless other techniques are used to approximate them, sometimes called shadow mapping, which essentially paints certain parts of the object with dark colours to simulate shadowing. Those shadows can be calculated during the design phase of the process, so accurate, attractive results are possible. That works fine until the object or the light moves.

Even with pre-calculated shadows, light still doesn't reflect between objects; a white object next to a red object will not pick up any reflected red light. That requires global illumination (GI), which simulates light reflecting repeatedly between objects, and can look very highly realistic. Again, certain types of GI can be calculated during the design stage and effectively painted onto objects, and again, that creates caveats around what aspects of the scene can change. GI can demand a vast number of calculations for a large number of points across the surface of an object as light diffuses from that surface.

Types Of Light

The types of light simulated vary between pieces of software, but most will be recognisably similar to the options discussed here, and can approximate many common film and television lighting tools.

Point lights broadly simulate a single light bulb in space, while directional lights will have similar behaviour, albeit restricted to a cone with a definable angle and potentially a variable falloff from the centre to the edge of the beam, somewhat like a Fresnel light. However, because both types of light are, in theory, infinitely small, they will usually create completely sharp shadows by default. A real Fresnel, while far from a soft light, has a real world size and will often create at least something of a soft-edged shadow depending how far it is from the subject. It's possible to simulate a soft-edged shadow using one of a few different techniques, from the crudest approach of simply blurring the shadow to much more sophisticated and accurate simulations.

Creating really large soft lights requires an area light, which has a controlled size in the virtual world and can accurately simulate the way soft lights illuminate objects and cast shadows. The earliest approximations of area lights created them using a large number of small, individually low-powered point or directional lights distributed across the surface of the area light. More recent techniques are more sophisticated, but it's easy to see how area lights usually create a much higher workload for the computer than point or directional lights.

Other types of light might include ambient light, which is assumed to illuminate all objects in the world regardless of their position. Ambient light can help simulate the general illumination of, say, an overcast sky, although because it is directionless, it risks creating a flat, overlit result. Most software now provides more sophisticated ways of simulating sky light which can use some of the more advanced lighting models we've hinted at to create very convincing lighting environments. Sometimes, this kind of light might be based on a 360-degree image of a real or computer-generated environment.

Optimisations & Approximations

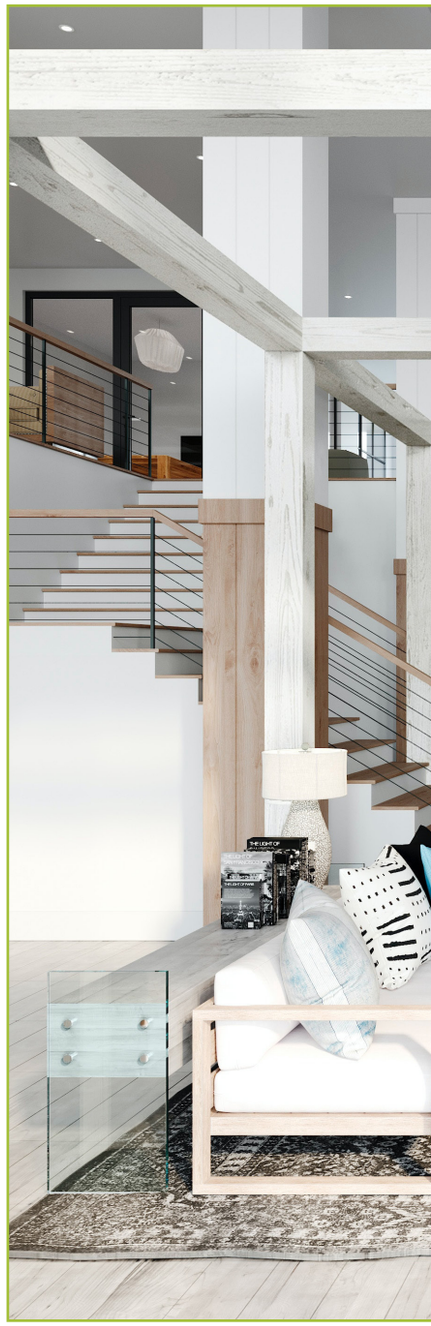
Calculating certain kinds of shadowing and global illumination in real time has only recently become practical. That allows things to move, but it's often necessary to nominate which objects and lights need to change during real time rendering, not the whole scene. Most current software can use a combined approach, where the shadows and highlights which fall on objects which won't move from lights which won't change can be pre-calculated. Meanwhile, objects and lights which must move and change can be rendered in real-time, and the two solutions combined. The assumption here is that concentrating computer power on things which must move and change will create the desired effect while maintaining workable performance.

Hybrid solutions are sometimes possible, where calculations for shadow and reflection are made for a single light and kept separate from the calculations made for other lights. This can allow the brightness and colour of an individual light to be altered, though not position, beam angle, falloff, or other settings which would change how its light falls on the world. Significant improvements in the ability to perform (or at least closely approximate) the more accurate types of lighting in real time have recently made it possible to reduce reliance on less-flexible pre-calculated lighting. The specifics will depend on the exact nature of the scene, what the scene is required to do, and how the cinematographer wants to light it.

Tools For The Cinematographer

Because of its reliance on technology generated for the vast market of video games, it's likely that the quality, variety and performance of lighting techniques for virtual worlds will continue to improve over time. With virtual production in general still a fairly new idea, the interaction between cinematographers and virtual production lighting is still being explored. It seems likely that best practices will arise when camera and virtual production specialists each learn something of what the other needs and wants, a situation which will be familiar to practitioners of such a collaborative artform as filmmaking. Some virtual production facilities have gone so far as to have their lighting specialists visit film sets and shadow the crew to improve their understanding of film and TV working practises, which seems likely to improve that collaboration.

In the meantime, modern virtual production systems are already capable of realistic lighting and lighting-adjacent techniques such as mist and fog, so it should be clear that tools to allow cinematographers to bring convincing and appropriate lighting to virtual worlds are already well-developed.



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