Virtual Production

Definition of Virtual Production

Virtual production is a broad term referring to a spectrum of computer-aided production and visualization filmmaking methods.Virtual Production(VP) combines virtual and augmented reality with CGI and game-engine technologies to enable production crews to see their scenes unfold as they are composed and captured on set.
With recent advances in real-time computer graphics, which are making virtual production even more accessible to filmmakers today.

The Problem and Its Solution

Filmmaking is an ever-evolving artistic and technological pursuit. You need to only compare silent films from the dawn of cinema with Avatar to see this progression clearly. Though vastly different in terms of subject matter and craft, the two extremes share a common aim of entertaining an audience with a good story. When we talk about virtual production and the benefits it offers to filmmaking, we're really talking about the next logical step in an ongoing evolution.

Most major films and TV series created today already leverage some form of virtual production.It might be **previsualization**, it might be **techvis** or **postvis**. The potential for **Virtual Production (VP)** to enhance filmmaking extends far beyond these current uses.

The Problem with Traditional Production at Scale

Many films today—certainly all modern blockbusters—are exceedingly complex productions featuring many moving parts on highly compressed schedules. The process is typically a linear affair, one that resembles an assembly line, encompassing development, pre-production, production, and post. Iteration is challenging and costly while development efforts are frequently isolated from one another, with incompatible resources.

Onset of Pandemic has also created a lot of restriction and problems for traditional film making.

Iteration is the act of refining a process over successive attempts to arrive at a desired result. All too often, the iteration process in traditional production is wasted on finding a common starting point instead of refining an agreed-upon shared

vision. Traditional production can be like learning how to play an instrument that you can't hear—you can't learn very fast when you hear the music two weeks after you hit the note. Compare that with a creative feedback loop in real time.

For filmmakers, this problem manifests itself as uncertainty. When a cinematographer has to take a best guess at the color of their lighting to match an unseen green screen element, or a director doesn't exactly know what the creature at the climax of the movie actually looks like, that's uncertainty. It's an overall process that feels disconnected and doesn't resolve itself until all shots become finalized.

All the professional expertise brought to bear on production may not go fully leveraged in the process due to the level of visual disconnection. Finalizing occurs deep into post-production, when major iterative changes are at best highly costly and at worst impossible due to a release deadline.

When an editor is attempting to cut on action and timing for a sequence featuring in-progress visual effects, that's uncertainty. The arrival to a final version of a scene is often a long road involving replacement of temporary or missing shots, adding score, color correction, and so on. Achieving shot-to-shot continuity and fluidity is challenging with so many components in flux. All of these issues make it more difficult for the editor to arrive at the definitive version of a scene, and the result is often a film released with some degree of creative compromise.

Taking into account more traditional forms of previsualization, there is room for improvement. Previs has traditionally been created via animation software optimized for premium image quality at the cost of long render times. The process involves artists painstakingly creating versions of scenes with neither optimal image quality nor real-time malleability. As a result, the filmmakers can feel decoupled from what should be a hands-on and collaborative development process, and the true talents of department heads are not being fully leveraged.

This technology breaks the barriers of difficulties faced by the cast and crew who choose to travel abroad and work in varied conditions to achieve beautiful shots, Instead we can bring any desired location into our studio therefore providing a comfortable space for actors and an entirely crew friendly atmosphere for working technicians which eradicates natural restrictions like availability of sunlight and extreme weather conditions etc.

How Virtual Production Solves the Problem

In contrast to traditional production techniques, virtual production encourages a more iterative, nonlinear, and collaborative process. It empowers the filmmakers (including department heads) to collaboratively iterate on visual details in the moment, not deferring all of these decisions to post. Iteration begins much earlier in the production schedule. With a real-time engine, high-quality imagery can be produced from the outset. Instead of different teams creating incompatible assets isolated from one another, assets are cross-compatible and usable from previsualization through final outputs.

Traditional vs. Virtual Production for Film

Visual development by Fox VFX Lab

For filmmakers, the uncertainty of traditional pre-production and visual effects production are replaced with working imagery far closer to final pixel. And because this high-quality imagery is produced via a real-time engine, iteration and experimentation are simplified, cost-efficient, and agile. The process feels much more connected and collaborative. Pre-production and principal photography can be executed organically and holistically. Filmmakers and department heads are empowered to respond to discoveries of the moment. Creative decisions about shots and sequences can be resolved much earlier in production, when the entire team is present, and not left to the last minute of post-production when crews have long since disbanded.

When it comes to editorial, virtual production also alleviates uncertainty by providing provisional imagery much closer to its final appearance and helping to eliminate missing or in-progress shots. When shots that might have been previously photographed in front of a green screen are replaced with in-camera, LED wall visual effects, the editor has much more to work with. It becomes possible to edit shots and sequences featuring major visual effects the same way as traditional non-effects scenes. The editor edits during principal photography so the crew can immediately shoot pickups, or make adjustments while shooting, instead of finding out about the issues long after principal has wrapped.

This has the potential to shave off days of unnecessary shooting. The result is much greater shot-to-shot continuity, fluidity, and agency over the scene. Definitive edits of scenes can be arrived at more quickly and collaboratively.

Creating previs imagery via a real-time engine unlocks additional benefits.Sequences can be quickly updated and output at very high levels of image quality. As a result, more members of the team can share the vision of the final content much earlier in production. Sets can be built to more exacting specifications with a closer match to the filmmakers' vision, stunts and special effects can be prepared in advance and executed with greater safety, and integration with visual effects can be accomplished in the most efficient and visually dynamic ways.

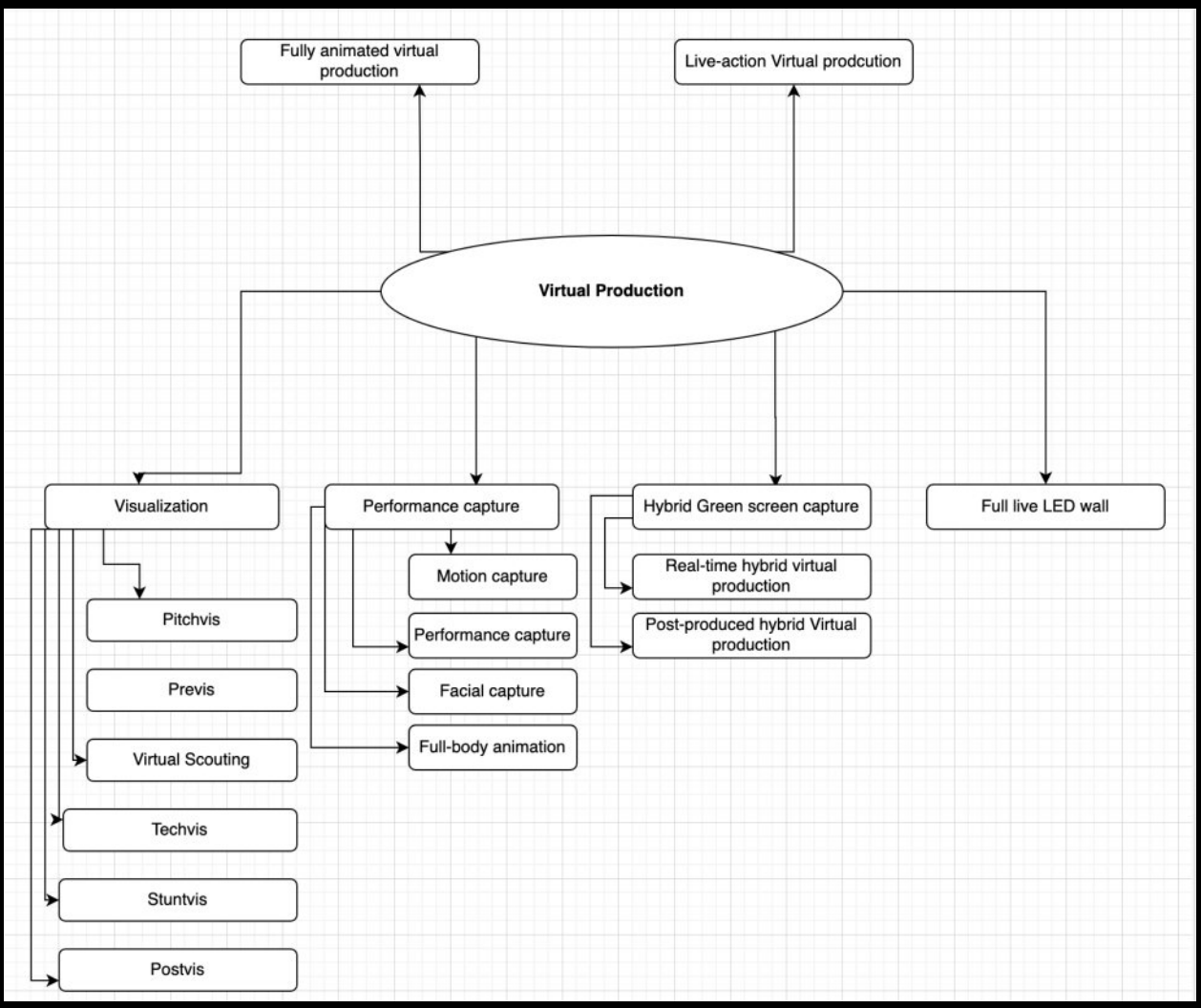
The physics in a real-time engine play a key role in the process. Of course, it's possible to create more traditional previs via 3D animation software, but if it has any real-world physics, such animation has to be precalculated and can't be changed on the fly as it can with a real-time engine. Previsualization and visual effects teams can also collaborate directly, playing in the same sandbox with shared assets and a unified pipeline because real-time assets and final effects shots can leverage the same base model.

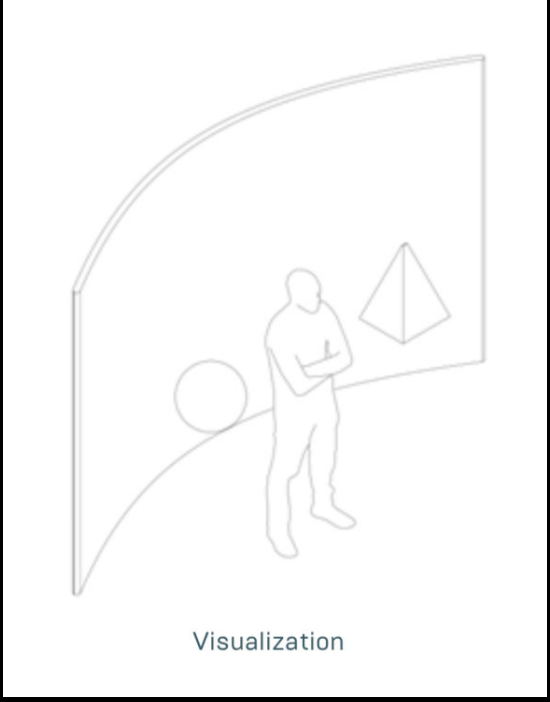
All of these efficiencies and increased image quality offer a trickle-down effect to more modest and tightly scheduled productions. By leveraging virtual production techniques with a real-time engine, network series, streaming productions, and indies can all achieve very high-quality imagery and epic scope. A real-time engine has the potential to eliminate many of the bottlenecks of budgeting, schedule, and

development time that can prohibit smaller-scale productions from producing imagery on par with blockbusters.

Types of Virtual Production

Various methods of **Virtual Production** involves Visualization, Performance capture, Hybrid Virtual Production, **In camera production** all using **Unreal Engine** as their **backbone.**





Visualization

Visualization is probably the virtual production use case most filmmakers are most familiar with. We can define visualization as prototype imagery created to convey the creative intent of a shot or sequence. Visualization can take the form of pitchvis, previs, virtual scouting, techvis, stuntvis, and postvis. Let's take a closer look at each.

Pitchvis is imagery created to help an in-development project earn a greenlight from a studio or gain interest from would-be investors. Pitchvis might include specific signature sequences from the proposed project or an overall trailer to help convey the filmmakers' creative intent. Some examples of movies which were greenlit in part due to a trailer created as pitchvis include Godzilla (2014), Men in Black 3, World War Z, Jack the Giant Slayer, and Oz: The Great and Powerful.

Previs is the most widely-recognized form of virtual production, as it's regularly presented in behind-the-scenes clips and in before/after visual effects presentations from popular movies. Previs can include music, sound effects,and dialogue designed to approximate the look and feel of final sequences. The advantage of previs is that it enables filmmakers to experiment with different staging and art direction options such as lighting, camera placement and movement, stage direction, and editing without incurring the higher costs of actual production.

Storyboards and animatics are both precursors to previs. From the earliest days of his career, George Lucas has been a major proponent of previsualization. He edited together clips from old World War II aerial dogfighting movies to convey his intentions to the visual effects artists on the original Star Wars. Later, Lucas' visual effects company Industrial Light & Magic (ILM) pioneered the use of 3D animation software to previs effects shots on Jurassic Park. Today, it's rare to find a major motion picture which doesn't deploy previs in some capacity.

Virtual scouting presents a completely digital version of a location or a proposed set which crew members can interact with. The interaction might take place in an HMD (head-mounted display) or simply on a computer screen. The VR version of

virtual scouting can include repositionable props and virtual cameras with lenses which can be used to plan out shots, define set builds, and/or shoot entire sequences without building a single flat. It also enables filmmakers to focus on specific areas of importance and filter out areas of less importance to avoid creating assets that won't be used. To date, many films have involved virtualscouting as part of their pre-production process.

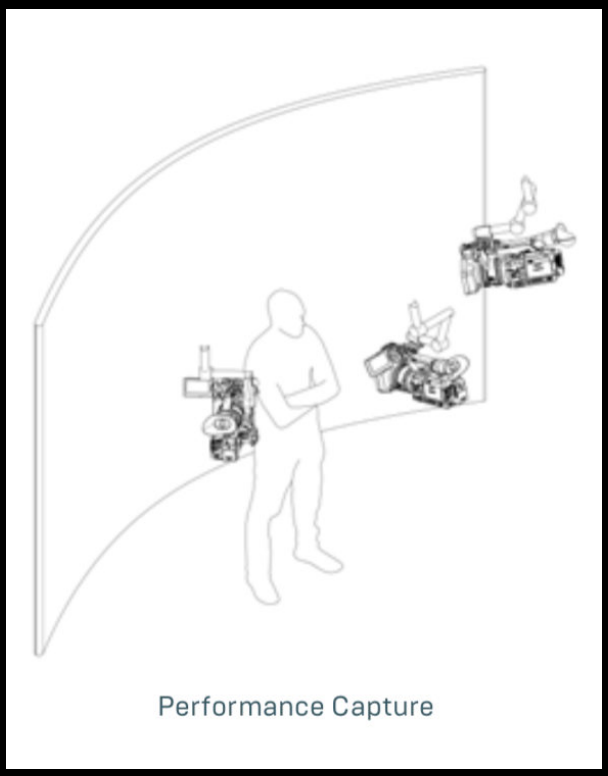
Techvis is the combination of virtual elements with real-world equipment for the process of planning shots as well as combining already captured footage with virtual assets. It is also the area where camera moves, camera placement, and lens choices can be validated, mitigating the risk of physically implausible virtual choices.

For example, on the first Avengers, techvis was used to help plot out animation for explosions captured partially on set and later greatly expanded via visual effects during post-production. The techvis helped determine the explosions' shape,volume, and rate of expansion relative to the camera movement to help ensure that the visual effects added in post would integrate believably with the live-actionfootage.Techvis is generally more concerned with physics and specific camera data for use of the effects artists, and less so with visual fidelity or usage in an evolving edit.

Stuntvis is a type of techvis tailored specifically to the planning of stunt work. Stuntvis is usually guided by the stunt coordinator or action choreographer. It includes the development of scene blocking, choreography, stunt testing and rigging, set design, prop and weapon concepts and—in conjunction with the director of photography—camera placement and movement, together with lighting setup. By leveraging the real-world physics simulation available in real-time engines, stunt coordinators can directly translate digital results into the real world. "Stuntvis has multiple purposes," says Chris Clements, a stuntvis artist whose credits include Netflix's Daredevil, The Punisher, and Pacific Rim Uprising. "It's used to sell the director and producers on the vision, to work out certain beats before a shoot to make sure they play correctly to camera and, most importantly, to act as a souped-up storyboard that can be referenced by multiple departments."

Postvis involves the creation of imagery merging live-action elements with temporary visual effects, or the creation of new CG shots to provide placeholders for editorial. For example, Halon Entertainment provided postvis shots on War for the Planet of the Apes by adding temporary versions of CG apes as well as military vehicles and artillery into many live-action plates, along with fully CG shots for shots intended to be completely CG. Postvis provides the director and editor more visually developed scenes to guide their work, especially for sequences with partial sets and in which visual effects drive the story. It also functions as a visual communication tool for the director to communicate with the visual effects team.

Performance Capture



Performance Capture

Motion capture is the process of recording the movements of objects or actors and using that data to animate digital models. When it includes the actor's face and more subtle expressions, it's often referred to as performance capture.

Body capture is accomplished by the actor wearing a suit covered in markers that are tracked by special cameras or a suit with built-in sensors.
Facial capture involves using either depth-sensor cameras for markerless facial capture, or tracking markers drawn directly onto the performer's face.

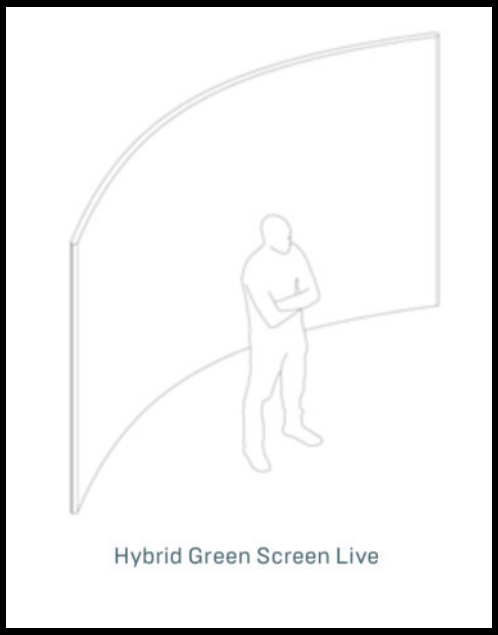
Performance capture can be accomplished on a traditional set where virtual characters are intended to interact within real-world environments. Simulcam is a technique where a virtual camera is synchronized to the movements of a real camera in the physical world. Simulcam is often used to superimpose virtual characters over the live action in real time and aid in framing and timing for the crew.

Or if the film is entirely animated, the capture process occurs on a specially designed performance capture stage called a volume. A capture volume has the added advantage of decoupling the camera from the performance. That is, once the motion data has been captured from the actors, the scene can then be re-animated from any camera perspective desired.

Although the performance capture process is advanced and refined, it has its roots in 2D rotoscoping, where the actors are filmed in scenes and then animation is hand-traced to match their actions. Many animated Disney films used forms of rotoscoping and it was also used extensively in the animated films of Ralph Bakshi. Performance capture can take the form of facial capture and full-body animation.

Facial capture is performance capture concerned primarily with capturing the facial performance of the actor. This data is used to transfer their performance to another character either human or non-human. Although full-body animation often includes facial capture, sometimes facial capture alone is required or can be done separately from the body performance. Some recent examples include Tarkin from Rogue One and The Curious Case of Benjamin Button.

Full-body animation transfers the entire movement of an actor onto another character. This usually involves some form of retargeting or scaling, specifically if the animated character is of a markedly different body geometry compared to the actor. Some popular examples of full-body animation include Avatar, Gollum from The Lord of the Rings, the dolls in Welcome to Marwen, and the most recent Planet of the Apes series.

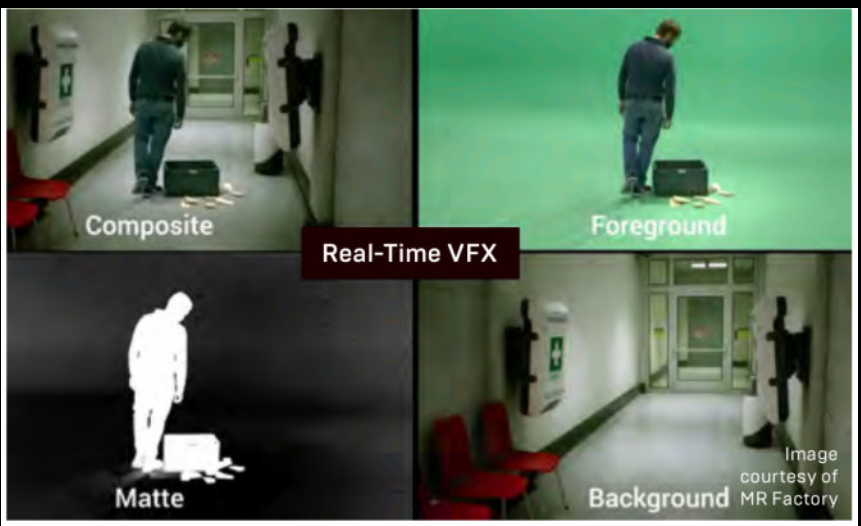


Hybrid Green Screen Live

Hybrid Virtual Production

Hybrid virtual production is the use of camera tracking to composite green screen cinematography with CG elements. This is created either as a live preview for the director of photography and the camera operator, and completed in post-production, or is intended as final pixel in camera. This type of virtual production has been used for a while for live broadcast, especially in sports, but has also proliferated increasingly into feature and episodic production. The two primary modes of hybrid virtual production are real-time and post-produced.

Real-time hybrid virtual production on green screens first appeared in broadcast news weather reports, where the weather person is chroma keyed live over a map with the forecast. These results are typically of passable quality with a locked-down camera and never intended to approach feature-level quality. That said, the quality of solutions has improved greatly in recent years with the addition of faster GPUs and real-time engines. For example, the Zero Density system leverages Unreal Engine to produce live-to-air composites for a variety of news and entertainment shows. Users of Zero Density for real-time virtual production in studio broadcasts include FOX Sports, Canal +, RTL, TF1, and Sky News.



Post-produced hybrid green screen virtual production uses Simulcam and camera tracking to make live-action production more interactive.

Post-produced hybrid virtual production uses camera tracking data to provide a live, in-camera composite image when shooting green screen. The live composite is typically at a proxy resolution and meant as a reference to block out the shot while capturing/filming the actors and props in front of the green screen. It is meant to help the director, director of photography, and camera operator gain a better spatial understanding of virtual elements such as CG characters and set extensions so that visual effects in post are better integrated. An advanced version of this approach was used to create The Jungle Book. This technique has also been popular in recent episodic TV series such as Revenge, Pan Am, Once Upon a Time, and American Gods.

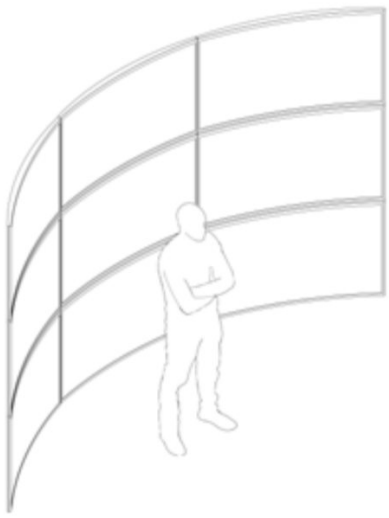
Live LED Wall In-Camera Virtual Production

The use of image output from real-time engines to a live LED wall in combination with camera tracking to produce final-pixel imagery, completely in camera,represents the state of the art for virtual production. The benefits of live imagery projected behind the actors are massive. In some respects, it's also the culmination of all of the previous development work done in the sphere of virtual production.

Compared to green screen cinematography, there is no uncertainty for cast or crew. Everyone can see exactly what is in the shot as it unfolds in real time. The camera operator can frame as they would any real object and the actors can react not to a marker representing an imaginary image, but the actual final imagery live in front of them. All of the natural reflections and lighting from the screen provide important artistic cues and enhance the realism of the imagery, compared to the typical struggle

to avoid contamination from the green screen's color spilling onto the subject as well as creating unwanted reflections.

To be clear, the concept of projecting live imagery behind the actors to photograph effects in camera is not new. Rear projection effects via film projectors date all the way back to the 1930s and were regularly used for vehicle driving shots, and to expand studio-bound productions. The drawback is simple—a fixed perspective that has to be carefully planned around to avoid a visual discontinuity between the perspective of the projected footage and that of the live-action camera.



Full Live LED Wall

Introvision was a notable update to rear projection which allowed for more camera movement and greater interaction between the foreground and background, although it still did not solve the parallax issue because the footage being projected was still locked into a specific angle. Some notable films over the years which used film projector front or rear projection include The Wizard of Oz, North by Northwest, 2001: A

Live LED wall virtual production creates final-pixel imagery in camera.

Space Odyssey, The Fugitive, and Terminator 2: Judgment Day. A precursor to live LED projection via real-time engines is the projection of pre-rendered or live-action footage.

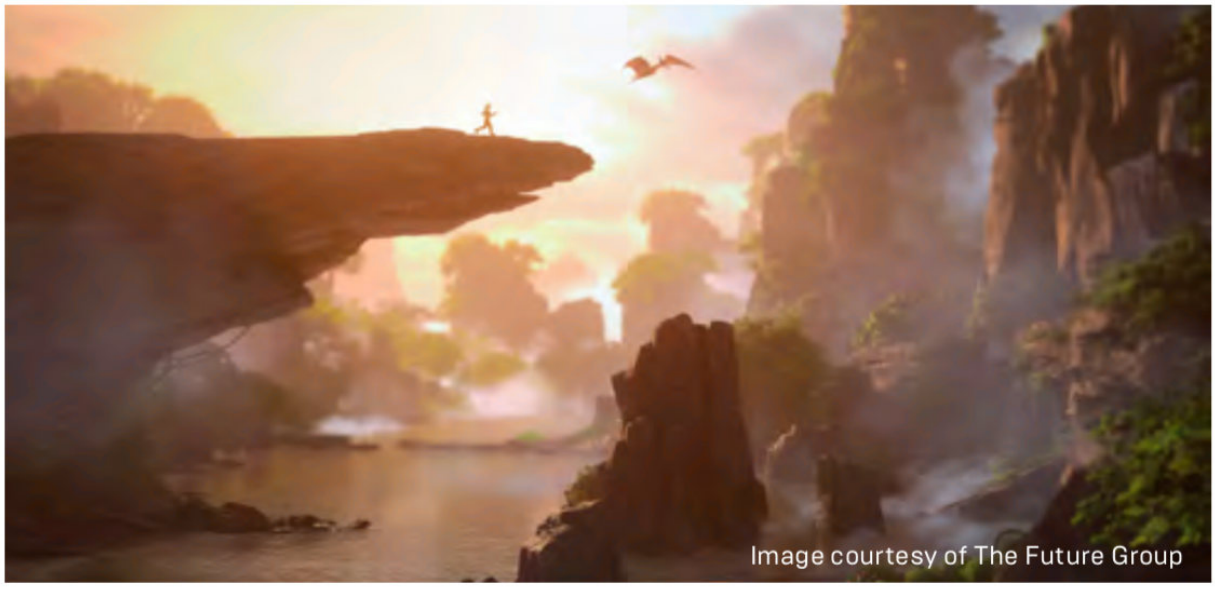
This technique achieves a high level of image quality and immersion, with the only exception being that the perspective is fixed and does not shift in relation to the camera's movement. Thus, it is still limiting in terms of shot design and blocking, and is generally best suited to objects that are some distance from the foreground action in order to help minimize the lack of parallax. Some recent projects which have leveraged pre-rendered projection for in-camera effects include Oblivion, Murder on the Orient Express, Solo: A Star Wars Story, and First Man.

The quantum leap of using a real-time engine to create imagery for LED wall projection is that unlike rear-projecting pre-rendered footage, the imagery shifts in perspective, creating perfectly synchronized parallax to the camera. As a result, the imagery is so believable, it's difficult to tell where the live action ends and the screen takes over. There are a number of projects currently in production which we are not at liberty to name at the time of writing. But we're incredibly excited by their advances and can't wait for you to see the results for yourself.

Virtual Production Project Types

Fully Animated Virtual Productions

Virtual production in the form of performance capture has already massively changed the way many animated films are produced. To understand this, we should take a few steps back to consider the history of animation. In many of the early hand-animated films, animators used a variety of reference footage to achieve more lifelike animation.



A frame from a fully animated virtual production.

Rotoscoping is the practice of tracing over frames of live-action footage to create realistic movement. The process was originally invented in 1915 by Max Fleischer, whose Fleischer Studios went on to apply the technique to animated characters such as Betty Boop, Popeye, and Superman.

Disney used a variation of this process by filming actors enacting scenes for reference and then using that to guide the movements in animation, though not traced precisely frame by frame. The technique enabled the animators to achieve an overall lifelike motion while not being rigidly tied to the live action footage.

The Disney rotoscoping process was used on films like Snow White and the Seven Dwarfs, Alice in Wonderland, The Little Mermaid, and many others.

We mention rotoscoping in particular because performance capture is its virtual production equivalent, in which the motion of an actor's body and face are accurately sampled for transfer to digital characters and environments. With performance capture, animated films gain much more realistic and lifelike animation, and do so far more rapidly and cost-effectively when compared to manual animation processes. Performance capture is often combined with virtual cameras, where the filmmakers create camera moves using real camera rigs or other virtual control devices as tracking devices to record the movement of the camera, which can then be replicated in the CG environment.

Some specific examples of fully animated films and series created via performance capture include: The Polar Express, Beowulf, Tintin, Word Party, Zafari, andThe Lion King. Many companies specializing in CG animation, such as Pixar, Dreamworks, and Illumination, still feature characters animated through manual keyframe animation.

Live-Action Virtual Productions

Virtual production has been used to plan or directly enhance imagery in a variety of major motion pictures. Typically, virtual production is more common on visual-effects-driven movies, but can also include effects enhancements to more traditional or non-effects films.

Major visual effects films of the past decade have come to rely the most on virtual production, and that reliance is increasing steadily. Virtual production helps from the planning phase in the form of pitchvis and previs. It continues on for performance capture, stuntvis, techvis, and postvis. Some examples of major motion pictures heavily reliant on virtual production include Disney's Marvel movies, Avatar, Star Wars, The Lord of the Rings, Jurassic World, Pirates of the Caribbean, Harry Potter, Transformers, and many others.

Of course, we should broaden our perception to encompass projects that are not necessarily effects-driven but still rely heavily on virtual production. These are films that leverage virtual production to portray an impossible situation or setting with veracity. Some examples include Rent, Jarhead, Life of Pi, Mad Max: Fury Road, Logan, Bohemian Rhapsody, Welcome to Marwen, Rocketman, and more.

Virtual Production in Action

Virtual Production Key Features and Benefits

One area in which VP offers great benefits is asset creation. The more effort put into creating an asset both in terms of visual fidelity and real-time efficiency, the more it can be used from previs to final pixel without having to recreate the desired object at additional cost and loss of time. Level of detail (LOD) control and decimation of assets is built directly into the engine to enable the same high-quality source asset to be decimated enough to work in real time at the desired frame rate, while still preserving the visual fidelity.

Also, because high-quality assets are part of the equation, additional business opportunities to create digital backlots and prop houses can benefit long-form productions through economies of scale and give rise to new service providers. These same production assets can be quickly adapted and delivered to ancillary pipelines to create screen-accurate promotional imagery, game assets, and toys.And this can be done without the need to rebuild the asset for each application,both saving time and avoiding the quality/consistency issues that can result from rebuilding.

A real-time engine offers more malleable tools and can be customized to fit the filmmaker because it's always in an active state of development. If you as a DP decide there's a particular set of framing lines you always want to see in the virtual scouting image, the engine can be easily customized for you. Or if you would like to see a certain kind of visual effect in your set, it can be added and re-used.

Remote/multi-user collaboration on a traditional movie set might typically consist of a remote video feed or screen share. A real-time engine, because of its roots in gaming, already has "multiplayer" remote collaboration and communication capabilities deeply integrated at its core. So it is possible, for example, to share remote virtual scouting sessions as well as allow participants to control and participate in performance capture sessions directly and collaboratively.

Real-time physics are another benefit which comes from a real-time engine's gaming origins. This means you can create stunts and check camera movement trajectories not just theoretically but with real-world physics simulation. You can also create animation for previs and final pixel with much more realistic physical effects, without having to invent them from scratch.

Distributed rendering is not a new concept to visual effects animation and may conjure up images of massive server rooms chugging away on frame-by-frame rendering. For real-time engines, distributed rendering can be leveraged in real time to increase both the performance of animations and their resolution. Having multiple instances of the engine in parallel and outputting in tandem to a video scaler means that live in-camera visual effects can go beyond 4K and even 8K image resolutions to deliver stunning image fidelity.

Real-world camera movement for enhanced realism can also be leveraged in virtual production. Because everything happens in real time, many other aspects previously relegated to post-production can be photographed live. Compositing can also be done live so that it can be assessed during production on set rather than deferred to later in the post-production schedule. Indeed, the embrace of virtual production can shift the entire crew's mindset from "fix it in post" to "fix it in pre" and "fix it in production."

Avoiding budget creep in post with increased levels of collaboration is an added benefit of virtual production. Because the imagery is created in a malleable real-time engine instead of being baked into more traditional modeling and animation pipelines, completed takes can continue to be refined and updated in post without losing excessive time or money.

Asset tracking and data management are always constant struggles with home-grown tools often created out of necessity to deal with the amount of assets and their versioning during a production. A real-time engine, due to its roots in programming and scripting, is designed from the ground up to precisely track and version all kinds of assets, turning a previously difficult challenge into a built-in feature. In short, all of the strengths that come "for free" as part of a real-time engine also have significant benefit and utility to movie productions.

Virtual Production by Department

From the producer and the director of photography to the editor and the visual effects supervisor, and many departments in between, virtual production is highly impactful.

Producer

As a producer, you stand to gain tangible benefits from virtual production. Real-time engines enable image fidelity of such a high level that it's entirely possible to previsualize an entire film during preparation to the degree that it can be shown to test audiences without any caveats. This approach enables you to workshop concepts,

explore a story's dramatic cohesion, and increase engagement with studios, all at a very affordable cost compared with actually shooting and post-producing a film.

You're already accustomed to working with more traditional forms of previs during project development. For example, you've likely worked with conceptual and storyboard artists to attempt to communicate a project's style and feel, above and beyond the script. You've also likely worked with previs animation to communicate complex action sequences during pre-production.

The advantages of a real-time game engine for a producer include higher-image fidelity and increased malleability. As an entire scene runs in real time, making changes to angles or actions is much easier than having to re-render frame by frame. You gain much more flexibility. Time is money, and virtual production, by its real-time nature, will save you both. The result is increased ability to refine concepts, so production time is spent realizing a well-conceived script rather than rewriting and developing during production when every moment is highly costly.

A live LED wall for complex visual effects scenes, in lieu of more traditional green screen, also provides a number of benefits to you as the producer. By creating an entire scene live on an LED screen, visible both through the camera and to the actors on set, your team entirely avoids "green-screen fatigue." This can occur when the cast and crew become inured to looking at the same flat-color screen for long periods and creatively disengage from the story.

Instead, a live LED wall gives everyone clear visual context, keeping them as engaged as they would be on a location shoot.

Director

As a director, you're responsible for guiding the many creative elements that make up a completed film. Your work is made exponentially easier by having a clear and common frame of reference to which all contributing crew members can refer throughout the project. Some additional benefits include: Increased agency over the final image. When collaborative elements such as previs are easier to change and quick to render, you gain more creative input for pre-production. The closer you can get to a shared vision that everyone can see and refer to, the more likely the final project will reflect that vision.

A real-time engine enables a more iterative workflow via the reduced friction to create reference imagery. It also means creative alignment during a period when assets are less costly to create and modify, with increased ability to contribute for
all department heads. Increased participation also means everyone can bring their entire experience and talent to bear without fear of budgetary constraints.

When using a live LED wall in place of a static green screen, you as a director gain additional benefits such as increased accuracy and control over framing

and lighting. Instead of requesting your cinematographer to make an educated guess about virtual elements in the frame, you'll actually be able to frame them directly in the viewfinder, and the cinematographer can light scenes according to their training and expertise.

Your actors will know what they're looking at and be able to modulate their performances to match the action instead of suffering from green-screen fatigue and disorientation. You can toggle between angles, sets, and locations rapidly to make the most of your shooting day and spend less time waiting for resets.

By using specialized VP tools like Sequencer in Unreal Engine, you can also gain a deeper level of direct orchestration of elements. Repeatable visual cues can be as complex and varied as you wish.

As a result, you can take bolder risks and create more varied sequences without fear of budget or logistics hampering the work.

Virtual production for the director comes down to the ability of your entire team to see with their own eyes precisely how the scene will look as you're creating it. The editor has all of the elements they need to make sure that the scene is working and any tweaks can be made immediately, which means fewer re-shoots. This ultimately can result in fewer, more efficient shoot days.

So you'll know when you have a scene on the day on the set, instead of having to wait days, weeks, or even months until a final version is ready. And by then, your sets have been struck and your actors and crew have moved on to another project. Instead of having to live with compromises, you'll be able to confidently complete production and use post as a time to finesse what you have versus needing to hastily rebuild it from scratch.

Director of Photography

As a director of photography, you're responsible for everything seen in the frame. But that becomes more of a challenge on a VFX intensive project, when so much of the frame is created long after principal photography wraps. The disorientation and frustration of shooting actors alone on a vast green screen is a familiar scenario in modern filmmaking. Virtual production can help increase the level of certainty you have over the final image.

VP can also provide you a greater level of collaboration with the art department, production designer, and visual effects team. The efforts of all of these teams have a major impact on the final image. Here are some examples of how these collaborations can work: During pre-production, virtual production goes far beyond previs animations. The development of previs used to be siloed away from the rest of the development process, because the work required time-consuming frame-by-frame animation.

Traditional previs is not as malleable or collaborative, and therefore not much different from working with a traditional storyboard artist in terms of direct interaction. With a real-time engine, previs including real-world physics can be manipulated directly by you working side-by-side with non-engineers.

A real-time location scout could involve your wearing a virtual reality headset (HMD or head-mounted display) and interacting directly with previs animation playing back. You would be able to manipulate elements of the virtual set directly via VR hand controllers, exactly how you'd be able to on a real set. You'd be able to plan shots out using virtual cameras all within the real-time engine. In short, you'd be able to more directly influence look development, previs shot design, and framing, which ultimately leads directly into decisions made on set. Getting everyone aligned to the same vision becomes easier.

If a production involves performance capture, VP will take various forms. You'll work with actors wearing motion capture suits to serve as a reference for later digital characters. Simulcam will aid you by providing a real-time preview of the virtual characters synced to the motion capture actor and superimposed live over the output of the camera. This makes framing and timing a lot more straightforward.

If the production involves a real-time LED wall, as a DP you'll find plenty of new options for control over the image. Turnaround becomes far less time-consuming because rather than having to physically move the crew, actors, set pieces, and so on, you can just rotate the background scenery on the screen and be able to reset for turnaround in moments instead of hours. This also means you can hold and control the time of day to any specific mood and color temperature you desire.

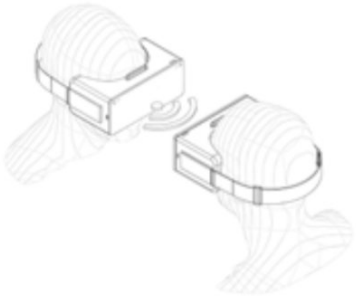
Interactive visual effects lighting can be another major challenge; that is, synchronizing movie lights with visual effects on a green screen. When working with a traditional green screen, you often have to settle for an educated guess that the color, intensity, and quality of your lighting matches what will eventually be composited into the frame. A live LED wall can greatly rectify this issue by providing a visible effect you can light to.

Furthermore, by connecting DMX/networked lighting controls into the real-time engine, movie lights can be combined with on-screen effects for automatic synchronization and infinite repeatability.

LED walls do present some photographic challenges as with any technology, which you'll want to take into consideration. Carefully coordinate with the team sourcing the LED panels to ensure a sufficient pixel pitch to avoid potential moiré issues. These can become more pronounced the closer the camera gets to the screen and the sharper the focus is on the screen versus the foreground. That said, moiré is easy to spot on the monitor during camera tests, so you'll know quickly if you have any issues with the sharpness of the LED panels chosen.

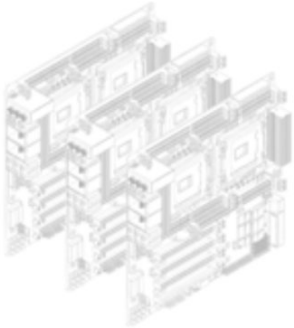
Asset Creation/Decimation of Assets/Virtual Backlot

Malleable Tools/ Fit to Filmmaker



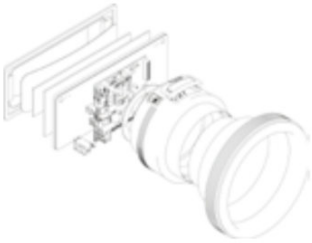
Remote/Multiuser Collaboration

Real-Time Physics Engine

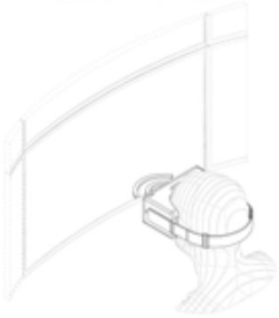


Distributed Renders: Scaler + Unreal

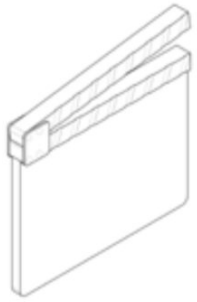
Capture Real-World Camera Movement



Real-Time Compositing



Live LED Walls



Live Production Mindset vs. “Fix it in Post”

Avoid Budget Creep in Post

Asset Tracking/ Data Management

Assets to Games/Toys/ Products etc.

Virtual Production Workflow Features

Visual development by Fox VFX Lab

Light contamination of movie lights back onto the LED screen itself presents another possible challenge. As the LED wall is an emissive source, a strong key or spotlight hitting the screen can create a hotspot. Careful flagging and a comfortable distance kept between lighting equipment and the screen can mitigate this.

Virtual green screen placement also greatly simplifies shots in which post-production compositing is desired. Instead of having to handle a giant, unwieldy green-screen rag and then carefully light it, you can simply place areas of green precisely where they are needed directly on the LED wall via the engine. The effect is seamless and perfectly lit. You can even combine the effect with camera and actor tracking to create a halo effect where the green screen area precisely follows the actor outline and minimizes spill and contamination.

The color science and bit-depth of the on-screen image should also be accounted for. You'll want to confirm that the color balance and possible LUT applied to the screen complement the settings of your camera and supporting equipment. Also if you are using the LED wall to extend a foreground set, careful color balancing to achieve the smoothest blend is required. Movie lights also have their own colorimetry and intensity that need to be balanced for appropriate combination. To make this process easier, real-time engine footage can be processed through real-time grading systems before output to the LED wall to help ensure the most precise color matching between all the elements in the frame.

Successful virtual productions arm you with the tools to experiment with multiple photographic approaches in response to artistic motivations and new variables, enabling you to treat the virtual elements as simply another tool in the toolbox. VP teams are there to support the efforts of the live-action crew. They are eager to collaborate with you for the shared goal of creating great imagery in the service of storytelling.

Virtual Production Supervisor

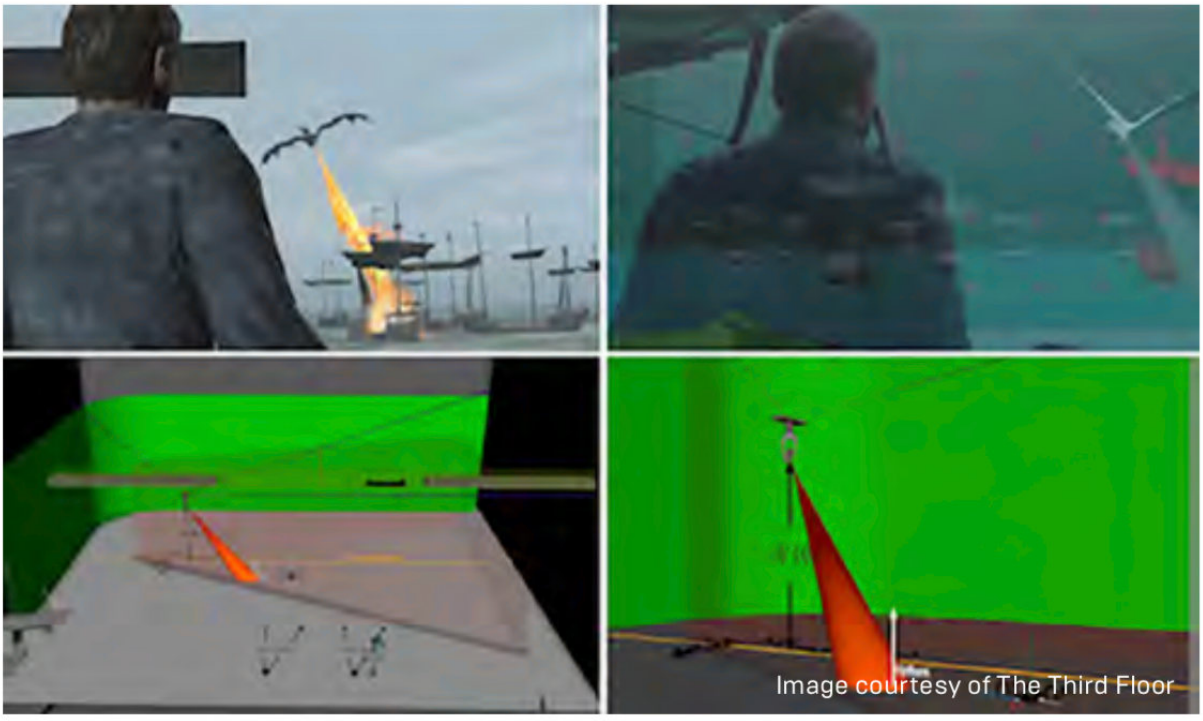
The virtual production supervisor is logically an integral part of any project involving virtual production. We include the role to highlight its importance as well to help crew members from other areas to better understand what the responsibilities of a virtual production supervisor are.

The virtual production supervisor is a liaison between the more traditional areas of the production team and the real-time areas such as the virtual art department. They also oversee the creation, decimation, and reuse of real-time assets to enable them wherever possible to be shared with other departments and become the basis for final visual effects animation.This opens up a whole new area of opportunity to create virtual prop houses and backlots where assets created for a long-form series can be reused over entire seasons to greatly increase efficiency and cost savings.

Another area the virtual production supervisor helps oversee is the creation and management of virtual scouting. This includes the creation of the virtual scout
locations themselves and the coordination of getting the key creatives together into the virtual space to complete the scout.

Addison Bath from The Third Floor speaks to actors in performance capture suits for a previs session.

Performance capture in progress for Robert Zemeckis' "Welcome to Marwen".



Previs and techvis created by The Third Floor with visual effects from Image Engine for "Game of Thrones".

Editor

As an editor, you're accustomed to working with raw footage from production, so you're used to using your imagination with the script as your guide to determine to how everything will fit together. Your challenge increases on a VFX intensive project, where much of the frame—or even all of it on some shots—may be temporary imagery or missing entirely.

Virtual production techniques can be a big help by giving you a clearer idea of shots and sequences, empowering you to complete edits more efficiently, and providing greater feedback to the team even while the movie is still in production. Here are some examples of how VP can work for you:

Previsualization, techvis, and postvis often generate imagery that winds up in an edit, albeit temporarily. The image quality often varies greatly due to trade-offs in image fidelity versus render times. Real-time engine image quality has increased exponentially over the past few years to the point where it can often look as good as, or even identical to, the final imagery. This empowers you to have a greater sense of how the movie is working from shot to shot and sequence to sequence. You can then communicate any concerns about story, continuity, performance, and so on to the director and other crew members before production even begins. This leads to not only improved efficiencies in time and costs but also more satisfaction coming from a more direct collaboration with the production team.

Scenes featuring real-time LED walls will also be a major help to your work as an editor. Instead of receiving footage with actors in front of an otherwise blank green screen, you'll have completed shots. And because LED walls eliminate the per-frame cost of post-produced visual effects, you'll be able to work with effects-intensive shots just as you would non-effects footage.

You'll have the entirety of each take from start to finish available to you versus just the portion with visual effects in progress. This affords you much greater fluidity to construct sequences without being locked into edits dictated by an already in-progress effects pipeline.

Finessing the final cut of a movie featuring previs placeholders for visual effects also often involves accepting creative compromises. Deciding to add more than a few frame trims on previously locked edits with completed or in-progress effects can add budget creep as well as delay the schedule while visual artists create new visual effects. Conversely, visualization created through real-time game engines can be more quickly changed to accomodate the edit, resulting in an improved creative process that doesn't come at the expense of lost budget or time.

The bottom line is that virtual production, due to its more malleable nature when compared to traditional post, gives you greater agency and collaborative

potential as you edit. You'll be able to provide feedback based on previs that looks a lot closer to final imagery during development and production.

You'll be able to provide feedback during production on any creative, storytelling,blocking, or performance issues that might not fully reveal themselves until much further down the pipeline in traditional visual effects workflows. Knowledge is power,and for an editor, the closer a frame looks to its final form, the better. This also means you can further decouple story concerns from budgetary realities, because making changes is a lot more economical for virtual production shots than for more finalized visual effects.

Stuntvis prepared for "Mad Max: Fury Road" leverages real-time physics in Unreal Engine.

Another view of stuntvis prepared for "Mad Max: Fury Road".

Performance Capture

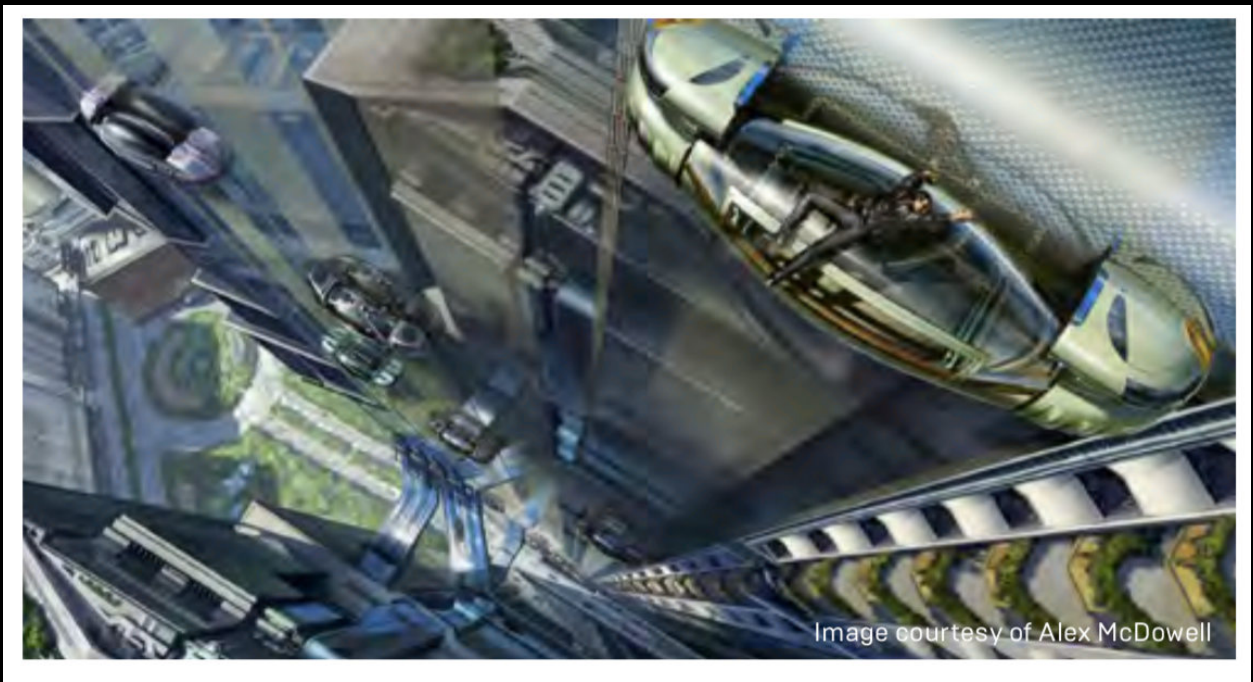
Performance capture is another area that has always been a part of the virtual production workflow. We include it here not only to survey its evolution over the years, but also to look at how it can be best leveraged to interact with other elements of the workflow.

Performance capture is actor-driven visual effects. By connecting the body and facial movements of a human being to a digital asset, more believable characters and emotions can be created. This is not to say that there isn't a place for

manually keyframed animation in visual effects, but nothing communicates the subtleties of a living character to an audience more realistically than a human performer.

Performance capture can take the form of reference photography on an otherwise live-action set or as a fully virtual capture volume to enable performers to act within a more fantastical setting. In either case, the direct use of real actors permits a greater degree of interaction between visual effects, camera, and director than would be possible with post-produced visual effects.

Previs



While you might have previously conceived of previs as focused on the pre-production phase of a project and less integral to production, that conception shifts with a real-time engine. Previs is also typically a hands-off collaboration. In a traditional pipeline, a previs artist receives creative notes and art direction, then goes off to create animation and present it back to creatives later for feedback.

In the real-time model, because the assets are malleable directly and rendering time is not a limiting factor, creatives can be much more directly and interactively involved in the process. This leads to higher levels of agency and creative satisfaction for all involved. This also means that instead of working with just a supervisor you might be more directly interacting with the director, editor, and cinematographer to design sequences and shots earlier in the project, often right in the

room with you as you edit the previs sequence and watch the results together in real time.

Previs image quality has continued to increase in visual fidelity. This means a greater relationship between previs and final-pixel image quality. When the assets you develop as a previs artist are of sufficient quality, they may form the basis for final models in visual effects. The line between previs and final pixel will continue to blur.

The efficiency of modeling assets only once is evident to all involved. By spending the time early in the project to create models of a very high quality, post-production begins at the outset of a project. Instead of waiting until the final phase of post to deliver the higher-quality models, the production has those assets from the beginning. And the models can also be fed into ancillary areas such as marketing, games, toys, and more.

Image courtesy of The Third Floor

Action Designer / Stunt Coordinator

In your work as a stunt coordinator, virtual production represents a huge leap forward not only in the complexity of stunts you can achieve, but also the degree of experimentation available to you for developing concepts. Stuntvis is its own specialized form of previs where the stunt coordinator uses virtual production tools to simulate stunts using real-time animation and with real-world, accurate physics. Above all, you'll have a higher degree of safety through the extended ability to design, analyze, simulate, and present concepts for stunt work.

Scenes featuring real-time LED walls add another new dimension to your toolbox. You can create live stunt sequences that look incredible but are no more dangerous than walking in front of a movie screen. Careful integration between the foreground set and its extension into the LED wall can create highly believable sequences.

Performance capture is yet another area where you as stunt coordinator can highly benefit. If a project requires non-human characters to perform specific stunt sequences, you can use performance capture to apply the motion of stunt performers onto completely digital characters. This can also be combined with visual effects to create the appearance of non-stunt performers performing complex stunts.

Production Designer

Production design is another area of movie creation that has been transformed by virtual production techniques in the form of provisional imagery. Advances in CAD design have already been happening for decades in set design and construction, making pure 2D drafting techniques increasingly rare in production design. The addition of real-time engine technology supercharges this approach and provides a variety of benefits for the production designer. Let's take a look at these benefits below:

Virtual scouting of set designs enables you as the production designer to view and share a highly realistic simulation of the planned set designs. You can view sight lines, determine if all desired camera angles will work, and make decisions on how much set to actually build. This empowers you to deliver precisely the set designs needed with much higher accuracy and cost efficiency while also enabling more experimentation during development.

You'll also enjoy a closer interaction with key collaborators such as the director of photography and director. With virtual production, the level of abstraction is much lower compared to reviewing traditional set design blueprints and architectural illustrations. The entire team can see the set in a form much closer to how it will look in

real life and be able to provide feedback that doesn't have to wait until closer to production when changes are more difficult and more costly.

Production design is further transformed via virtual production with real-time LED wall technology to seamlessly blend foreground sets with digital set extensions. You'll be able to create more fantastical and elaborate set designs than ever before.

This requires close coordination with the virtual art department in order to determine which portion of the foreground set should be built and where the virtual wall set should begin.

Virtual Imaging Technician/Grip

As a grip on a traditional movie set, you have the responsibility of setting up camera rigs, controlling natural light, building lighting grids, and many other vital tasks. On a virtual production, your duties are similar, but the workflow will be different and often more free-form and evolving.

Here are some examples of tasks you might be called upon to perform:

On a performance capture or virtual camera (v-cam) production, that is, where the camera crew is operating reference cameras to capture animation within a real-time engine, you may be called upon to do many familiar tasks. For example,you might rig up a dolly on tracks within a motion capture volume. Instead of having to build a track around and over obstacles, you'll be more concerned with securing optical motion encoders into the gears of the dolly wheels.

There may be a scale factor between the physical crane or dolly track you build and its virtual equivalent. Let's say you wanted to make a 150-foot dolly move. In this case, you would work with the real-time artists to scale the real physical movement from a 10-foot stretch of track to drive a 150-foot virtual move.

You can consult the operator to make sure the dolly is geared down enough to feel like a much longer move. And instead of using tape measures, gaffer's tape, and lasers to set dolly marks, you'll be able to set limits within the digital set and never miss a mark.

You might be asked to build a truss above the capture volume. Instead of lighting,the truss could be used to hang motion control trackers or witness cameras. You'll build special cranes, sliders, and handheld units that incorporate tracking sensors so they can be tracked in 3D for the real-time engine. Sometimes there may not even be a traditional camera, but a stand-in you'll rig onto the dolly, crane, or handheld with all the standard camera accessories and similar weight and feel for the operators. In other words, you're responsible for translating the look and feel of a more traditional production into the virtual production world.

You might find yourself in a virtual reality headset (HMD or head-mounted display) on a virtual scout with the director and the DP inside the real-time engine, seeing each other and the environment. You might physically move items in this virtual world with a hand controller. Your knowledge of the physical grip world will be invaluable in helping to ground the virtual set.

If the production involves a real-time LED wall, you might be tasked with helping set up the modular wall itself. This work can include fitting together individual 27” LED panels onto a support platform and then wiring them to each other and back to a video scaler. Sometimes a single flat LED wall is not enough to cover the desired action, so you might be asked to help to create an amalgam of multiple LED walls at different angles and curvatures.

When it comes to lighting, DPs often supplement the reflections and indirect lighting coming from the emissive LED wall with additional movie lights. So could find yourself hanging SkyPanels near LED walls and cabling them to sync up with the output of the real-time engine.

Although you’ll be working in a single location, you may need to make video village more portable. The DP will be operating their shots more from this village than they would generally, since they will be seeing the real-time virtual action only on a viewfinder or monitor and not directly. You’ll be responsible for rigging a collaborative space where the department heads can have the tools they need to collaborate in proximity.

The bottom line is all the familiar tools you currently use, like apple boxes, c-stands, and truss rigs, speed rail, still find a home on a virtual production set. They will just be used in new ways. Discovering these methods to enhance production is a collaborative effort.

Visual Effects Supervisor

Any visual effects supervisor active within the last couple of decades is already well acquainted with the utility of virtual production as a planning and revision tool in the form of previs, techvis, and postvis. Your department is now on the precipice of a revolution on par with its progression from optical to digital compositing and the advent of CGI animation. Real-time live visual effects via LED walls and screens enable final-pixel visual effects to be achieved live on set instead of relegated to post-production.

Virtual production brings both new benefits and new challenges to the visual effects department. On one hand, you’ll be able to deliver visual effects live on

the day without compromises, ready to go into the edit without temporary placeholders.
On the other hand, it also means that many of the creative and technical decisions that are normally deferred until much further downstream in the schedule will need to be settled earlier in the production.

Many of the key challenges of traditional green screen compositing go away with live virtual production. For example, green screen spill goes away because there is no green screen. In its place is the actual desired background which means you get desirable reflections instead of spill. Check out any of the space sequences in the film First Man to see how believable and natural the exterior reflections achieved through live LED projection look compared to more traditional post-production composites.

In order to take maximum advantage of virtual production, it's also helpful to conceive of the emphasis of work as inverted when compared to a more traditional visual effects workflow. Instead of the lion's share of the work happening after production and in the run-up to final delivery, virtual production for live visual effects presupposes the greatest visual development and finaling during pre-production and leading up to production.

You may also identify potential adjustments in the skill set of visual effects artists who comprise your team.

Traditional modeling places the highest emphasis on visual fidelity with render times measured in up to hours per frame. Real-time virtual production shifts the priority to real-time performance, with frame render times expressed in fractions of a second, up to 60 frames per second and sometimes more. Assets need to be created with efficiencies in mind and optimized for real-time playback.

Visual fidelity is of course still the main goal, but as a corollary to real-time playback performance. You'll want to seek artists with experience modeling and optimizing assets for real-time. Their backgrounds might include game asset development as well as traditional visual effects work.

What's Next for Virtual Production

One likelihood for VP is that the computing hardware which makes it possible will continue to improve and evolve. Specifically, CPUs and GPUs will get more and more powerful with each new release. That means image fidelity will increase even more. And of course, Epic Games will continue to develop Unreal Engine to leverage new real-time technologies like ray tracing to further increase image quality.

Along with ongoing technological improvements, we also believe the growing adoption of virtual production will create more opportunity for everyone. All the traditional departments should investigate its potential and leverage the expertise of seasoned CGI artists. Visual effects vendors should look at how they can collaborate even more in the development phase.

Demand for specialists such as virtual asset designers and other key members of the virtual art department will increase. Another opportunity is VP asset repositories / virtual backlot services. The current 3D marketplaces such as TurboSquid, CGTrader, and Quixel are just the tip of the iceberg in terms of what future demand may bring.

Demand for virtual production services will also increase. It's not hard to look at the current cutting-edge companies offering VP services and envision entire industries cropping up alongside them. One need only look back to the onslaught of CG animation companies that appeared in the '90s at the dawn of CGI for visual effects to imagine the possibilities.

The increasing accessibility of virtual production tools and the quality of the images they can produce also means more voices creating more content. The limits will become imagination and raw talent and not final budget, as should be the case fo any artistic endeavor. One need only look at applications like CineTracer and indie projects like FRAGMENT to see that tools we couldn't even imagine a few years ago are now available to the most modest of budgets.

The ease and malleability of real-time animation means that the process will trend toward filmmaker-driven imagery with less reliance on engineering. That means final imagery closer than ever to the creative vision with less friction along the way. When the virtual and real worlds meet, anything is possible. VP leads to a more collaborative workflow, where the many departments involved in a project can share assets and creative vision versus a more isolated, traditional workflow.

Compiled by Arun EM from Unreal Engine VR Production guide and additional information from Matt workman from cinema database and Adam Maier from FOX VFX lab