The New Art of Virtual Moviemaking

Virtual Production processes are set to transform the way filmmakers and their teams create high quality entertainment.

New digital technologies are providing filmmakers and their production teams with real-time, interactive environments and breakthrough workflows, transforming the way they plan and create movies. Using the latest 3D software, gaming and motion capture technology, they can explore, define, plan and communicate their creative ideas in new, more intuitive, visual ways helping them reduce risk, eliminate confusion and address production unknowns much earlier in the filmmaking process. Innovators – from production companies like *Lightstorm* to pre-visualization specialists like *The Third Floor* – are already using Virtual Production technologies to push creative boundaries and save costs.

> *"Through the [Virtual Moviemaking] process we are able to optimize the entire film, to make it more creative, and to insure that more of the budget ends up on screen. That's where all the technology – all the hardware and software – comes into play: to make sure that the vision of the director is preserved throughout the entire process."* **Chris Edwards, CEO The Third Floor – Previs Studio**

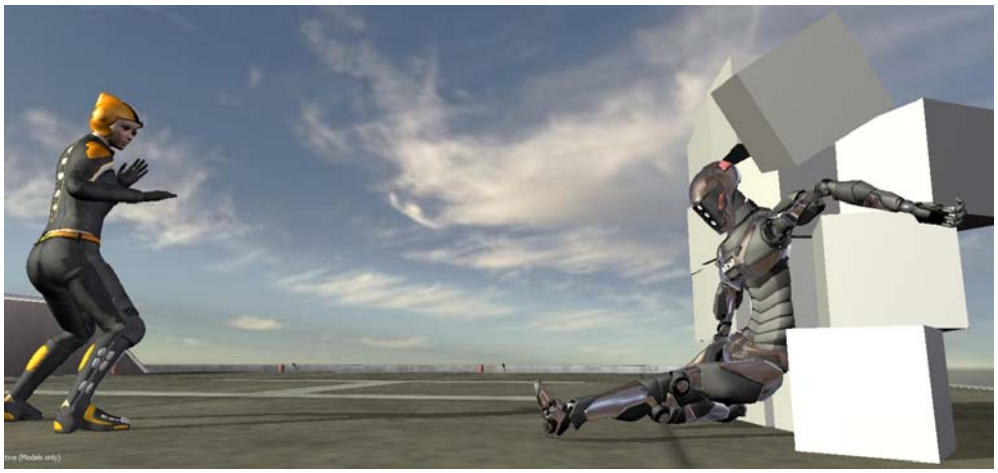

Fig 1. Virtual Moviemaking uses real-time 3D applications such as Autodesk® MotionBuilder® software to visualize and explore computer-generated scenes for feature film and game cinematics production.

The purpose of this whitepaper is to help directors, production designers, art directors, visual effects supervisors, cinematographers, and other film professionals to better understand Virtual Production processes for moviemaking; mastery of which will enable you to have greater creative control and input into the entire production process – including digital production processes – as well as a clearer understanding and ownership of your individual contributions to these processes. We hope that on reading this you will have a better understanding of the increasing relevance and importance of Virtual Moviemaking to the entire film production industry.

Virtual Production, or Virtual Moviemaking, is a new, visually dynamic, non-linear workflow. It blends virtual camera systems, advanced motion and performance capture, 3D software and practical 3D assets with real-time render display technology, enabling filmmakers to interactively visualize and explore digital scenes for the production of feature films and game cinematics.

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Historical Perspective

The film production process is a constantly evolving one as technologies emerge enabling new types of creativity. Today, the use of digital technology is becoming pervasive in filmmaking. Its adoption has been marked by significant tipping points, one of the first of which was the introduction of non-linear editing (NLE) systems in the late 80s. All of a sudden the craft of the editor changed radically. Editors could experiment more and be far more creative. Because their edits became virtual they could change them at any time; and so today editors begin editing from the first storyboards and keep on editing until the film is ready to print for distribution – sometimes even afterwards. The digital edit became the first virtual representation of a movie, albeit a rather low quality one.

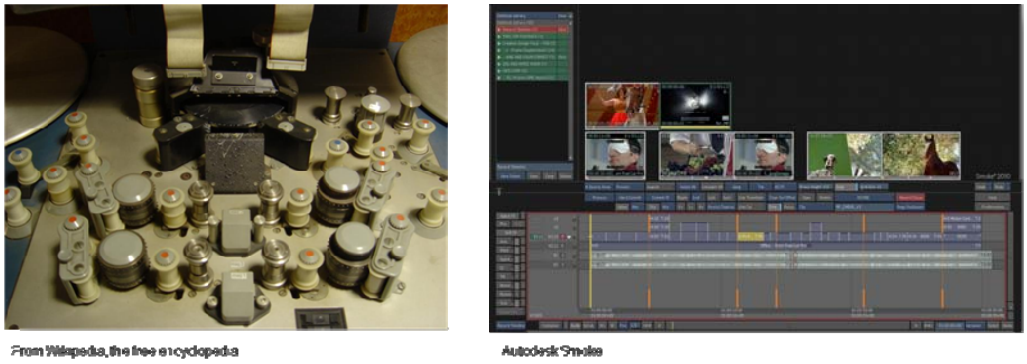


Fig 2. Digital non-linear editing radically changed the craft of editing[1]

Another tipping point occurred when it became feasible (and cost effective) to scan the entire movie at high resolution. This paved the way for Digital Intermediates (DI) and changed the way movies are color graded. The DI process enabled the creation of a high-quality, high-resolution, virtual representation of the movie – a digital master. Between these events use of digital visual effects had also rapidly expanded and full length CG animated movies had become highly popular (*Sidebar*).

Editors and cinematographers needed to develop new knowledge and skills to take advantage and control of the new technology. In return they got greater creative freedom, but also greater responsibility. One advantage of digital technology is that it removes physical constraints. While this is truly liberating in terms of creativity it is also a source of potential error, especially if the scope and impact of the technology is not fully understood. Avoiding pitfalls requires effective collaboration between crafts, respect for the different skills and requirements of key stakeholders, and a solid understanding of how to guide technology to produce the desired creative outcome – a problem sometimes referred to as maintaining **creative intent**.

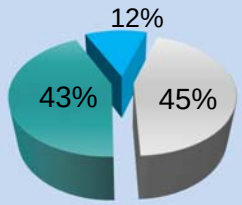
Virtual Moviemaking is another such tipping point impacting a broader range of film production professionals from directors, art directors and cinematographers to visual effects supervisors and other production teams. But why is it so important? The answer lies in the increasing use of computer generated characters and visual effects in movies. A director wants to (and should be able to) scout locations or direct the performance of characters irrespective of whether they are real or virtual; but today much of computer graphics production is treated as a post-production process for review and approval and not as a hands on directive experience. Virtual Moviemaking processes help change that dynamic enabling filmmakers to have hands on creative input into what is an increasingly important part of the movie making experience.

1 Image: Steenbeck film editing machine by Andrew Lih, Courtesy Wikpiedia, the free encyclopedia under Creative Commons Attribution-ShareAlike 2.0 license

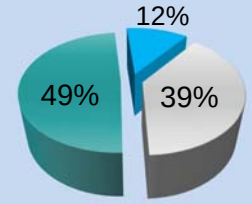
The Demand for Computer Generated Imagery (CGI) in Movies

The last decade has seen a rapid rise in the demand for computer generated imagery in movies and has been a major driver behind box office success.

2007 Share of Box Office Gross (US)



2009 Share of Box Office Gross (US)

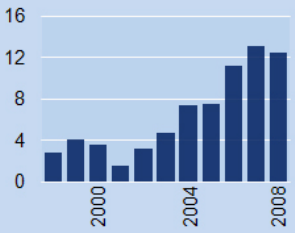


VFX Blockbusters*
Animation
Other

**Visual Effects*

Increasing Use of Digital Visual Effects 1998-2008

(VFX shots per minute)

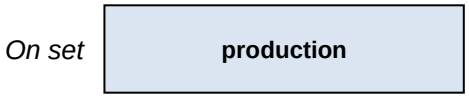


The graph above shows the trend for increasing numbers of digital visual effects shots per minute of movie based on the Academy Award® winners for Best Visual Effects.

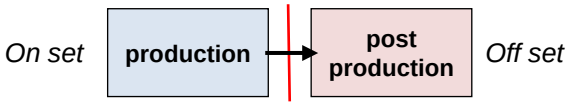
Note: by 2006 almost every shot in the winning movies involved some level of digital visual effects

Full Circle? The Promise of Virtual Production

Not so long ago, if a director wanted to shoot a special effect or add a monster to the scene he or she would have to figure out a way to shoot it on camera. This obviously imposed some limitations as to what could realistically be done, but at least he or she could interact directly with the process and see it unfold before their own eyes on set. They could *direct* the performance of the monster and control the execution of the special effect on set. Then along came digital technology.

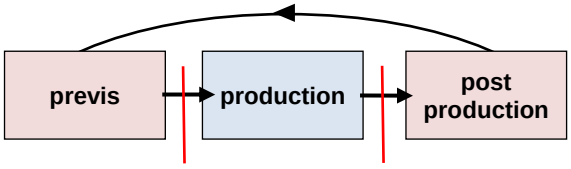


By the late 1980s high-resolution image scanners and high-performance computers made it possible and feasible to create digital visual effects. Suddenly the director's imagination was given free reign. It was possible to create the impossible: pyrotechnic explosions that defy the laws of physics, dinosaurs and alien creatures and planets. CGI was born but in the process the director lost the ability to get involved directly in the creative process which was now done after production in *post*-production. The director's role became primarily a role of review and approval at scheduled screenings of pre-rendered shots. The process could be compared to reviewing dailies without actually ever going on set.



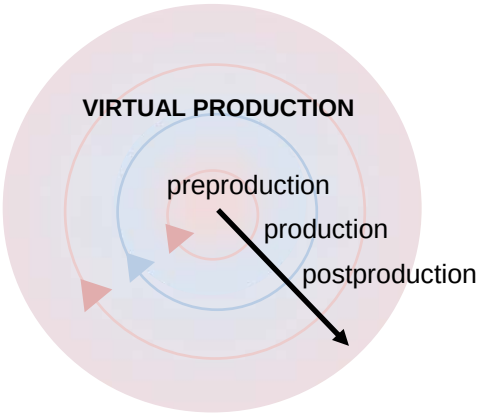
However as digital effects shots became more common, increasing from a few shots to tens, then hundreds, of shots, and finally in some cases the entire movie, effective planning became crucial and previsualization became important. Previsualization enabled the director to at least plan the visual effects shots better and make up-front decisions that would affect the final look and feel.

But there was a discontinuity between previsualization and post-production processes and still no real possibility for the director to interact directly with the creative process itself. As CGI tools moved into preproduction the on set production processes were increasingly isolated from the digital processes that surrounded them. This became problematic for directors working on productions that involved large amounts of CG for visual effects and digital character creation.



As leading filmmakers and their teams tried to tackle the creative problems inherent to the traditional production processes it became increasingly clear that they needed tools that would enable them to direct the CG processes as effctively as they could direct live action. It was from this need that virtual production tecniques were born.

Virtual production is an interactive, iterative and integrative process that starts from pre-production and continues till the final frame is printed to film (or packaged electronically) for distribution.



Virtual Production is an iterative, collaborative process that starts at preproduction and continues through production and into postproduction.

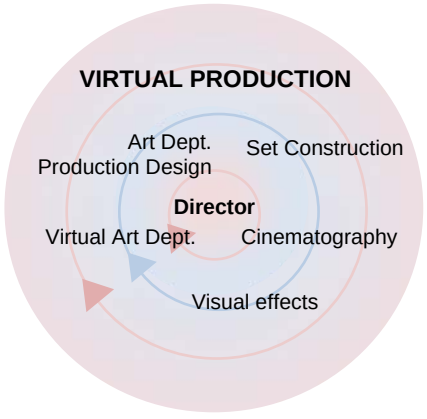
Digital technology blurs the boundaries between these process enabling a single virtual production space where the story continuously evolves fed by elements from both CGI and live action shoots.

Virtual production processes leverage the proliferation of CG technology upstream and downstream of the production process, together with the latest breakthroughs in gaming technology and real-time graphics performance to provide filmakers with the instant feedback and the '*in the moment*' interaction that they have long experienced on live action shoots. Creating CG animation and visual effects shots can be experienced more like a live action shoot yet still offer the creative flexibility than is impossible on the real world set. when virtual production becomes interactive it feels much more like traditional moviemaking, hence the term **Virtual Moviemaking**.

Virtual Moviemaking also differs from traditional CGI in that it is driven by the lead creative team members themselves. The Director and Cinematographer actually hold the camera and perform the shots as opposed to this being done secondhand by computer animators and previs artists. Powerful real time rendering engines make it possible to create visually appealing images that are worthy of the highest quality concept art. Filmmakers no longer have to wait hours, days or even weeks to see CG shots presented in a visually appealing way that is representative of the images they have visualized in their mind's eye.

"Virtual Moviemaking can liberate filmmakers from the often stifling visual effects and animation process by allowing them to experience the production in much the same way they do while shooting live action. They are immersed in the world of their film and the entire production benefits immensely from that kind of immediate creative discovery and problem solving

***Rob Powers**, Pioneered the first Virtual Art Department for Avatar*



The improved accessibility offered by the Virtual Moviemaking process fosters greater collaboration and communication throughout the entire production team, encouraging productive conversations between team members that would previously have had little or no contact.

The Virtual Moviemaking forum as a conduit for increased collaboration and a hub for communication throughout the production is arguably one of its strongest benefits for the inherently collaborative medium of moviemaking

Applications of Virtual Moviemaking

Virtual Moviemaking represents a significant metamorphosis in the use of digital technology for film production, enabling greater creative experimentation and broader collaboration between crafts. It transforms previously cumbersome, complex and alienating digital processes into more interactive and immersive ones, allowing them to be driven by the filmmakers themselves. As a result, Virtual Moviemaking is helping filmmakers to bridge the gap between the real world and the world of digital performers, props, sets and locations. It gives them the freedom to directly apply their skills in the digital world – whether for the hands-on direction of computer generated characters, or to plan a complex shoot more effectively. Being digital, Virtual Moviemaking technology is highly flexible and can be easily molded to fit the exact needs of a given production. As a result its applications vary extensively in scope ranging from previsualization to virtual cinematography (*Sidebar*).

The term **virtual cinematography** was popularized in the early 2000s with the digital techniques used to create the computer generated scenes in *The Matrix Reloaded* although, arguably, both the term and many of its concepts and techniques predated the movie. In its broadest sense, virtual cinematography refers to any cinematographic technique applied to computer graphics, from virtual cameras, framing and composition to lighting and depth of field. In this broadest sense virtual cinematography is a key part of effective digital visual effects creation and essential to creating imagery that serves to develop and enhance the story. More recently the term has been specifically applied to real-time tools used during production to make directive decisions.

CG and CGI

CG = Computer Graphics
CGI = Computer Generated Imagery

CGI is a specific application of CG in that it refers to the use of computer graphics to create synthetic imagery. However, the two terms are sometimes used inter-changeably in the visual effects industry.

In a broad sense, computer-generated is an adjective that describes any element created by a computer– as opposed to shot live on a set or location.

Virtual Moviemaking technology provides significant benefits to live action visual effects production. The technology can be used to immediately visualize how the shot will look after post-production. Camera moves can be planned and tested in real-time and both creative and technical aspects of the shoot carefully evaluated and tested. The director can see and understand the full context of the shot including the visual effects that will be added later, enabling him, or her, to direct performance appropriately.

Another application can be found in the way top production designers are using Virtual Moviemaking to design and explore virtual movie sets before they are built by the construction crews. At first glance this appears to be a fairly logical evolution of the previsualization process commonly used by many film productions to plan and trouble shoot the production. However, Virtual Moviemaking offers much more flexibility by providing an infinitely customizable real-time stage within which to work.

The real-time aspects of Virtual Moviemaking technology are also highly beneficial for CG animated movies and videogame cinematic sequences where real-time virtual cameras and lighting help simplify and accelerate the camera animation and layout process.

Previsualization*

Previsualization (previs) is the use of digital technology to explore creative ideas, plan technical solutions to production problems or communicate vision and creative intent to the broader production team.

On-Set Previsualization*

The use of interactive technologies on set to produce (near) real-time visualizations that can help the director and other crew members quickly evaluate captured imagery and guide performance.

Virtual Cinematography

Virtual Cinematography involves the digital capture, simulation and manipulation of cinematographic elements using computers – in particular the properties of cameras and lighting.

Technical Previsualization*

Technical previsualization focuses on technical accuracy in order to better understand and plan real-world production scenario. Dimensions and physical properties must be accurately modeled in order to determine feasibility on set.

Pitchvis and Postvis*

Pitchvis and Postvis describe the use of visualization in either the early conceptual development (for project greenlighting) or the later post-production stages of film production.

* *Definitions based on the recommendation of the joint previsualization subcommittee comprising representatives of the American Society of Cinematographers (ASC), the Art Directors Guild (ADG), the Visual Effects Society (VES) and*

Today, Virtual Moviemaking technology is being deployed by pioneering directors working on large-scale, blockbuster, science fiction and animation projects. Examples include James Cameron on *Avatar*, Steven Spielberg and Peter Jackson on *Tintin* and Robert Zemeckis on *A Christmas Carol*. These directors and their production companies are already designing and building special virtual cinematography sound stages and it is not a stretch to envisage a future in which most major sound stages will have Virtual Moviemaking capabilities. Today the technology is the preserve of large-budget productions but, given the rapid evolution of computer performance and capability, there is no reason not to expect that, as with Digital Intermediates (DI), Virtual Moviemaking will become accessible to a broader range of production budgets.

So profound is the impact of Virtual Moviemaking on the creative process that it will most certainly be felt across all departments and all levels of production by offering greater creative options and fostering a new collaborative environment to explore the moviemaking process.

In the next section we will take a more detailed look at the actual technology used for Virtual Moviemaking.

The Technology of Virtual Moviemaking

Virtual Moviemaking blends several, previously distinct, technologies and workflows from the film production and gaming industries. When used together the sum of these individual workflows becomes far greater than their individual parts creating a revolutionary new interactive workflow.

Core components of the Virtual Moviemaking include sophisticated hardware devices that allow direct input into the computer programs without having to use a keyboard or mouse, advanced motion capture systems, virtual asset kits or libraries and real-time rendering and display technologies (*Sidebar*).

As a result, the director can control the virtual camera in the computer using a familiar device such as a real but modified camera body. The movements of the camera and the actors performing can then be captured using special motion sensing devices and the results displayed in real-time on a computer screen. This allows actors and crew to shoot digital performances in ways that are intuitively similar to live action shooting.

Virtual Moviemaking workflows consist of several distinct but related components designed to make this all possible. The following sections describe these components in more detail.

Fig 3.
Exploring a computer generated scene using virtual cameras and actors
Chris Edwards at the Autodesk User Group, SIGGRAPH

Virtual Moviemaking in Action

Computer applications like Autodesk® MotionBuilder® allow directors to control a virtual camera using hand-held devices such as the mock camera shown below.

The camera movement is tracked in real-time and translated directly into the computer.

MotionBuilder also allows real time capture and display of actors' performances applied to digital characters.

This allows the director to shoot a computer generated (virtual) scene by simply directing the actors and moving the camera in the same way they would during a live-action shoot.

Motion Capture Camera Systems

The core of any Virtual Moviemaking workflow is the camera system. The camera system consists of two key components: a virtual camera and a device to control it. Basic systems use standard computer peripherals (a keyboard and mouse) to control the virtual camera. More sophisticated systems use specialized devices, or **tracking controllers**, that an operator can manipulate much like a physical camera. Depending on the user's preference such controllers can range from gaming controllers to flat panel viewfinders to full camera bodies (*Sidebar*).

In many cases the virtual camera is controlled by the operator moving a tracking controller within a **tracking volume**– a volume of space defined by a series of remote sensing devices capable of detecting the exact orientation and movement of the tracking controller (*Figure 4*). A computer translates the data from these sensors into instructions that control (animate) the virtual camera causing it to behave exactly like the controller. The sensing devices and the tracking controllers form an integrated system known as a **motion capture camera system**.

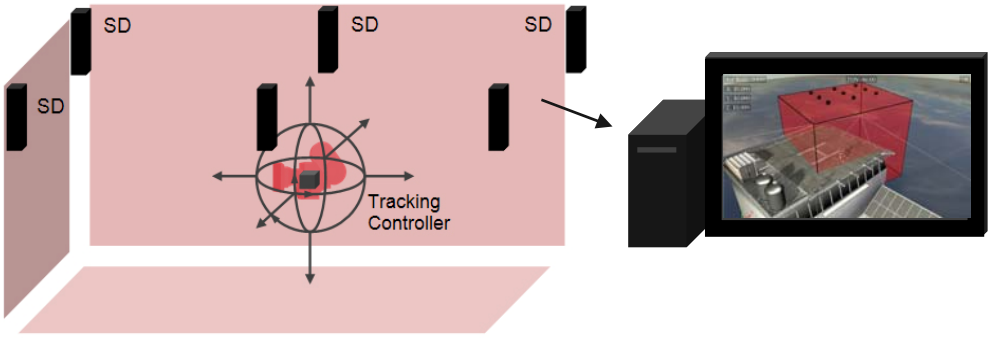


Fig 4. Schematic representation of a basic motion capture camera system

Sensing Devices (SD) are arranged in a room or on a soundstage to create a tracking volume (red box). These devices detect and analyze the movement of special objects, known as tracking controllers, within the defined volume. The detected movement is then applied to a virtual camera in a computer.

Sophisticated systems combine a range of technologies for greater precision. The InterSense VCam, for example, uses a combination of ultrasonic sensing devices combined with acoustic speakers, accelerometers and gyroscopes, mounted in a camera body, to track the position and orientation of the camera with millimeter precision and to within one degree of angular rotation.

Other systems feed data directly from the controller into the computer and do not require special sensing devices. These include games controllers and several other types of hand held devices. They have an advantage in that they can be used anywhere where the device can be hooked up to a computer. However, the camera is often 'tethered' to the computer which can affect mobility.

Image Courtesy of The Third Floor

Fig 5a. What You See is What You Get:

Here the display device acts as the camera controller. Its movements are tracked and applied to a virtual camera allowing the camera operator to see exactly what the CG scene will look like as they move the camera.

Virtual Camera Devices

Advanced Virtual Moviemaking techniques use specialized hardware devices to control a virtual camera (CG camera).

Some of these devices are based on familiar camera form factors and include controls for focal length, zoom, and depth of field as well as common film-specific setups such as virtual dolly and crane rigs.

Other devices have unique and unconventional forms geared more for extended hours of hand held operation.

The InterSense VCam

The InterSense VCam offers a simple and natural way for camera operators to create virtual camera moves with realism. The VCam device controls the motion, camera angle and point of view so that shots can be set in a natural and intuitive manner.

Visualization of virtual content occurs in real-time providing the director with a high degree of flexibility and creativity.

Image Courtesy of InterSense

Fig 5b. What You See is What You Get:

The MotionBuilder virtual camera (light-green icon) in the CG scene is controlled by a tracking controller, providing the director with a viewfinder perspective (inset) of the set and characters during shooting.

The devices used to control the virtual camera can be completely customized to reflect the unique working style of the director. Not only can they take different physical form factors discussed above, each one of the device's various buttons, knobs and other controls can be customized to match the individual preferences of the operator. Customization of the camera's virtual features can be as simple as using a special software application with an easy-to-use graphical user interface (GUI) to modify and set the different CG parameters controlled by the camera. The camera parameters are then integrated into software drivers which plug into real-time 3D animation applications such as Autodesk® MotionBuilder®. These applications react to the camera input allowing the director to have complete cinematographic control over how they shoot the CG world.

While the goal of a virtual camera system is to replicate the functionality of a real world camera, they offer the additional advantage of being able to extend the camera's functionality, and therefore the Director's creative options, far beyond the physical limits of real cameras. For example, a virtual camera system can be scaled to any size– enabling the Director to view a full-size set as if it were a miniature model in order to quickly cover a large area for exploration and initial decision making. Once a specific shooting location and approach have been determined the camera can then be scaled back to actual size to shoot the scene correctly. This type of Instant adjustment of scale is just one of many additional creative options provided by virtual camera systems.

The field of motion capture is rapidly evolving. Every year new systems emerge which offer greater flexibility at lower cost. The price of motion capture has dropped significantly in the past few years as the technology has improved. Previously, even basic systems were complex, cumbersome and very expensive to set up. Today newer, more compact systems are simpler to set up, more flexible, and start at only a few thousand dollars for basic motion capture functionality.

Image Courtesy of Halon Entertainment

Fig 5c. Halon Previs Supervisor Justin Denton films a CG scene in Maya in real-time with the Gamecaster GCS3 virtual camera controller.

Virtual Camera Devices

Another method of controlling a virtual camera is by using visual display systems such as the Gamecaster® GCS3™ virtual camera controller, which does not require sensing devices arranged in a room or soundstage to create a tracking volume. It allows the director to view the CG scene, as if through the lens of a camera.

The GCS3 can be mounted to a tripod fluidhead and panbars, or a shoulder mount for hand-held operation, enabling users to film CG scenes the same way they would shoot live action -- by looking through the GCS3 "viewfinder" and panning, tilting, trucking, craning and zooming the virtual camera in real-time with real-life camera hardware.

The Gamecaster GCS3

The GCS3 features include a stylized form factor, internal motion sensors, an HD color LCD viewfinder, and two thumbstick controls. It takes only 15 minutes to set up, plug into a computer via USB and start filming.

Real-Time Performance Capture

Good performance capture is as important as s important as the motion capture camera system when it comes to creating believable CG characters. In of itself, performance capture is a not new phenomenon and has long been used for visual effects creation. Early uses of performance capture date as far back as *Titanic* in 1997, and it has been essential to the successful completion of a diverse range of projects– from *X-Men* to *Beowulf*– as well as the creation of some truly memorable movie characters– such as Gollum in *The Lord of the Rings*.

Modern performance capture systems are designed to capture more of the nuances and personality of the actors' performance required to create more realistic– or at least more believable– CG characters. To that end, it has become increasingly common to capture the actors' facial expressions along with their body movements to enhance the CG performance. Recent examples of innovations this technique include the Robert Zemeckis films *Polar Express* and *Beowulf* where computer-generated facial animations were layered on top of captured facial performances from popular actors such as Tom Hanks and Angelina Jolie.

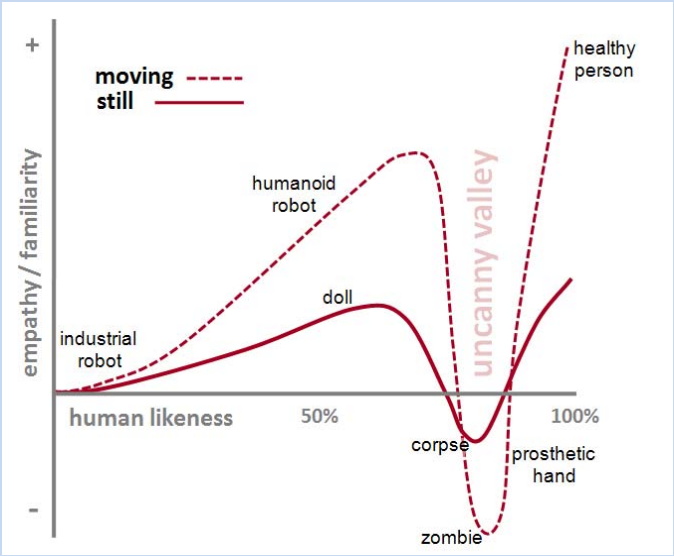
The talent and creativity of the actor is critical to driving believable performance from the CG character. Technology is no substitute for personality, and whether the creative talent is that of an inspiring actor or a highly skilled animator, the human element is essential to creating engaging digital characters. However, it is through the advanced combination of body, facial and vocal performance capture technologies that the invaluable craft of the actor is being integrated into the Virtual Moviemaking pipeline. Recent movies such as *The Curious Case of Benjamin Button* have demonstrated just how believable performance capture can be and the advances the industry has made in overcoming the uncanny valley effect.

The Uncanny Valley of Eeriness – Or why does some animation look so creepy?

In the 1970s, Masahiro Mori, a Japanese researcher in robotics, introduced the uncanny valley hypothesis to describe a human observer's empathy – or lack of it – for non-human anthropomorphic entities. Although the concept was originally applied to how humans relate emotionally to robots, the phenomenon also applies to an audience's empathy for computer generated characters.

In its simplest form the relationship states that, at first, a human observer's empathy will *increase* as an anthropomorphic entity becomes more humanlike but will ***drop sharply*** when the entity becomes close to human, but not quite, effectively becoming ***creepy***. This decrease in empathy is called the uncanny valley effect.

The phenomenon is magnified three-fold when observing entities in movement (as opposed to still objects/images) and appears to be intrinsic to the way the human brain processes information related to human interaction.



The Uncanny Valley

Adapted from Mashiro Mori and Karl MacDorman

Neuroscientists have used fMRI scans to observe the human brain's response to various types of computer-animated characters confirming both the effect and its correlation to increasing anthropomorphism; observing, for instance, that the same motion capture data will often appear less biological, or real, the more humanlike the character. Our understanding of the uncanny valley phenomena and how to overcome it has dramatically improved in the past few years, enabling the creation of ever more believable digital characters – although many challenges still lie ahead.

The worlds of performance capture for visual effects and Virtual Moviemaking are fast converging as technological improvements enable filmmakers to capture actors' performances and apply them to CG characters in real-time. Today an actor's performance can be captured using body, facial and vocal capture systems all of which can be simultaneously remapped onto the virtual character in real time. This allows the director to see the live actor performing in front of them and simultaneously see the virtual character performing the same actions through the virtual camera.

Similar to the additional creative options offered by the virtual camera systems virtual performance systems also allow the actor and director to explore some unique creative possibilities by eliminating the real-world constraints of the human body, prosthetics and make-up. Actors can play an infinite range of character types and no longer need to be type cast based on physical appearance, race, sex, age or even species – as evidenced by recent motion capture performances by actors such as Andy Serkis (playing Gollum as well as a giant ape in *King Kong*), Tom Hanks (playing multiple characters including a child in *Polar Express*) and Brad Pitt (aging in reverse in *The Curious Case of Benjamin Button*).

Virtual P offers filmmakers a powerful, new, non-linear, story-telling methodology – a **virtual production space** in which a story can be developed with as much creative freedom– and perhaps more– than in the non-linear editing suite. Since each 'take' can be recorded, saved and replayed on set, the director can start to literally build the story 'in 3D' cutting together takes and replaying them live 'in camera,' changing only the elements that need to be changed to enhance the story. A rough cut can therefore be built on set walking the director through the story as it is being shot.

In addition the director can easily combine multiple takes into a single shot. The best takes from each actor can be selected and combined into a master scene that the director can re-camera and do coverage on as many times as needed. In each new take the actors' performance will be as flawless as the last, selected, recording and the director can focus on only the things that really need to change– such as camera movement, composition, or other aspects of the shot sequence: if the performance was perfect but the camera angle wrong the actor will not have to try and rematch his or her 'perfect' performance while the director reshoots. The scene is simply reshot using the previously captured performance.

As with motion capture camera systems, performance capture systems are fast evolving and becoming more accessible. At the bleeding edge new advanced systems are capable of recording both live action and motion capture performances simultaneously and blending them in real-time enabling the director to film CG characters interacting with live actors. This is a significant breakthrough. Previously CG characters had to be composited with live action after production.

Fig 7. New motion capture suits offer actors and stuntmen the freedom to perform complex action sequences easily on location as well as on set. Images Courtesy of Xsens

Xsens

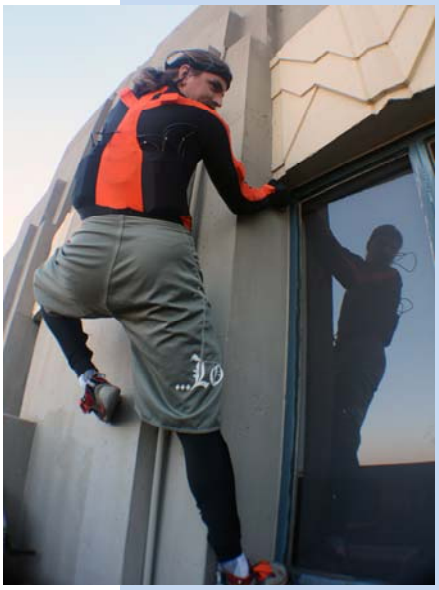
Cameraless motion capture suits like the Xsens MVN suit offer filmmakers an easy-to use, cost efficient system for full-body human motion capture.

Since these suits do not require external cameras, emitters or markers they don't have lighting restrictions and avoid problems such as occlusion or missing markers.

They are therefore well suited to capturing body movement for outside action shots that require extensive freedom of movement – from climbing to complex fight scenes

MVN is based on state-of-the-art miniature inertial sensors, sophisticated biomechanical models and sensor fusion algorithms. The result is an output of high quality kinematics that can be applied to a CG character to create realistic animation.*

** Kinematics describes how a chain of interconnected objects– such as the jointed bones of a human limb– move together.*



Images courtesy of Xsens

Real-Time 3D Animation Engines

In addition to motion capture systems, the Virtual Moviemaking process also requires a robust 3D animation engine for the real-time render and display of the CG characters in the 3D scene. The animation engine provides necessary visual feedback for the director to see the action in context, make creative decisions and interact with the actors and scene. The quality of the visual feedback is determined by the quality of the animation engine.

Rendering 3D scenes with any kind of visual fidelity is computationally expensive and requires significant resources and time. Even today, it can take hours, or days, for a large render farm with hundreds of processors to render a single photo-real frame of a complex 3D scene– and every second of film requires 24 frames. Complex visual effects and 3D animated movies like *Shrek* and *Wall-E* are all created this way– where each image is rendered frame by frame for a period lasting many months. However recent technologies, many deriving from the requirements of the video-game industry, are rapidly improving the quality and capability of real-time rendering systems, making advanced Virtual Moviemaking techniques feasible.

Computer processing capacity has increased dramatically in recent years and low-cost, high-performance, graphics cards have become common (*Sidebar*). In addition, gaming technology is driving real-time rendering towards ever increasing photo-realism at frame rates that provide the viewer with immediate, interactive feedback. This is enabling high-quality real-time (24 or 30 frames/second) rendering and display needed to eliminate undesirable side effects such as strobing and stuttering that make timing hard to judge.

Fig 7. Autodesk MotionBuilder uses a real-time render engine to display animated characters in a 3D scene

Applications like Autodesk MotionBuilder provide real-time 3D animation engines capable of processing large amounts of 3D data in real-time and displaying them at high resolution so the director can see and judge the performance being captured. Given the importance of lighting in filmmaking, the quality and capability of the **virtual lighting kit** provided with the 3D animation engine is critical to effective visualization. The virtual lighting kit determines exactly how the system will render and display lights, gobos, shadows, object transparency, reflections and in advanced systems, even certain types of atmospheric effects.

Computer Performance

Several trends in computer performance are facilitating real time calculation and display of 3D computer scenes and animation:

Central Processing Unit

The Central Processing Unit (CPU) of the computer has increased in speed. CPU performance is measured in terms of clock speed (Hertz) – which is the speed at which the processor can change state from 0 to 1. At the time of writing processor performance exceeded 3:0 GHz or 3 billion cycles a second.

Multi-Core Processors

However there are physical limits to how far you can push processor speeds until you start getting undesirable quantum effects. As a result chip manufacturers have started developing multi-core processors instead of trying to increase clock speed. These processors offer more efficient and faster processing to highly multi-threaded applications – software where the processing algorithms have been specifically designed to run in parallel.

Graphics Processing Unit

The Graphics Processing Unit (GPUs) is a specialized processor for rendering 3D graphics. Although many PC motherboards have GPUs built-in, high-end graphics cards from NVIDIA and ATI offer better performance. GPU efficiency and parallelization enable significant performance increases to applications whose rendering algorithms have been GPU optimized.

Accurate display of properties like reflection and transparency can be critical to shooting certain types of sets, vehicles, or props virtually. For example, when shooting a scene through a car windshield or a window the director will not be able to frame the shot properly if the system cannot display transparent objects correctly and he/she is unable to see the actors through the glass.

Today, 3D animation engines are capable of rendering very sophisticated, realistic visualizations of the scene. However filmmakers typically want to push creative boundaries and try things that have not been tried before. To do this the real-time animation engine needs to be customizable. The development of custom shaders (*Sidebar*) allows the production team to create specific visual looks or styles and apply them to the 3D scene giving the director a much more accurate depiction of the scene in terms of art-direction and cinematography.

Real time render engines will continue to improve with time delivering real-time images that are increasingly photo real. Current real time render engines such as the one built into Autodesk MotionBuilder provides filmmakers with extensive creative tools to implement compelling art-directed representations of locations, sets, and other virtual assets.

Art Directed 3D Assets

In previous chapters we have discussed how 3D data is captured on set and applied to both cameras and characters in the virtual environment using a real-time animation engine. This gives the director and production crew the ability to interact live with the virtual CG environment and performers. However for the experience to be compelling and authentic the virtual environment should resemble the real thing. The virtual set or location should look like a real set or location, and a prop – whether it's a chair or a gun – should look like a real prop. The closer these virtual elements resemble the intention of the Production Designer and Art Department the more realistic the virtual production experience becomes. 3D assets which resemble the visual intent of the Production Designer and Art Director are termed **Art Directed 3D Assets**.

Fig 8. Real-time Art Directed 3D Assets such as the jungle scene above improve esthetics and increase realism. Virtual Art Departments bring Art Direction to Virtual Production workflows by focusing on lighting and atmosphere to invoke appealing environments. MotionBuilder image courtesy of Rob Powers

The visceral exploration and discovery of a set or a location helps inspire the Director, Cinematographer, and other members of the creative team. This inspiration happens in impromptu ways and helps uncover new and better ways to tell the story. Art directed 3D assets can help facilitate a similar creative process in the virtual world.

3D Shaders

3D shaders are software instructions describing how 3D objects should be rendered. They are executed on the GPU (graphics processing unit) of a computer graphics card.

Each shader provides precise instructions on how the 3D data should be rendered and displayed. Common types of shader include pixel, vertex and geometry shaders

Shaders can be created using one of several specialized programming languages:

- *HLSL (High Level Shader Language)*
- *GLSL (OpenGL Shader Language)*
- *Cg (C for Graphics)*

Recent developments in programmable graphics such as GPCPU (general purpose computing on CPUs) enable very sophisticated rendering pipelines to be implemented; and companies like Nvidia are further expanding graphics programming capabilities with technologies like CUDA (Compute Unified Device Architecture).

One of the biggest challenges for developers remains the hardware specificity of many software development kits (SDK's) and application programming interfaces (API's). This can cause unpredictability in results and might require work to be done twice when working with different graphics pipelines (e.g. Direct3D versus OpenGL, Nvidia versus ATI).

However the fact remains that continued progress in this field will drive increasing image quality and photo-realism in real-time graphics display.

However, most of the 3D assets that are used today in early production and in previs tend to be fairly basic in form and of limited visual appeal. They are often just simple blocked out shapes with flat, grey shading. Their primary purpose has been to help provide purely technical information to the production team – primarily to help solve problems related to motion, scale, composition, and timing. It has been argued that simpler assets simplify the process allowing the team to better focus on only what is important when making a decision. Additionally, it has been difficult for visual effects pipelines to generate polished, high-quality CG assets with proper texturing and lighting without significant prior pipeline setup and development.

While working with grey shaded model assets can be a valid workflow there are times when it can prove to be less helpful. After all it is rare to hear a director ask for the live action set to be painted a flat grey with no obvious lighting cues so that he or she can more clearly understand it. Today, the grey shaded workflow is an imposed limitation of the CGI asset creation process that has grown to be accepted by the production community at large.

If given the option most directors would choose to work with assets that are in a form that resembles how they should be experienced in production: with all their relevant colors, textures, shading, and lighting. This is all the more true given that CGI assets evaluated in the unnatural void of a grey shaded world and in an inaccurately lit environment can sometimes send false cues and be creatively misleading. Fortunately, new digital technologies can help take things much further by enabling greater fidelity in the real-time assets used. Using advanced techniques such as baking texture and lighting into the assets the Production Designers and Art Directors can actively drive the asset creation process to preserve conceptual design esthetics at every step of the process.

Art directed 3D assets are the basic building blocks of Virtual Moviemaking worlds. Innovative production teams use a **Virtual Art Department** to create and optimize 3D assets for virtual production. The Virtual Art Department will work closely with the Director, Production Designer, traditional Art Department, and other production team members to create compelling virtual assets that allow for efficient production and development. The highly visual virtual assets, when used dynamically within a real time display engine, provide the production team a sense of “in the moment” discovery and improved problem solving. Having said that, it is important to point out that the Virtual Moviemaking workflow is inherently flexible enough to offer both grey shaded and fully art directed assets as desired.

Virtual Art Department

The Virtual Art Department (VAD) is responsible for translating Art Department designs and digital matte paintings into virtual 3D asset which match the design work as closely as possible and which are optimized, organized, and assembled into flexible kits providing the best real-time performance and maximum flexibility while shooting.

Practical Asset Kits

Practical asset kits need to be easily modifiable, modular, quick to deploy, and have corresponding practical and virtual counterparts.

Deploying assets on set, whether live for a Broadway production or digitally for Virtual Moviemaking, needs to be fast and efficient for production to proceed smoothly. Cumbersome assets that take too long to set up or tear down are as unusable in the virtual world as they would be on a live stage. To that end, a successful Virtual Production workflow requires a modular asset kit that has been carefully planned for easy deployment – without such a kit the immediacy of Virtual Moviemaking cannot be fully realized and the benefit of a real-time interaction will be lost.

Developing virtual asset kits needs to be carefully coordinated with that of the real-world production assets (i.e. the practical assets). This is required to ensure that the virtual interaction between CG characters and a set or prop accurately mimics the real-world interaction on set. Without such co-ordination it will be difficult to provide proper cues to the Director and actors on the virtual capture stage, which in turn makes it harder for them to deliver a compelling performance.

Therefore, during preproduction, special attention needs to be paid to coordinating the work of the Virtual Art Department with that of the traditional Art Department: production design, art direction, set design and construction and props. It is important to note that there are almost no physical limitations in the virtual world. Anything is possible, even behavior that defies the laws of physics. CG cameras can move and shoot in ways that are impossible on set. Without careful co-ordination between the different departments during production results might be unpredictable or even undesirable.

For example, it is very easy to plan a virtual shoot with fly-out removable apartment walls, or a foreground tree whose limbs can be repositioned perfectly to frame a desired shot. However unless one also takes into account the physical, on-set reality during planning and development, then when it comes to capturing the performance the shoot will not go according to plan. The real camera will not be able to move around the set as planned and pieces of the set like the foreground tree will not be as easily configurable as they were on the computer.

To develop effective asset kits, the virtual and traditional Art Departments need to work together. The Virtual Art team needs to fully understand the real-world limitations of practical assets, including such constraints as budget and logistics, while the Traditional Art team needs to understand the objectives of the virtual production team in order to develop practical assets that better support them. Working together these teams can generally find better, more innovative, solutions to production problems than if they work separately.

Pre-animated Asset Handling and Real Time Effects

While virtual and practical asset kits most often refer to set construction and props, pre-animated assets and real time effects typically refer to animated characters and visual effects.

Pre-animated assets and real-time effects further enhance the Virtual Moviemaking experience by speeding processes and increasing realism. For example, as two characters fight one can be shoved into a stack of crates and automatically send the crates tumbling down in real time. Rather than have to manually animate this behavior advanced workflows integrate pre-animated assets and sophisticated simulation capabilities.

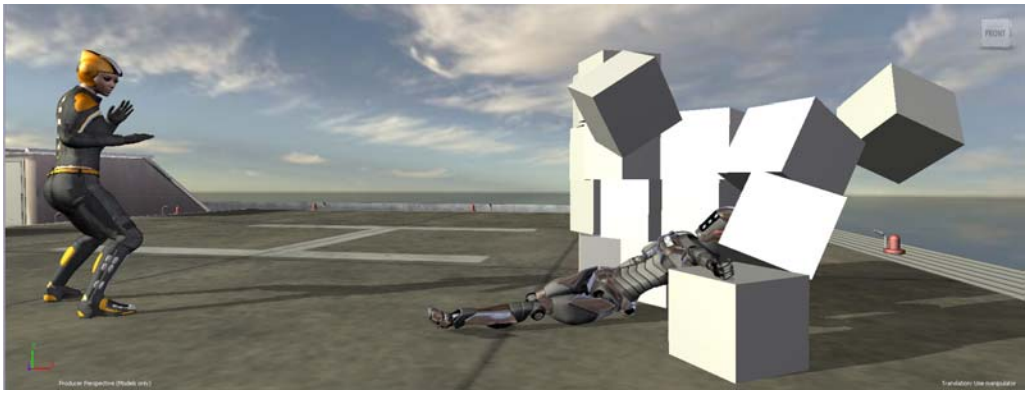


Fig 9. Animated behavior such as falling crates can be simulated automatically in advanced systems.

Interoperable tools such as Autodesk® Maya®, Autodesk® 3ds Max® and MotionBuilder software help provide efficient workflows for incorporating pre-animated data into a virtual production. For example, data caches, such as geometry caches, allow 3D assets created within Maya to be streamlined and shared in a more efficient form for real time playback within the Motion-Builder render engine. Techniques like geometry caching help reduce the processing overhead inherent in the complex rigging setups and hierarchies typical of most animation today and are a

Asset Types

*The term **3D Asset** is used to broadly describe any 3D object (geometry) created using 3D modeling and animation software such as Autodesk Maya, Softimage or 3ds Max. 3D assets are used in a wide range of production pipelines for visual effects, CG animated movies and previs.*

***Virtual Assets** are 3D objects that have been optimized for real-time manipulation and display in virtual moviemaking. In many ways, they are similar to video game assets but differ in organization, metadata tags and naming conventions. **Video Game Assets** are 3D assets that have been optimized so that game engines can render them in real-time during game play.*

***Pre-Animated Assets** are 3D objects that have been pre-animated and "banked" so that they can be called up without delay when needed on the virtual stage. They are often derived from 3D animations created at postproduction houses. Like virtual assets, they require optimization as well as translation into formats that are compatible with the real time render engine being used in the virtual production.*

***Practical Assets** – real-world objects of wood, steel etc, as well as painted stage pieces, that have been designed by the art director and built by the film construction team to easily match – and be interchanged with – the 3D virtual assets on the motion capture stage.*

necessary optimization for virtual production – without them it would not be possible to achieve efficient real time playback of diverse asset types.
Autodesk MotionBuilder has also recently added groundbreaking real-time simulation tools for rigid-body dynamics as well as a real time rag doll character rig solver to its feature set. These capabilities help filmmakers achieve more realistic, real-time effects on the Virtual Moviemaking stage. These innovations offer a rich and stimulating, interactive, Virtual Moviemaking experience and add to the Director's creative toolkit.

Today much of the development of these production assets occurs concurrently in different departments or even within different companies. The process of integrating pre-animated assets into production therefore requires careful coordination and collaboration between Visual Effects, the Previs Department, the Virtual Art Department and others in order to develop an efficient pipeline.

Progress in animation technique, whether through innovation or refinement, tends to originate within one department or entity first – such as the Visual Effects facility or the in-house Previs Department. Therefore, to be effective the Virtual Moviemaking pipeline needs to be highly efficient at incorporating these changes and applying them throughout the production process. It must be able to quickly integrate the latest developments in animation, rigging, blocking, or other cg assets so that the Director and production team can make full use of them on set.

Integration with Current Art Department Development and Design Workflows

Art Departments are already making extensive use of 3D modeling and CAD applications offering the potential for better integration with Virtual Moviemaking and previs processes.

The use of CG modeling and design has become relatively widespread within feature film Art Departments. There is no question that a CG-based design workflow is proving to be extremely useful, even indispensible, to modern production design, or that it is often used to develop extremely sophisticated visuals. This workflow is increasingly being used by Set Designers, Art Directors, Concept Artists, Production Designers, and Directors during the early stages of visual development and design. However, this CG-based design workflow currently only produces static frames or rendered sequences that are consumed passively by the creative team. They can watch but they cannot interact directly with the CG environment.

Virtual Moviemaking requires pushing beyond typical CG approaches to production design to create an interactive and immersive experience that can be driven by the Art Director, Production Designer or Director themselves. This requires packaging the concepts created into virtual assets that can be loaded into a real-time system that offers the creative team control of the camera. This, for example, would give them the option to walk around a set on a '**virtual location scout**' as opposed to relying on a computer artist to move a cg camera while they view the results. This can be more easily achieved if the virtual and traditional Art Departments, Previs Department and other stakeholders collaborate on developing a more interoperable and integrated workflow for developing and sharing assets.

So, while design elements such as sets and props can currently be evaluated with real world camera lenses in mind, the Virtual Moviemaking workflow makes a much more "production relevant" evaluation easier. It allows virtual assets to be seen in a likely shooting scenario and lighting environment so that they can be experienced in the same way that a real world set would be.

Geometry Cacheing

Geometry caching enables efficient exchange of 3D data (assets) between applications improving workflow efficiency and overall performance.

3D assets can be created a using a variety of modeling techniques such as polygon meshes, NURBS surfaces or subdivision surface deformations. Once modeled complex animation techniques are often applied in order to get the asset to behave as required. The resulting data files can be quite large and complex and therefore time consuming to render.

Geometry caches help solve this problem. They are special files that store the 3D asset as simple vertex transformation data and are therefore often referred to as point caches.

They help improve rendering performance by reducing the number of calculations required to play back scenes that contain many animated objects. They also allow object deformations to be more easily combined and edited.

The cache file can be saved to a local hard drive, or better yet to a central server where it can be easily shared with other applications.

Autodesk® FBX® data interchange technology provides an open framework for software applications such as Autodesk Maya, 3ds Max, Softimage and MotionBuilder as well as third party applications, to exchange point data as geometry caches with each other.

The increased fidelity and detail in visual and spatial information provided by the Virtual Moviemaking workflow facilitates the creative team to find answers to production decisions much earlier in the process. The process inherently allows for much more thorough vetting and preparation for the Art Department in general prior to full scale production, and can help the team make more informed production design decisions earlier. It also helps ensure that concept art, previs and even final post-production assets are more closely aligned in look and feel.

Previsualization

Previsualization is defined fairly accurately on Wikipedia as any technique, whether hand drawn or digital, that attempts to visualize movie scenes before filming begins for the purpose of planning. Its primary purpose is to allow the director "*to experiment with different staging and art direction options such as lighting, camera placement and movement, stage direction and editing – without having to incur the costs of actual production*[1]". So, where does previs end and Virtual Moviemaking begin?

The answer is that previs blends into the broader Virtual Moviemaking process. Virtual Moviemaking is a natural expansion and extension of the previsualization process, tying pre-production and production processes together into a consistent virtual production environment where the director and broader creative team can not only plan but also execute on key production elements. Ground-breaking new productions like *Avatar* and *Tintin* are clear demonstrations of this new, broader approach to Virtual Moviemaking.

Virtual production techniques have evolved from the merger of several unique creative processes and technologies. These include previs, production design, art direction, cinematography, performance and motion capture, 3D animation, visual effects and real-time gaming technology to name a few. Today sophisticated previsualization uses virtual production techniques, and virtual cinematography uses previsualization techniques.

Properly designed Virtual Moviemaking pipelines should enable previs teams to share assets bi-directionally with the virtual production environment. This requires greater awareness of the virtual production needs early on in the planning process; but if the groundwork is properly laid for flexible asset interchange overall production will be more cost effective and efficient. If the asset interchange is bi-directional the Previs department can benefit directly from the large number of assets generated by the Virtual Art Department and virtual shoots. At the core of current file interchange standards are robust new formats such as Autodesk® FBX® technology that allow 3D asset interchange between various different software programs. This makes it possible for all departments and creative teams to benefit from the development of CG assets created anywhere within the production process.

Stereoscopic 3D (S3D)

Dynamic stereoscopic intraocular and convergence adjustment

The demands of Stereoscopic 3D (S3D) film production are novel and complex. Creating a compelling entertainment experience requires careful planning and significant attention needs to be paid to the 3D depth aspects of the story. If the depth characteristics of each scene (and every shot) are not fully understood the director will not be able to engage the audience's emotions appropriately. 3D depth planning needs to begin right from the start – from early storyboard and production design – and continue through production where special care and attention needs to be paid to capturing the scene depth correctly.

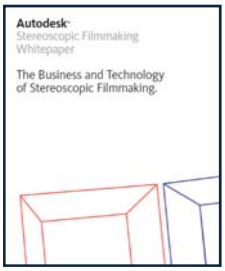
If not, the final result will not have the desired effect on the big screen: it might be too aggressive, too subtle, or even disorienting to the viewer. Problems such as incorrect framing for screen surround – where objects that

[1] Quoted from: Wikipedia contributors, "Previsualization," *Wikipedia, The Free Encyclopedia,* Oct 2009. Original source: Bill Ferster, *Idea Editing: Previsualization for Feature Films*, POST Magazine, April 1998.

should appear to be in front of the screen plane are abruptly cut off by the edge of the screen (making them appear to be both *in front of* and *within* the screen plane at the same time) – need to be avoided.

While it is relatively easy to change camera properties such as intraocular separation and convergence in CG animated movies and then re-render the shot, changing these properties in post-production on live action shots is time consuming and costly and the quality of the stereo effect may suffer. It is best to avoid such an eventually through careful planning. Previs and virtual production techniques are highly valuable tools in stereo production for exactly these reasons.

By allowing the director to view a set dynamically, virtual production technologies provide immediate feedback and direct interaction to the production crew. The director can experiment with 3D depth and feel on the fly, changing camera properties such as position, orientation, intraocular distance and convergence. Special S3D viewing systems allow him/her to experience changes to depth immediately and get a better feel for how the final production will look and make informed creative decisions on how to shoot a scene before production begins. He/she will no longer be "shooting blind" when it comes to live production and can therefore reduce the margin of error as well the need for expensive retakes, reshoots or post-production fixes.



A more detailed description of Stereoscopic 3D production can be found in the Autodesk Whitepaper, The Business and Technology of Stereoscopic Filmmaking.

This whitepaper examines the S3D business case, the current state of the industry and the technical and creative considerations faced by those looking to make compelling stereoscopic movies. It also provides background information on stereopsis and perception, the science underlying stereoscopy. It is hoped that increased knowledge of the science and technology of S3D will help empower the reader to create more effective and compelling movie entertainment.

Post Production

Virtual Moviemaking ties pre-production and production more directly to post-production. By creating a virtual production environment with shared assets the different teams, from the previs team to the visual effects crew can better collaborate and share insights and expertise. When managed well the result is better planning, reduced costs and greater consistency: the virtual and practical production design elements are consistent; previsualization processes are consistent with production design; and previsualization and production design are more consistent with visual effects.

Production assets captured on the virtual sound stage can be shared with visual effects facilities and, although virtual production is not without its own problems in terms of data quality, consistency and interoperability, overall the process enables filmmakers to be more involved in directing the creation of CG content in ways that can still directly influence post-production. It is important to point out that although the real-time imagery of Virtual Moviemaking can be extremely appealing visually, the current generation of real time engines cannot produce the high image quality achieved in post-production by the visual effects teams. In post-production extensive attention is paid to each minute detail in modeling, animating, texturing, lighting, rendering and compositing the CG elements to create the final image seen on big screen. The files produced during virtual production are primarily sent to post production to provide motion capture data and to provide guidance to the visual effects team.

Getting input from the visual effects team early in the Virtual Moviemaking process is crucial to making informed decisions and can eliminate production errors which, when propagated down the production pipeline, become costly to fix. A lot of wasted effort trying to second guess the final look and feel can be avoided by the entire team if information that more closely represents the desired final look is dispersed throughout the production early on. It also allows for more immediate and spontaneous creative exploration by the Director and the creative production team.

Looking Ahead

The movie industry is currently in the very early adoption stages of virtual production workflows. The technology is still nascent and the processes far from standard. It requires skill, talent, patience and a taste for risk to embark upon the path of virtual production but the rewards are rich. However as with Digital Intermediates (DI) and visual effects the steady march of technological progress will make the technologies discussed in this whitepaper ever more accessible. Already today lower budget productions are using many of these techniques to improve the quality of their CG production.

As virtual production workflows become more commonplace and more and more film production professionals become comfortable with the new technology it will disseminate throughout all levels of the film production pipeline. All departments stand to benefit from real-time, immersive digital toolsets and the added level of discovery and preparation which they provide. The impact is already clear on high profile film projects such as *Avatar* and *Tintin*, not only with the Directing Team but with Cinematographers, Visual Effects Supervisors, Actors, and throughout the Art Department, as Production Designers, Art Directors, Set Designers, and Costume professionals get exposure to the benefits of the technology. Virtual Moviemaking technology allows every one of these professionals to vet out their various creative contributions and experience them in the same way that the filmmaker and ultimately the audience will see them.

Already it is no longer necessary to invest in extremely expensive motion capture technology to start virtual production. Affordable solutions exist allowing smaller productions and Art departments working on projects pre-greenlight to explore virtual workflows. As the project evolves the technology can be fairly easily scaled to meet increasing production requirements. As the technology continues to become more scalable and more accessible a broader range of creative professionals will able to adopt Virtual Moviemaking techniques.

Fortunately, research and development in interactive devices, graphics processing and powerful software tools is at an all time high, fuelled in great part by the videogame and mobile device industry. Software development for devices ranging from the Xbox 360® and Sony® PlayStation® 3 game consoles to the Nintendo® Wii® and iPhone® entertainment devices offers interesting insights as to the future potential for applications on the next generations of these devices. Another interesting breakthrough would be the emergence of more modular motion tracking systems that can be scaled from a small portable virtual capture volume to a full large scale production stage – this would allow Virtual Moviemaking technology to be implemented at every stage of the production process without a heavy budgetary burden early on.

Although it Is not possible to predict exactly how the technology will look five years from now, it is reasonable to expect that it will be easier to use, more affordable and produce higher quality real-time results, all key factors for ensuring broader industry adoption.

Given the importance of virtual production leading industry organizations such as the Visual Effects Society (VES), American Society of Cinematographers (ASC) and Art Directors Guild (ADG) are collaborating to ensure that, in the future, their members and the industry as a whole can benefit from both the technology and the workflow. The Previsualization Society was also recently created (September 2009) to exactly that end. Its stated purpose being to facilitate the inter-disciplinary collaboration and exchange of knowledge required to implement virtual production methods.

Virtual Moviemaking

Virtual Moviemaking will continue to evolve and in the future move closer toward a completely immersive nonlinear production workflow connecting all departments.

This innovative workflow is being pioneered at the highest levels of Hollywood film production to facilitate the more complex visual effects heavy and animated productions.

However, the benefits of virtual moviemaking workflows are potentially useful to many other types of film production especially considering the wide number of animation and effects shots present in films not traditionally categorized as visual effects or CG animation movies.

By fostering a 'production relevant' environment for creative exploration and problem solving early in the moviemaking process, and by creating a central hub for team-wide interchange between departments, Virtual Moviemaking enhances the collaborative nature of the movie-making process. This is important as it is the individual members of the creative team and not the technology that drives the Virtual Moviemaking workflow.

Ultimately, Virtual Moviemaking can be seen as the next evolution of previous technologies, workflows, and crafts. As feature films and video games have grown more sophisticated and reliant on CGI, visual effects, and animation, filmmakers seen themselves distanced from the creative process.

Virtual Moviemaking is the revolution that will allow filmmakers and their creative teams to recapture the organic and iterative discovery process of hands-on interaction which many find to be crucial of the film production process.

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Additional Resources & Information:

The Previsualization Society http://www.previssociety.com

The Previsualization Society is a non-profit organization dedicated to the advancement and development of previsualization, or "previs," for all who participate in or benefit from the previs process. By fostering an interdisciplinary community that is as collaborative and cross-disciplinary as previs itself, the Previsualization Society promotes effective applications, standards and practices, education and practical knowledge exchange and is committed to cultivating, documenting and articulating the capabilities of an evolving medium that is playing an integral role in how content is made.

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Autodesk

Autodesk contributes to the realization of Virtual Movie-making by sponsoring various professional committees and think-tanks which are exploring and defining this new technology and workflow. Additionally through innovative development of industry wide file interchange format standards, real time dynamics simulation technology, and innovative stereoscopic GUI, Autodesk continues to push the envelope by providing leading solutions for moviemakers at all levels.

www.autodesk.com/film

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