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Technology-driven Virtual Production: The Advantages and New Applications of Game Engines in the Film Industry

Producción virtual impulsada por la tecnología: las ventajas y las nuevas aplicaciones de los motores de juegos en la industria cinematográfica

Produção virtual orientada para a tecnologia: as vantagens e as novas aplicações dos motores de jogo na indústria cinematográfica

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Abstract: The "subversive" technological drive of game engines for virtual film production is gradually being valued by filmmakers. This technical advantage is manifested in the game engine's (1) real-time rendering of final pixels (speed and image quality), (2) "post-production in advance" and multi-pipeline for project production, (3) open-source code sharing and plug-ins for VFX. Based on the advantages, this article takes the mainstream Unreal Engine (UE) and Unity as the research objects to clarify the application prospects of game engines in four aspects: digital humans with high fidelity, real-time ray tracing in complex scenes, in-camera VFX, and remote collaboration in the post-pandemic era.

Keywords: Game engine. Virtual production. Real-time rendering. Ray tracing. In-camera VFX.

Resumen: El impulso tecnológico «subversivo» de los motores de juegos para la producción de películas virtuales está siendo valorado gradualmente por los cineastas. Esta ventaja técnica se manifiesta en la (1) representación en tiempo real de los píxeles finales (velocidad y calidad de imagen) del motor del juego, (2) «posproducción por adelantado» y canalización múltiple para la producción de proyectos, (3) y apertura uso compartido de código fuente y complementos para VFX. Con base en las ventajas, este artículo toma el Unreal Engine (UE) convencional y Unity como objetos de investigación para aclarar las perspectivas de aplicación de los motores de juegos en cuatro aspectos: humanos digitales con alta fidelidad, trazado de rayos en tiempo real en escenas complejas, in- cámara VFX y colaboración remota en la era pospandémica.

Palabras clave: Motor de juegos. Producción virtual. Renderizado en tiempo real. Trazado de rayos. VFX en la cámara.

Resumo: O impulso tecnológico "subversivo" dos motores de jogos para a produção de filmes virtuais está sendo gradativamente valorizado pelos cineastas. Esta vantagem técnica é manifestada no motor de jogo: 1) na renderização em tempo real de pixels finais (velocidade e qualidade de imagem); 2) na "pós-produção antecipada" e multi-pipeline para produção de projetos; 3) no código aberto compartilhamento de código e plug-ins para efeitos visuais. Com base nas vantagens, este artigo toma o *mainstream* Unreal Engine (UE) e o Unity como objetos de pesquisa para esclarecer as perspectivas de aplicação de *game engines* em quatro aspectos: humanos digitais com alta fidelidade, *ray tracing* em tempo real em cenas complexas, *in-câmera* VFX e colaboração remota na era pós-pandemia.

Palavras-chave: Motor de jogo. Produção virtual. Renderização em tempo real. Rastreamento de raios. VFX na câmera.

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Introduction

The game engine is the platform through which the game runs. It can achieve real-time rendering of the environment, characters, collisions, and sounds in the player's story world; it can use similar program codes to avoid repeated game development and provide a basic framework for constructing projects. With the rapid iteration of the speed and quality of the frames generated by the game engine, Hollywood filmmakers have begun to pay attention to the "what you see is what you get" of real-time rendering of the game engine and the technical drive of virtual production of films and TV series. Specifically, the game engine bridges the boundary between pre-production and final visual effects. With the help of "real-time rendering," directors can unfold multi-person scouting and determine the trajectory of the lens in a virtual camera, view real-time digital human facial expressions generated by performance capture technology on the set, and complete in-camera VFX in a virtual studio equipped with LED screens. In the industry, the game engine has been used in the virtual production of well-known works, such as *Westworld* (2020), *Run* (2020), *His Dark Materials* (2019), *The Mandalorian* (2019), and *The Lion King* (2019).

1 Game engine as a tool

In virtual production, the game engine is regarded as a "renderer" to achieve millisecond-level rendering speeds. The game engine does not provide creativity and ideas; it is a general tool for participating in all stages of the project. The virtual production will involve image rendering issues, whether the previs, the virtual scouting, motion (performance) capture, or the VFX in the post-production. Compared with traditional tools, its biggest advantage is that it saves the waiting time of the rendering farm, makes the visual rendering of complex scenes less expensive, and provides real-time images of cinema-level standards.

Second, additionally to the function of the renderer, it is also used as a film "assembly" tool to ensure that multiple users work at the same time. Each shot in the engine is stored as a separate file, and multiple project members can work on a shot simultaneously. This allows the project to create lighting, props, and scenes while producing key frame animations, realizing parallel development of upstream and downstream work (Shannon, 2017). Additionally, users can still create and edit timelines in the Final Cut Pro, After Effects, and other CG software. For example, in the sequencer of UE, users can complete the work of adding key frames to the camera in the timeline and setting the movement trajectory for the asset while constructing the asset.

Third, the game engine can ensure that users can immediately view the appearance and shot design of the project. This is because the visual script based on Graph and Nodal is constructed inside the game engine (see Figure 1). Visual scripts are friendly to artists; users can modify Nodal parameters instantly without mastering the programming language. Take UE as an example. Users work in an interface called Blueprint. According to project requirements, they can stack countless visual effects graphs, link various workplace parameters, and view the real-time pre-rendered images of the environment, characters, and special effects represented by this graph in the Viewport window. As Unity's chief artist Adrian Lazar said, "Users can share the screen, pull a graph and change the coloring to present the appearance that suits the character, and start a dialogue with the art director with instant-generated effects (FAILES, 2019)."

In short, the game engine as a "tool" can participate in the entire process of virtual production of film and TV series. It also provides visual technical support for ideas in the artist's brain with high-fidelity image quality and millisecond rendering speed.
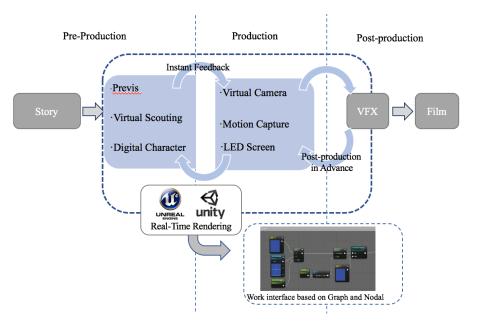
Figure 1 – The workflow and interface of game engines in virtual production

Source: The author.

2 The advantages of game engines in virtual production

Virtual production refers to all computer-aided visual filmmaking methods, including visual effects. In *The Magazine of the Visual Effects Society*'s 2020 interview, many industry leaders noted that game engines and "real-time" functions would be the most creative processes to reshape visual effects in the next decade (MCCULLAUGH, 2020). The primary reason for triggering expectations is that in the era of streaming media when the demand for high-quality works is surging and the production cycle is compressed, real-time rendering can be responsible for the quality and progress of the final pixels while providing immediate feedback to ensure that the project does not deviate from the desired goals.

2.1 Improve efficiency: Real-time rendering guarantees final pixels and progress

In order to improve the efficiency of the project, the "real-time" function of the game engine presents two major advantages. First, in the early stage of the project production, the game engine can drive the virtual camera to render the environment in real-time, realize the shot simulation before shooting, and replace the traditional storyboard with virtual scouting. Second, "real-time" can reduce the waiting work for the post-rendering farm, get the approximation of the final shot as soon as possible, and reduce the number of iterations (VAN DER SCHALK, 2020).
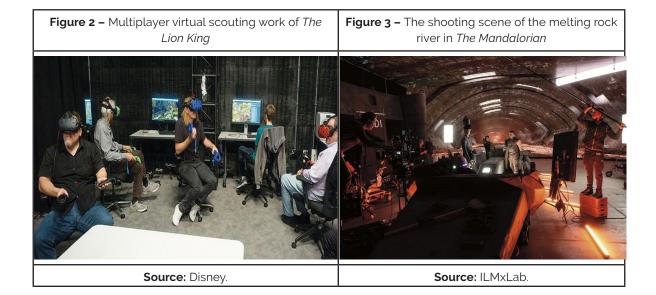
At present, the representative of exploring the first major advantage is Disney's animated film *The Lion King*. The team pre-captured real images of the vast expanse of African grasslands and used VR tools to enter the engine-driven virtual environment for multi-person virtual scouting before shooting to determine the trajectory of the virtual camera, lens selection, and scene construction in advance (Figure 2). Additionally, in HBO's original series *His Dark Materials*, the shooting of polar bears also benefits from game engine-driven virtual cameras. According to the film's visual effects director Russell Dodgson, the team used UE's assets and bear image to survey the shooting, real-time camera tracking, and real-time synthesis functions to provide instant feedback to VFX (FAILES, 2020a).

The innovation of this production method is that when the project is located worldwide, it

eliminates the on-site scouting work of the chief creators. Further, in the virtual setting rendered by the engine, the scouting lens data is recorded, and the position and effect of the simulated light are used to realize the "visual" communication between the personnel of various departments to reach an agreement on the details of the later shooting.

Additionally, the Star Wars live-action series, *The Mandalorian*, produced by Industrial Light & Magic (ILM) is a successful practice of the second advantage. The project uses UE to build a Stage Craft virtual production platform, which drives a 20-foot-high Led wall to generate a real-time high-dynamic background to match the actors' performance and synthesize the final visual effects on the set. Figure 3 is the shooting scene of escaping the underground melting rock river. The deep tunnel and flowing magma

in the distant view of the picture are all dynamic materials of up to 28 million pixels generated in real-time. UE's Fortnite technology helps the director achieve the "what you shoot is what you get" on the set. There is no need to build a green screen or do Matte painting. The final rendering of the post-pixels can be completed on the set.

Its advantage is to return the control of cinematography to the photographer. The photographer does not need to shoot in a green screen world or simulate the light in the post-compositing; the project is shooting the film (HOLBEN, 2020). At the same time, the dynamic background rendered by the game engine in real-time eliminates the need for the team to migrate scenes frequently. In *The Mandalorian*, the main scenes of the frozen planet, Alva 7, and the space station are all finished in Manhattan Beach Studios. While saving the budget, it also speeds up the project's progress.

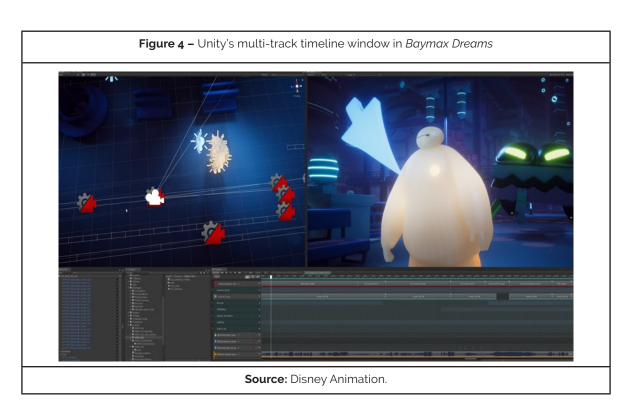| **Figure 2 –** Multiplayer virtual scouting work of *The Lion King*	**Figure 3 –** The shooting scene of the melting rock river in *The Mandalorian*
Source: Disney.	**Source:** ILMxLab.

2.2 Optimize the process: "post-production in advance" to realize the multi-pipelines

The advantage of the game engine is also shown in the destruction of the linear workflow of film and TV series production; it can realize the "post-production in advance" and multi-pipeline operation. Traditionally, filmmaking generally goes through a "waterfall" workflow, such as screenplay, artistic concept, storyboard, shooting, editing, VFX, and so on. The game engine

can run through the whole production process in virtual production. This advantage is that different departments can stand on the same baseline to collect and distribute information, share the generated material and technical data in project progress, and help later departments get into work ahead of time. The multi-pipeline operation of the process can reduce the waiting time of the transfer, modification, and downstream departments and make the virtual production process more democratic.

For example, Andy Wood, the producer of the Disney series *Baymax Dreams* (2018), once introduced that Baymax's experiment skipped the storyboard link. Previs is directly performed in Unity and became the basis of the final rendering. "VFX synthesis is in progress from the beginning, upstream and downstream artists can watch and modify the scenery, lighting, characters, sound effects, etc. at the same beat and any angle, forming an interactive story feedback loop (SMITH, 2020)." Figure 4 shows the timeline of Baymax's rendering screen in Unity. The adjustment of lighting and camera trajectory in the left window can be operated by multiple users simultaneously and can be rendered instantly in the window.

The success of Disney's "Baymax Experiment" also confirmed the flexibility of the game engine in optimizing the production of the project. This flexibility has greatly benefited the production of the *Blade Runner 2049*. According to Wes Potter, CEO of Digital Monarch Media, "All objects can be synchronized in Unity's open and flexible structure. When one person moves an object, everyone will see the change. The director can do the animation of the camera, move the object, and illuminate it. This is like magic (DIGITAL MONARCH MEDIA, 2020)." The game engine opened up the pipeline of project production, allowing the special effects work of the post department to start as soon as possible. This subverting linear production process is more prominent under the technology sharing mechanism of open source code.

Figure 4 – Unity's multi-track timeline window in *Baymax Dreams*

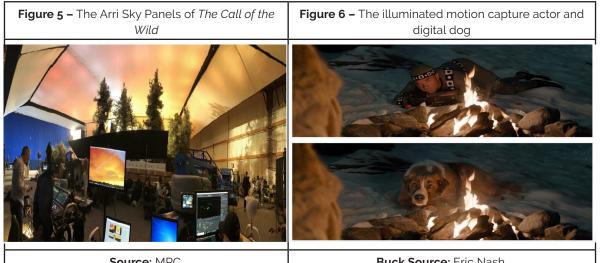**Source:** Disney Animation.

2.3 Open source code: "compatibility" activates the creative sandbox of visual effects

Game engine developers uphold the concept of "gathering communities" and implement an open-source code-sharing mechanism for the VFX industry. They built a plug-in framework to make "compatibility" a habit for VFX artists to work with game engines. The biggest advantage of the open-source code is removing the link barriers between different software. For example, UE's code is published on GitHub; anyone can modify it to make it compatible with third-party applications. Similarly, VFX artists can also download the plug-in code that companies integrate into the game engine on GitHub, such as Houdini Engine

for UE, Tencent's Slu-Unreal, Google's VR SDK for Unity, and the like. Open source can accelerate the interaction between engine developers and VFX artists, allowing artists who use traditional CG software to achieve high-quality, real-time rendering without having to break away from the familiar tool since mainstream software, such as MotionBuilder, ZBrush, Maya, and Houdini, all have integrated the link of the game engine.

Additionally, many leading VFX companies have accepted the advantages of game engines and have developed or are using source code to develop unique virtual production tools or plug--ins. For example, MPC, the production company of *The Call of the Wild* (2020), has used a plug-in written by Technicolor for Unity to drive the dome image of the hemispherical studio. The artist built 300 Arri Sky Panels based on soft lights (MARTIN, 2020) (Figure 5), and all the light sources on the set can be controlled through plug-ins. Since the plot of *The Call of the Wild* involves a variety of extreme weather conditions, it is necessary to simulate lights with a variety of light and color temperatures in the studio. The soft light array driven by the Unity stimulates the team's creativity. The director uses the accumulated parameters to change the appropriate luminous quality at any time to illuminate the snowy environment and the virtual CG dog Buck (Figure 6).

Figure 5 – The Arri Sky Panels of *The Call of the Wild*	Figure 6 – The illuminated motion capture actor and digital dog
Source: MPC.	**Buck Source:** Eric Nash.

3 The application prospects of game engines in virtual production

The rendering waiting time between upstream and downstream is always a stumbling block to the project's progress in the digital VFX industry. Artists need to build huge cluster servers to cope with the offline rendering of complex scenes. This time-consuming and high-budget workflow is beginning to be challenged by the "real-time" rendering performance of game engines. In the work of high-fidelity, real-time digital humans, real-time ray tracing, in-camera VFX, and multi--user remote collaboration in virtual production, the project has used the game engine.

3.1 Assets: high-fidelity real-time digital human

Digital humans are not the latest field of computer-generated characters. They are digital characters with high fidelity generated by multi-dimensional scanning, motion binding, and facial performance capture technology. Indeed, traditional 3D software can also render high-fidelity characters. The advantage of the game engine is that it can be "real and fast" and provide efficient support for the generation of digital characters.

In the industry, many companies specializing in facial capture technology have used game engines to complete experiments on digital humans with high fidelity. For example, in 2018,

3Lateral used 4D volume capture technology to demonstrate a digital human based on actor Andy Serkis in UE (COWLEY, 2018) (Figure 7). The innovation of this technology is the facial data of an actor can drive two distinct characters in UE. The performances of the digital human Andy and the digital monster Osiris Black can achieve synchronization and seamless transition. The fidelity and similarity of facial expressions, muscle movements, and skin textures are enough to shock the audience. In film production, this technology will be friendly to the performance of one person playing two roles. Two characters can be rendered in real-time in the game engine through one capture.

Additionally, in 2019, Doug Roble, the software development director of Digital Domain, wore a helmet-mounted camera to broadcast his real-time digital avatar DigiDoug on TED (Figure 8). From facial contours to finger movements to the blood flow presented on the face, all human digital data needs to be calculated, transmitted, and rendered within 1/6 of a second (FAILES, 2020b). The provider of this rendering speed is UE. When DigiDoug appeared on the screen and Roble's funny performance, the audience had to admit the real-time high-fidelity performance of the game engine.
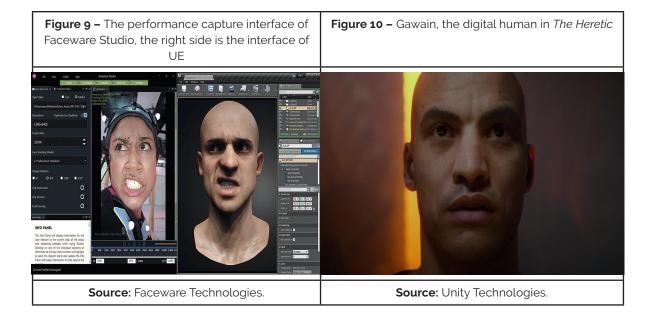
At the same time, Faceware Technology, an industry leader in facial capture technology, has also integrated the UE rendering link in its latest work interface. Their vision is to provide a faster, higher frame rate facial solution. The key to achieving their goal is to directly transmit the captured facial motion data stream to the game engine for rendering. As shown in Figure 9, the captured facial expressions of the actors are seamlessly connected to the UE on the right side of the interface.

Figure 7 – Real-time digital human Andy Serkis and digital monster Osiris Black generated by UE	**Figure 8-** DigiDoug, Roble's real-time digital avatar
Source: 3Lateral.	**Source:** Digital Domain.

Game engine developers are also competing with VFX companies and launching self-made digital human movies to expand the blueprint in film and TV series production. Among them, Gawain in *The Heretic* (2019) is the latest role of Unity in the field of digital humans (Figure 10). The film tells the story of Gawain being terminated by the flame particle character Morgan. Unity performed a 4D body scan of the actor Jake Fairbrother (TAMNEV; NECHEVSK, 2020), and focused on the specular and diffuse reflections of the iris and sclera of Gawain's eyes and the pores and light transmittance of the skin. In order to pursue the ultimate physical reality, this project uses Unity's latest rendering technology: High-definition render pipeline (HDRP).

In the digital entertainment industry, as VFX continues to test and expand the existing bou-

ndaries of storytelling, the audience's concept of reality and man-made on the big screen will become increasingly blurred (HOGG, 2018). Additionally, for Gawain, Akali, a virtual K-pop band member at the final of the League of Legends, and Siren, a real-time anchor cooperating with

UE and Tencent, are the latest examples of digital human technology. In the future, the exploration of digital humans at the time of high fidelity will have bright commercial prospects in special effects characters, humanoid monsters, and interactive virtual idols.

Figure 9 – The performance capture interface of Faceware Studio, the right side is the interface of UE	**Figure 10 –** Gawain, the digital human in *The Heretic*
Source: Faceware Technologies.	**Source:** Unity Technologies.

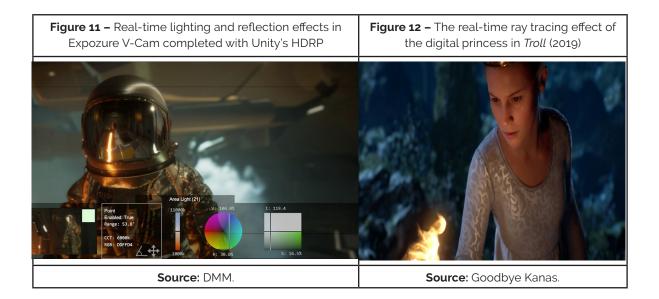### 3.2 Lighting: real-time ray tracing of complex scenes

There are usually millions of polygons in complex VFX scenes to be rendered. The commonly used rendering techniques are Rasterization rendering and Ray Tracing. Among them, the artist is most familiar with the "Rasterization" rendering technology, which colorizes the intersection of triangles or polygons on the object's surface. Still, its most obvious flaw is the unsatisfactory light fidelity when simulating a real lighting scene. Ray tracing is essentially a method of generating images through a computer "tracing" the light path of the camera's line of sight. In layman's terms, it is a rendering technology that calculates the direction of light. For now, the limitations of ray tracing are its high expenses, high rendering speed, high energy consumption, and a rendering farm that requires supercomputers to work together.

The technical advantage of the revolutionary Real-time Ray Tracing is that its lighting effect is closer to the physical reality of the real world than

Rasterization rendering. It can also simulate the direction, reflection, and refraction of light and form soft shadows and accurate ambient light shading (REAL-TIME..., c2004-2022). Additionally, it allows creators to directly illuminate the scene, saving waiting times for servers and rendering farms. In the artist's adjustment and modification of the scene, they can make an immediate response to the change of light.

Currently, UE and Unity have cooperated with NVIDIA to achieve real-time ray tracing. Use NVIDIA's RTX technology to drive the engine's rendering pipeline and achieve the purpose of real-time adjustment of lighting on the premise of achieving visual fidelity. For example, at the Siggraph 2019 annual conference, VFX company DMM used Unity's high-definition rendering pipeline to demonstrate the real-time ray tracing effect of astronauts trapped in the space station environment (Figure 11). The project hopes to illuminate the virtual scene by illuminating the real scene, which realizes the rendering of the ambient light refraction. The light outside the

camera can still form a clear specular reflection in the helmet.

Additionally, UE released the Hollywood-level lighting standard *Troll* in 2019. The short film tells the fantasy journey of the digital princess through the misty forest. The whole story is set in a dark night environment in the forest. The artist used Nvidia's RTX graphics card to complete real-time ray tracing in UE to make the overall lighting effect of the character look more natural. Among them, the artist focused on the soft shadows reflected by the pulsating flames on the cheeks of the digital princess and the realistic lighting effects of silk and satin materials realized on the clothes (Figure 12). In 2020, UE continued to make efforts to demonstrate the short film *Lumen in the Land of Nanite* (2020) in real-time on PlayStation. They provide a fully dynamic global illumination solution named "Lumen." When moving objects in the scene, even if it is an asset with millions of polygons, UE can react to light changes immediately without relying on specialized ray tracing hardware (A FIRST…, c2004-2022).

The rendering technology of game engines to achieve lighting is rapidly iterating. Engine developers are trying to eliminate the dependence on traditional rendering hardware and strive to reduce rendering costs. Their ultimate goal is to save time for artists while ensuring the quality of physical light restored in virtual scenes.

Figure 11 – Real-time lighting and reflection effects in Expozure V-Cam completed with Unity's HDRP	**Figure 12 –** The real-time ray tracing effect of the digital princess in *Troll* (2019)
Source: DMM.	**Source:** Goodbye Kanas.

3.3 Led screen: in-camera VFX foresees a green screen "dusk"

In-camera VFX is a method of directly generating visual effects at the shooting site, similar to the shooting method in film history using a projector to generate the rear projection effect of the set. It has been practiced in classic films, such as *The Wizard of Oz* (1939), *North by Northwest* (1959), and *2001 A Space Odyssey* (1968) (KADNER, 2019). However, the perspective of these projectors is fixed, and most of the projections are pre-rendered pictures. The game engine uses the images transmitted on the LED screen, combined with real-time camera tracking and off-axis projection technology, to create a seamless integration of the real shot foreground and the virtual background (IN-CAMERA…, c2004-2022). For example, Figure 13 shows the shooting scene of Pixomondo's test short film *Memory Container* (*Ji Yi Rong Qi*, 2020) completed in Beijing. The artist used the LED screen to bridge the boundary between the real sand in the foreground and the virtual cave in the background, completing post-production special effects at the shooting site.
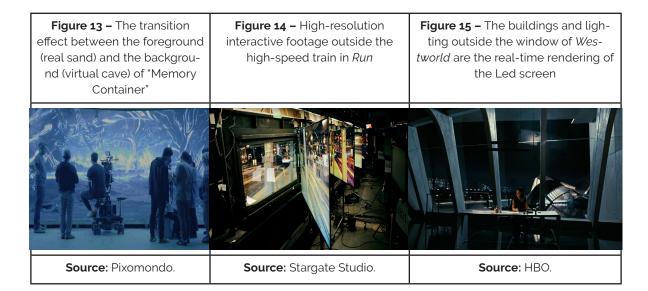
The advantages of in-camera VFX in virtual production are that it is more friendly to the actors' performances. Ewan McGregor once confessed that the actor's performance in a green screen environment is devastating and destroys the soul (DUNCAN, 2020). Compared with the traditional

green screen, the in-camera VFX allows the actors to perceive the background, reduce the "performance fatigue" caused by guessing in front of the green screen in an immersive environment, and reduce the uncertainty of the performance the day of shooting. The second is that the real-time dynamic background moves synchronously with the actor's performance, and the photographer no longer relies on imagination to determine the shot. The lens parallax can be adjusted through camera tracking, reducing the color overflow and the loss of information level when shooting on the green screen and making the virtual picture closer to reality.

Stargate Studio has explored the in-camera VFX implemented by the engine in the industry. The artist looks forward to achieving the goal of generating and modifying the final shot on the set in the ThruView production platform driven by UE. They used 8k to synthesize realistic images, which requires the background to be played at 60 frames per second, and the key to real-time transmission and processing of data streams is the UE (POHL, 2019). Stargate has completed the filming of the TV series *Run*. During the actors' journey across the United States by train, they captured the composite image of the high-speed moving train window in real-time on the LED

screen of the studio (Figure 14). This in-camera VFX method solves the delay problem of green screen shooting and post-compositing and is more feasible for reducing budgets and controlling the shooting cycle.

Additionally, the production of the third season of HBO's high-profile science fiction *Westworld* also benefited from in-camera VFX. In the floor-to-ceiling window scene of the protagonist Charlotte Hale's office, the buildings and lighting outside the window are real-time images presented by the LED screen. The in-camera VFX reproduces the landmark architecture of the City of Arts and Sciences in Valencia, Spain, on the set (Figure 15). The team was able to shoot the ambient light coming in through the glass consistent with the real scene, and when the camera moved in the scene, they all showed the correct parallax (MAYEDA, 2020).

The iteration of technology will always attract the first crab-eater, and the head VFX company has successfully implemented the engine-driven in-camera VFX. In virtual production, it will be possible to replace the green screen environment in the future under its friendliness to actors and photographers and the technical advantages of directly generating the final visual effects on the set.

Figure 13 – The transition effect between the foreground (real sand) and the background (virtual cave) of "Memory Container"	**Figure 14 –** High-resolution interactive footage outside the high-speed train in *Run*	**Figure 15 –** The buildings and lighting outside the window of *Westworld* are the real-time rendering of the Led screen
Source: Pixomondo.	**Source:** Stargate Studio.	**Source:** HBO.

3.4 Remote: social isolation and collaboration in the post-pandemic era

In the post-pandemic era, virtual production has become a tool for artists to create. Under the restrictions of social isolation orders in various countries, the VFX industry that requires multi-person collaboration is actively exploring remote virtual production. Game engines are based on the nature of game development, multi-user, and multi-pipeline work, the functions of remote collaboration and communication have been deeply integrated into the interface. It can share remote virtual scene scouting sessions and directly allow users to control and participate in motion capture collaboratively (KADNER, 2019).

For example, UE is equipped with the Remote Multi-user Session function. This technology allows multiple artists living all over the world to enter the work interface simultaneously. Each user has an independent editing window and can move the characters in the scene at any time. Project members can watch the changes in lighting and camera position and ensure that other people's operations are not covered in real-time screen feedback. In Figure 16, the artist obtained a digital environment and role in the UE Store. A team of eight people completed a remote shooting experiment involving motion capture in different spaces. Similarly, Netflix and Bron Digital Studios are using UE's remote workflow. Department leaders collaborated at home to visualize the content in real-time, solving the periodic travel time-limit problem (GOMEZ, 2020).

Additionally, the Chinese team of Unity led and completed the production of the short film *Windup* during the pandemic. Upstream and downstream artists from many countries also work in remote collaboration. For example, in the performance capture session of the little girl's facial movements (Figure 17), project members used the iPhone to complete the facial capture work in Unity's Facial AR Remote work set.

At present, the biggest advantage of remote collaboration is to use the multi-user mode of the engine to allow artists scattered around to complete the collaboration. However, we found that what is currently done remotely is only advertisements and short films, and the choice of digital environment, models, and characters has multiple limitations. The studio is still a gathering place for creative bursts, and remote work still faces the limitations of cross-time zone communication and lack of face-to-face communication. It is unclear whether engine-driven remote virtual production is the last resort during the pandemic or the future direction of the game engine.

Figure 16 – Remote multi-user session and motion capture experiment of UE	**Figure 17 –** Facial AR Remote capture of Unity's 3D animation short film *Windup*
Source: Epic Games.	**Source:** Unity Technologies.

Conclusion

"Unity for All" is the slogan of Unity Technology. This call sign swears that the game engine will enter more areas. The advantages of real-time rendering, multi-pipeline operation, and open-source codes of game engines are prominent in the digital VFX industry. On the premise of ensuring good storytelling, the improvement of project promotion efficiency has become the core demand of VFX companies. The technical advantages of the game engine have updated the workflow of real-time digital humans, complex scene lighting, In-camera VFX, and remote collaboration. The game engine is indeed broadening the horizon of virtual production.

In October 2020, UE helped complete the production of more than 100 film and television works and won the 72nd Engineering Emmy Awards. As the "new force" of the film industry, we must conquer the power of the engine's "real-time" function. However, the engine has also triggered artists' worries about new technologies. Will "out of the box" digital assets in the engine store reduce the creative vitality of artists? Will the game engine let filmmakers fall into the trap of technology?

We try to answer these worries from the perspective of film history and contemporary directors' attitudes towards new technologies. When looking back on film history, film aesthetics can always improve with the impact of technology. Sound, color, and widescreen technologies have brought innovations to the film viewing experience. Recently, scholar Yin Hong from Tsinghua University put forward the concept of "Technological Aesthetics" and the advancement of digital technology to the ultra-high definition and immersive narrative of movies. As a real-time rendering technology, the game engine can fill the VFX of animated movies and sci-fi movies with the advantages of high efficiency, low budget, and multiple users.

Additionally, we found that well-known directors in the industry do not regard new technology as an enemy. For example, in the special commemorative issue of the 40th anniversary of *Cinefex*,

George Lucas compared the new technology to the brush and paint for telling stories (FORDHAM, 2020), affirming that digital technology is enhancing the ability of storytelling. James Cameron also used iterative virtual camera technology in the sequel production of the *Avatar* (EDWARDS, 2020). In the future, with the further iteration of the 5G network, graphics, image processing, computer hardware, deep machine learning, and other technologies, it is hoped that the game engine "as a tool" can dispel the doubts of artists and present a higher-quality sensory experience to the audience under the production philosophy of "story first".

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