Real-Time Animation, AI and Virtual Production: Opportunities and Challenges

- And how to build a low-budget ICVFX stage

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ABSTRACT

This paper explores the opportunities of utilizing real-time animation and AI in Virtual Production (VP) workflows. The investigation is based on insights from the ViZARTS project, where filmmakers, TV producers and animations are educated during hands-on workshops to utilize the potential of VP. The study will describe some of the challenges we have encountered and introduce a few innovative workflows, we have developed during the workshops, including how to build a low-budget sustainable VP training facility studio. Finally, we will look ahead and discuss the future of real-time animation and AI-driven workflows in Virtual Production.

CCS CONCEPTS

• Applied computing→ Arts and humanities; • Computer systems organization → Real-time operating systems; • Humancentered computing→ Interactive systems and tools;

KEYWORDS

Virtual Production, Real-Time Animation, Final Pixels in Camera, In-Camera Visual Effects, ICVFX, Rear-projection, Projector-based, DIY, low-budget, Unreal Engine, Unity 3D, Generative AI, DMX.

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1 Introduction

While there is a growing number of studies attempting to define and investigate the novel concept of Virtual Production, where real-time game engines and large display technologies are used in live-action film production, it seems like that there is limited research specifically detailing the potential of low-budget virtual production studios for educating filmmakers and content creators.

Several YouTube creators demonstrate how to build low-budget table-top or room-scale VP set-ups. However, many educational institutions often opt for expensive complicated solutions with LED walls and professional camera tracking systems. We argue that independent filmmakers and training facility studios can do more for less and start building VP set-ups with minimal financial resources.

In this paper we will thus explain how we have built a simple low-budget, sustainable, DIY-style projector-based VP training studio at Aalborg University's Medialogy education by using readily available technologies.

This studio is an integral part of the ViZARTS project, an initiative supported by Nordisk Film Fonden, which trains filmmakers, TV producers, game developers, and animators to harness the new opportunities that Virtual Production offers [1].

As our working definition of VP at ViZARTS (which will be introduced later) includes real-time animation as a fundamental element, this study will also describe how real-time animation and AI helps to address challenges and supports the various approaches for Virtual Production pipelines and workflows, we are working with at the ViZARTS project.

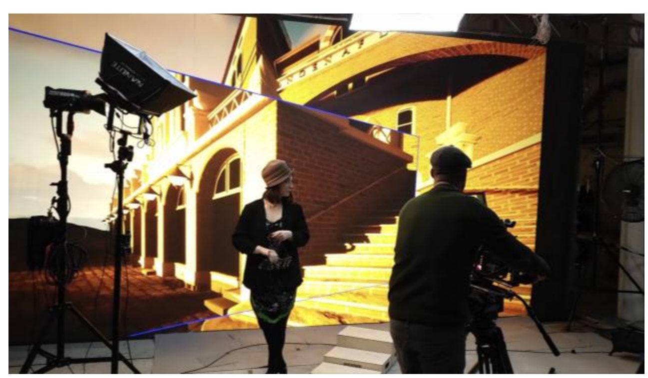

Figure 1: Filming at the Virtual Production Training Facility Studio

Finally, we will discuss advancements in our AI-driven VP workflows, which integrates automated 3D depth maps based on prompted images and examine AI's future role in virtual production workflows at ViZARTS.

2 Defining Virtual Production

In The VES Handbook of Virtual Production, S. Slade defines Virtual Production as "The augmentation or replacement of traditional visual effects or animation workflows by the use of real-time, digital technology." [2]. This encompasses a range of techniques, from live green screen replacement to the complete digital substitution of actors, environments, and cameras.

At Weta Digital, VP is described as an integration of physical and digital filmmaking techniques in real-time: "Virtual production is where the physical and digital worlds meet." [3].

The Moving Picture Company (MPC), describes VP as a collaborative and technology-driven approach to filmmaking that bridges the gap between pre-production, production, and post-production and that "VP combines virtual and augmented reality with CGI and game-engine technologies to enable production crews to see their scenes unfold as they are composed and captured on set." [3]. This is e.g. employed in Motion Capture productions, where performers are visualized with 3D models in virtual environments with game-engines for immediate live-reference and quality checking

These descriptions align with an overall understanding in the industry, which is emphasizing the use of tools like real-time rendering, CGI, game engines (e.g. Unreal Engine or Unity), motion capture, LED screens and virtual reality tools (VR) to create immersive environments and visualize complex scenes in real-time before or during filming.

Our working definition is thus that Virtual Production is an overarching term that covers the use of various real-time game- and media technologies in film, television, and animation production workflows.

3 Using Real-Time Animation in Virtual Production Workflows

Real-time animation is by definition a fundamental element integrated into many VP workflows during pre- and postproduction as well as on set. We have identified three primary virtual production workflows in our workshops:

- 100% Game Engine-Based Production
- Real-Time Live Compositing
- Final Pixels in Camera

3.1 100% Game Engine-Based Production

This workflow relies entirely on real-time animation enabled by game engines such as Unreal or Unity running on workstations with powerful GPUs. It leverages their ability to render photorealistic CGI at over 60 FPS. The workflow enables storytelling entirely in virtual scenery, eliminating the need to wait for individual image rendering to complete sequences. Modern CGI can produce fully computer-generated rendering films, as recently demonstrated by 'Mufasa: The Lion King' (2024). However, Animated TV shows and short 3D animations can now run in real-time, similar to in-game cinematics, with examples such as 'Time Ghost' [4] and 'Meerkat' [5].

This capability enhances creativity and efficiency throughout the production pipeline, enabling filmmakers to integrate various techniques to enhance planning, execution and finishing a production. At the ViZARTS project, we have identified and worked with several of the following real-time animation supported workflows in our workshops:

- Pitchvis – A process of visualizing key film scenes through real-time animation instead of written scripts, helping secure funding by previewing essential moments.
- Previs – Previsualization employs real-time animation with virtual cameras and motion capture to visualize scenes before shooting. It supports set construction, background creation for virtual production, and camera work planning, while allowing simulation of actor movements through rough motion capture.
- Techvis – Uses real-time animation to model scenes and integrate filming equipment like cranes and lights. This helps optimize equipment placement and predict spatial constraints before physical set construction.
- Stuntvis – Combines real-time animation and motion capture to visualize and plan stunts efficiently, reducing production time by simulating action sequences beforehand.
- Virtual Location Scouting – Directors and cinematographers use VR headsets to explore and modify virtual locations pre-filming, allowing real-time adjustments to camera angles, lighting, and set design.
- 3D Location Creation – Technologies like laser scanning, photogrammetry, and Neural Radiance Fields enable digitization of real-world locations for virtual production, creating photorealistic real-time animated backdrops for LED screen studios and rear-projection stages.
- Virtual Actor Creation – Scanning techniques and modeling pipelines, such as Unreal's MetaHumans, enable creation of photorealistic real-time animated virtual extras and effects like de-aging.
- Performance Capture – Tracks actors' movements and expressions to integrate them into real-time animated characters.
- Postvis – Combines green screen footage with preliminary low-quality virtual environments in post-production, enabling visual preview before final rendering.

3.2 Real-Time Live Compositing

The second virtual production method uses real-time animation for live compositing, merging live-action and green/bluescreen shots in real-time. This process, sometimes called Simulcam, traditionally combined live-action elements with low-resolution virtual sets. Directors and cinematographers could then preview scene composition, motion capture performances and lighting in real-time, enabling creative decisions before final rendering. Notable examples include 'Avatar' (2009) and 'The Jungle Book' (2016). While this technique does not traditionally produce final pixels in-camera scenes, it recently has become possible to do this process in real-time as well due to faster GPUs.

3.3 In-Camera Visual Effects or Final Pixels in Camera

The third and most advanced technique, "Final Pixels in Camera" or "In-Camera Visual Effects" (ICVFX), utilizes LED volumes or projector-based systems to display virtual set-extension as a backdrop for physical props and actors. With camera tracking controlling the animated backgrounds, the resulting parallax effect is creating a realistic illusion of being on location, when looking through the camera.
Instead of relying on green screens and “fix it in post", in-camera visual effects allow for a more interactive and immersive "what you shoot is what you get” experience, reducing the need for post-production. Notable examples include TV-Series such as 'Star Wars: The Mandalorian' (2019) and '1899' (2022)
While many ICVFX productions use simple video plates or photographs for backgrounds, a growing number of filmmakers employ fully 3D photorealistic environments. We have also at the ViZARTS project focused on working with 3D environments, as they are more flexible.
These real-time-animation-supported VP workflows optimize resources by shifting costs from post to pre-production. VP also has several sustainability benefits. VP reduces travel emissions, minimizes physical set construction, and enables asset reuse across platforms.

Figure 2: Shooting ICVFX with 3D virtual set extensions mixed with physical props in the foreground.

3.4 AI assisted Virtual Production

Generative AI and machine learning are furthermore becoming essential tools in virtual production by streamlining workflows and enhancing creativity. In previsualization, AI tools can e.g. assist the artists in generating concept art or storyboards. For asset creation, AI can help 3D artists with e.g. generating 3D models, textures and vehicle animations, reducing tedious manual work. During filming AI can support real-time cinematography through automated basic lighting, and virtual environment animated effects like dust particles or smoke. Performance capture can be improved with AI for facial/body tracking and digital doubles. 3D Virtual sets and textures benefits from AI upscaling which is boosting the image quality. In post-production, AI can aid the editor with e.g. organizing shots, color grading, digital effects and dialogue replacement.
In the ViZARTS project, we have experimented with using AI in order to discuss the possibilities, limitations, ethics and property rights. During the filmmaker workshops we have also utilized real-time animation pipelines and implemented many of the above VP workflows. Our recent focus on the Final Pixels in Camera approach necessitated a studio with a large screen setup.

Figure 3: Creating a “Final Pixels in Camera” Scene with AI enhanced backgrounds.

4 Case Study: Building a low-budget, Indie Virtual Production Training Studio

Educational institutions and independent studios seeking to explore virtual production opportunities often face budget constraints. Our experience building a low-budget virtual production studio at Aalborg University's Copenhagen campus began with the ViZARTS project, funded by the Nordisk Film Foundation, Samsung, and Aalborg University. Starting in 2017 at the Samsung Media Innovation Lab for Education (SMILE Lab), we experimented with game technologies for in-game rendered shorts using Rokoko motion-capture systems, before focusing on ICVFX workflows.
Originally, Samsung provided the SMILE Lab with a 4x2m LED wall comprising nine 55-inch screens with 0.64mm pixel pitch

(distance between pixels), enabling close to the screen video shooting. We began experimenting with matching physical and virtual lighting using large figurines and props, and in 2019, we implemented parallax effects with camera tracking by using a 360 Kinect through AutoDesk Motionbuilder, later upgrading to a Vive tracker implemented in the Unreal Engine [6].

In 2021, bachelor students developed a VP system using the Vive tracker in Unity with our LED wall. A master thesis supported this project with integrated DMX-controlled lights in the Unity pipeline [7]. The resulting short film adapted to viewers' attention using brainwave measurements, making it one of the first VP shorts of its kind [8]. However, visible bezels in the LED Wall setup required post-production fixes, necessitating a seamless screen solution.

So, we needed a larger screen without bezels, but with LED walls costing upwards of 200,000€ at the time, we chose to build a rear-projection set-up for its simplicity and affordability (approximately 1,000€ for a 6.6x3m screen plus projector costs).

The rear-projection approach is well-known; however, it is important to remember to reserve space behind the screen for the projectors [9]. We used the Gerriets Optiblack 2.2 specialized black rear-projection fabric to reduce reflections from physical lights in front of the screen and started out with recycled classroom projectors. Later additional funding made it possible to upgrade to two Epson PU2010B 3LCD Laser Projectors with 4K Enhancement, which we stacked for an output of 2 x 10.000 Lumens. With this simple setup, we only need one CGI workstation to project the virtual set-extensions, and over the years, our workstations evolved from Nvidia 1080ti GPUs to 3090s and recently we secured funding for a 5000 Ada Generation Nvidia workstation. The camera tracking system utilizes Unreal 5.5 and an HTC Vive tracking system featuring four base stations. Due to its relative simplicity, the rear- projection-based system provides an energy-efficient and more sustainable alternative to LED walls. Per shooting day, a projection-based screen like ours consume around 5 kWh. In contrast, a LED wall of similar size can use approximately 10-15 times more energy and thus emits much more CO_2 and costs more to use. However, while a rear-projection setup can also reduce moiré effects and maintain visual quality and sharpness in the virtual backgrounds, one should bear in mind that the LED wall is much brighter than the rear-projection screen, so we often use additional lights when filming.

The training facility studio today hosts the ViZARTS workshops and sessions with the Danish Filmworkshops and the Super16 Film school. Since 2022, we have conducted over 20 workshops and trained more than 200 filmmakers, animators, and game developers, bridging technical expertise and artistic talent through creative workflows. The feedback from the participants have always been that they learned a lot and several of them moved on to produce their own productions on professional LED stages in Denmark and abroad.

5 Novel Creative Opportunities with Real-Time animation and VP

Virtual Production workflows in combination with real-time animation unlocks new creative possibilities for exploration during pre-production and on set. We have thus experimented with many different approaches in the studio.

The virtual set-extensions can for example be dynamically altered with real-time animation - for example opening doors or fast-moving clouds. A character can also be placed atop a skyscraper, and the roof can be raised or lowered hundreds of meters in real time. In-camera visual effects can furthermore manipulate set elements, such as bulging walls or rotating stages, with synchronized lighting changes.

We have also often worked with in-camera VFX such as particles, fire, fog and clouds. We have even shot scenes with animated virtual vehicles, such as a train nearly running over a character. Virtual characters can also serve as background extras, and we can control creatures in real-time through puppeteering [10].

6 Overcoming Challenges

At our workshops, filmmakers work closely with technicians, so communication challenges naturally arise in all production phases, so we equip workshop participants with basic terminology used by both film crews and technicians to smoothen the processes.

Besides on-set communication, lighting remains the most significant technical challenge, requiring new approaches for realistic integration between virtual set-extensions and physical elements. We have set up pipelines with DMX controlled lights and experimented with KinoFlo's Mimik lights controlled by Unreal Engine to e.g. dynamically simulate rotating lights. In one case, an actor pulled a simulated moon down to earth, making it appear to increase in size and brightness as it approached, while the Mimik's intensity increased from zero to full power to support the weaker light from the growing virtual moon on the rear-projected background.

Figure 4: Controlling 'Mimik' lights in real-time via the Unreal Engine to enhance the brightness of the moon.

Camera tracking has been another major challenge. A team of Medialogy students therefore developed a smartphone-based tracking system in Unity, providing affordable and effective solutions for real-time camera movements [11]. The solution included mounting an Android smartphone with inside-out tracking onto an ARRI Alexa camera, allowing movement tracking far away from the screen without loss of accuracy [12].

7 A Glimpse into the Future of Virtual Production at ViZARTS

At the ViZARTS project, we constantly develop novel VP workflows to enhance creativity and efficiency while disseminating knowledge to filmmakers and industry. One challenge we had in the first ICVFX workshops, was the time needed to build detailed 3D locations, such as recreating the historic "Hotel Kongen af Danmark" from Fanø Island, which took 10 weeks before we could use it in our ICVFX workshops [14]. To accelerate this process, we've now developed a generative AI solution, enabling us to go from prompt to image, then to 3D depth map and rear-projection in 20 minutes. The images can be generated by prompts or real location photos.
Recent research also includes AI-assisted hand-drawn sketching to 3D location conversion through the drawing software Krita. Furthermore, a master thesis project has aimed on automating light setups in the virtual background based on DMX controlled lights on a physical actor's face [13]. The goal is automated lighting setups covering 80% of light needed on stage.
We're now developing a new VP pipeline to insert augmented 3D props, creatures, extras, and particles in front of actors while filming them with real-time animated rear-projected 3D set-extensions in the background. This approach aims to achieve 'Final Pixels on Harddisk'. The setup could be enhanced by integrating real-time performance capture, enabling live-action actors to perform with virtual characters captured via mocap or real-time puppeteering.

8 Conclusion

Virtual Production workflows supported by real-time animation are transforming filmmaking processes across all production phases. Through our work at the ViZARTS project, we have demonstrated that VP is becoming increasingly accessible, even for independent filmmakers and educational institutions. Our DIY rear-projection-based VP studio proves that sustainable, cost-effective solutions can deliver professional results compared to expensive LED wall setups.
The integration of real-time animation in our three identified VP workflows - 100% Game Engine-Based Production, Real-Time Live Compositing, and Final Pixels in Camera - has shown significant potential for enhancing creative possibilities while reducing production costs and environmental impact. The challenges we've encountered in lighting integration and camera tracking have led to innovative solutions, including smartphone-based tracking systems and AI-driven automation. Examples of these productions can be seen on the ViZARTS YouTube channel [14] and readers are welcome to contact the authors for guidance to build their own low-budget VP Stages.
Looking ahead, the convergence of AI and VP technologies promises to streamline workflows further, particularly in rapid 3D environment creation, automated lighting setups, and real-time character animation. Our ongoing experiments with augmented VP pipelines, combining rear-projected backgrounds with integrated virtual elements in front of actors, suggests that we are moving toward more sophisticated "Final Pixels on Hard disk" solutions. These advancements, coupled with our commitment to knowledge dissemination through workshops, are helping to democratize Virtual Production technologies for the next generation of filmmakers.

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