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In-camera VFX implementation study using short-throw projector (focused on low-cost solution)

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Abstract

As an important part of virtual production, In-camera VFX is the process of shooting actual objects and virtual three-dimensional backgrounds in real-time through computer graphics technology and display technology, and obtaining the final film. In the In-camera VFX process, there are currently only two types of medium used to undertake background imaging, LED wall and chroma key screen. Among them, the In-camera VFX based on LED wall realizes background imaging through LED display technology. Although the imaging quality is guaranteed, the high cost of LED wall increases the cost of virtual production. The In-camera VFX based on chroma key screen, the background imaging is realized by real-time keying technology. Although the price is low, due to the limitation of real-time keying technology and lighting conditions, the usability of the final picture is not high. The short-throw projection technology can compress the projection distance to within 1 meter and get a relatively large picture, which solves the problem of traditional projection technology that must leaving a certain space between screen and the projector, and its price is relatively cheap compared to the LED wall. Therefore, in the In-camera VFX process, short-throw projection technology can be tried to project backgrounds. This paper will analyze the principle of short-throw projection technology and the existing In-camera VFX solutions, and through the comparison experiments, propose a low-cost solution that uses short-throw projectors to project virtual backgrounds and realize the In-camera VFX process.

Keywords: *Virtual Production, In-camera VFX, Short-throw Projector, Low-cost solution*

1. Introduction

Since the outbreak of the COVID-19, social distancing, online office and etc. have become daily routines in social life. The production method of the video contents industry has changed due to the epidemic. The concept of virtual production proposed by James Cameron in the pre-visualization of the movie Avatar in 2009, driven by the COVID-19 and with the development of computer graphics technology and artificial intelligence has gradually been concretized. The tools originally used for game production have has been gradually upgraded to a real-time engine that can render movie-level images in real-time, which makes the virtual production method greatly improve the efficiency of video production has become a popular production method. So then favored by many video producers, virtual production is also increasingly used in the creation of video content such as movies, TV series, and TV commercials.

Epic, which integrates this "real-time" virtual production method with the game production industry, has

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developed a complete virtual production workflow using Unreal Engine. In the "Virtual Production Field Guide" issued by Epic, the workflow of virtual production is divided into four parts: remote cooperation, visualization, In-camera VFX, and animation [1]. Among them, the In-camera VFX is the most critical step. It is mainly to compose the subjects of the real shot and the virtual background in real-time, which achieved the WYSIWYG as the actual shooting in the real world. However, In-camera VFX has high requirements on software and hardware equipment, it takes a lot of time and money to build a virtual set, so the video content produced by virtual production is mainly produced by some large companies with sufficient funds. It is difficult for small production teams such as independent filmmakers and self-media to use virtual production for video contents production.

This article will discuss the conditions required for imaging hardware in the In-camera VFX process by comparing the advantages, disadvantages and costs of existing In-camera VFX solutions, design an experiment to discuss the feasibility of short-throw projector in In-camera VFX is discussed, and propose a low-cost solution for In-camera VFX by using short-throw projector.

2. Related research

2.1 Analysis of the advantages and disadvantages of existing solutions in In-camera VFX

In the "Virtual Production Field Guide", two mainstream In-camera VFX solutions are proposed: live compositing and live LED wall cinematography. Live compositing uses excellent computer computing power to perform real-time keying of the objects in front of the blue or green screen and compose them with the virtual background, while live LED wall uses the LED wall as a medium to display the virtual background and provides real lighting conditions for the subject to achieve real-time compositing [1].

2.1.1 Live compositing solution

The live composition solution is a low-cost solution in In-camera VFX. In addition to the necessary camera image transmission (image acquisition device) and camera tracking device, only blue or green screen and lighting devices are needed. The cost for display devices is low, and it is an In-camera VFX solution currently used by many low-cost production teams.

The live compositing solution is to transmit the picture captured by the camera to the real-time engine for calculation in real-time, then remove and compose the blue or green screen background into the virtual background. Since the whole process is carried out in real-time, it requires a high computer computing power. At present, the more commonly used live compositing tool is the composure plug-in in the Unreal Engine. In the actual use process, because the blue or green screen background cannot provide real lighting and reflection conditions for the subject, it is necessary to match the subject to the virtual background's lighting condition when shooting. The quality of lighting also affects the quality of real-time keying. It takes a lot of time to light the real environment before the shooting or after the virtual background changes, which reduces the shooting efficiency. When shooting a subject with reflective properties such as metal, the reflection on the surface of the object cannot be truly restored. In terms of details such as hair and object edges, the fineness of real-time keying has not yet reached the level of film and television program. Although this solution can be applied to the pre-visualization of video content production, it is difficult to apply for final production.

2.1.2 Live LED wall cinematography solution

The live LED wall cinematography solution is the mainstream solution for virtual production at present. The works such as the television series "The Mandalorian" have already applied this solution, and the quality of the final film can also compare with the video content produced by the traditional workflow. Compared with live compositing, this solution replaces the blue or green screen with LED wall, and uses LED wall as the medium to undertake the virtual background.

The LED wall is assembled from many small LED panels. As a medium to undertake virtual background, LED wall must have photorealistic image display capability, so the quality of LED wall affects the final result of virtual production to a great extent. The mainstream display technologies currently on the market can be divided into emissive display technology based on self-emissive light-emitting materials such as LEDs and liquid crystal display (LCD) technology using monochromatic LEDs or other light-emitting materials as backlight units. Since backlit LCD display panels do not perform as well as emissive display panels in terms of color and brightness, the use of such panels is hardly considered in current In-camera VFX process. The emissive display technology can be divided into RGB-chips emissive displays with red, green, and blue LED chips and color conversion (CC) emissive displays with monochromatic LED chips (usually uses blue LEDs), depending on the color of the LEDs used. These two technologies are generally superior in terms of color and brightness, although there are subtle differences [6]. The emissive display technology also can be divided into traditional LEDs made of inorganic materials such as silicon and OLEDs made of organic materials, which have emerged in recent years, according to different materials. The traditional LED display technology can be divided into three types, according to the spacing between unit LEDs in the display panel: small-pitch LED with a spacing greater than 0.1mm, mini LED with a spacing between 0.05mm and 0.1mm, and micro-LED with a spacing of less than 0.05mm [3]. OLEDs made of organic materials have a shorter service life and higher cost than traditional inorganic LEDs, the LED panels used in live LED wall cinematography solutions are mostly traditional LEDs made of inorganic materials. Due to the influence of the Moiré effect, when camera is shooting directly at the LED wall, if the LED wall within the shooting range of the camera cannot provide sufficient resolution, it will cause Moiré pattern in the picture captured by the camera [1]. For live LED wall cinematography, LED panels with a high enough resolution per unit area must be used to form the LED wall, but the higher the resolution per unit area the smaller the unit LED spacing in the LED panel and the price is higher. Although the camera can be far away from the LED wall by expanding the shooting space to avoid the Moiré effect, but when the virtual set becomes larger, the LED wall will also become larger, and the cost will also increase. And the refresh rate and brightness of the LED wall also greatly affect the quality of virtual shooting. Therefore, although it is similar to live compositing in terms of other hardware equipment requirements, the cost of LED wall hinders the popularization of this solution.

In terms of imaging performance, the live LED wall cinematography solution uses the self-illumination property of the LED wall to provide a real lighting environment for the subject while allowing actors to perform in the “seen environment”, compared to blue or green screens. In terms of the production process, the visual production scene allows the creator to flexibly adjust the shooting according to the different scenes to obtain the most perfect picture, just like the real scene shooting. With the launch of the nDisplay plug-in in Epic's Unreal Engine 4.27, the assembly of the LED wall has become easier, allowing video content producers who are not familiar with display technology to easily build a virtual set. Although it takes a lot of money to build a virtual set in the pre-production stage, but for a large production team with multiple locations, a lot of travel expenses can be saved during the production stage.

To sum up, among the existing In-camera VFX solutions, the live compositing solution costs relatively low, but the image quality is not guaranteed, and the lighting needs to be adjusted before shooting or the virtual background change, which is less convenient. Live LED cinematography solution has good performance in all aspects, but the cost is too high for most production teams to use. Table 1 compares the existing In-camera VFX solutions from three perspectives.

Table 1. Comparison of existing solutions in In-camera VFX

Solution	Imaging performance	Convenience	Cost
Live compositing	Low	Low	Low
Live LED wall cinematography	High	High	High

2.2 Imaging principle analysis of short-throw projection technology and feasibility of application in In-camera VFX

Short-throw projection technology has been widely used in the home projector market in recent years, many home appliance manufacturers such as Epson, LG, Samsung, and Sony have their own products. With the development of projection imaging technology and projection light source technology, 3-chip projection imaging technology and laser projection light source technology have been heavily invested in the production of short-distance projectors. The short-throw projector industry chain has made the market price of short-throw projectors cheaper and cheaper. The following three points analyze the imaging characteristics of short-throw projection and illustrate the possibility of its application in In-camera VFX.

2.2.1 Short projection distance, convenient for the construction of virtual set

The biggest difference between short-throw projectors and conventional projectors is that they have a smaller throw ratio (throw ratio refers to the ratio between the distance D between the projector lens and the screen and the projected picture width W [4]). Short-throw projectors generally use convex lens reflection for imaging, which can obtain a larger picture with a smaller projection distance. The throw ratio of conventional projectors is generally above 1, while the throw ratio of short-throw projectors is generally below 0.5. So conventional projectors require a long projection distance to ensure the size of the picture, but this will cause a blind spot between the projector and the screen, and any object entering within this blind spot will cast shadow on the screen. The short-throw projection just solves this problem, and it is convenient for actors to perform in front of the screen during In-camera VFX process.

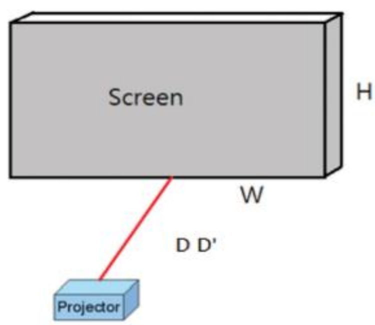


Figure 1. Projector Throw Ratio [4]

2.2.2 High-quality projection images improve the quality of shooting

In terms of imaging principle, unlike LED display technology which forms a visual signal by directly illuminating the light to the human eye, projection technology projects the picture onto the receiving medium, and then enters the human eye through diffuse reflection which formed by the receiving medium to form a visual signal. In the In-camera VFX process, the moiré effect caused by the camera directly shooting the picture and the stroboscopic phenomenon caused by the low LED flicker frequency can be greatly reduced.

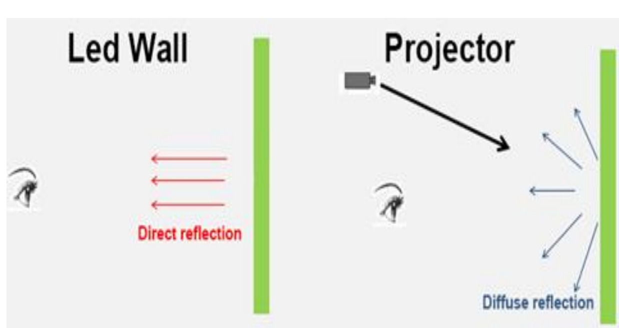


Figure 2. Imaging principle of LED and projector [2]

In terms of imaging quality, the main factors that affect the quality of projection imaging are imaging technology and light source technology. Projection imaging technology is mainly divided into single-chip LCD, LCoS, DLP and three-chips LCD, LCoS, DLP, projection light source technology is mainly divided into Lamp, LED, Laser. Projection imaging technology affects the color performance of projector, and light source technology affects the brightness performance of the screen. Generally speaking, in terms of color performance, the performance of single-chip DLP is better than that of LCoS and LCD, and the performance of three-chip imaging technology is better than that of single-chip imaging technology [9]. In terms of brightness performance, Laser light source is the best, followed by LED, and Lamp is relatively poor [8]. At present, most short-throw projectors on the market use DLP imaging technology plus Laser light source technology, which ensures the imaging quality of short-throw projectors.

2.2.3 Relatively low price, reduces production cost

With the home use of short-throw projection technology, the price of short-throw projectors is as affordable as home TVs. Table 2 is the price range comparison of related brands in Amazon. There are many more brands not listed, but the price range is roughly similar to the Table 2.

Table 2. The price range of short-throw projectors from some brands on Amazon (Data Acquisition Date: 2022.03.28)

Brand	Price Range（USD）
Epson	385~1799.99
LG	1296.99~4996.99
Samsung	3497.99~6497.99
BenQ	799~3499.99

3. The application of short-throw projection technology in In-camera VFX

Single short-throw projector can be used in In-camera VFX process. If the venue is large enough and there are higher requirements for object light reflection, multiple short-throw projectors can be used for the virtual set. This article will use a single LG HF85JA DLP laser short-throw projector for In-camera VFX background imaging. The specific parameters of LG HF85JA are shown in the Table 3.

Table 3. Related parameters of LG HF85JA

Throw ratio	Resolution	Brightness	Contrast	Minimum throw size	Max throw size
0.19：1	1920*1080	1500ANSI Lumen	150000：1	1992*1121(mm)	2657*1494(mm)

This experiment will use UE4(Unreal Engine 4.27) for real-time rendering and use Davinci Resolve for color correction. Figure 3 shows the workflow of this experiment.

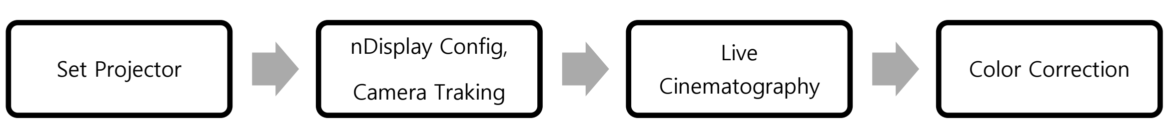


Figure 3. Workflow of In-camera VFX using short-throw projector

Connect the projector to the computer and set the projected screen to “Duplicate main screen” in computer display setting. Then create nDisplay config in UE4 (Figure 4 shows the interface of the nDisplay config), set the projected screen size measured in advance to the size of nDisplayScreen in step 1 of Figure 4, set the scene origin in the 3D viewport, finally create a cluster node in step 2 set the IP address of the rendering machine and set rendering area through the cluster in step 3 to complete the nDisplay config.

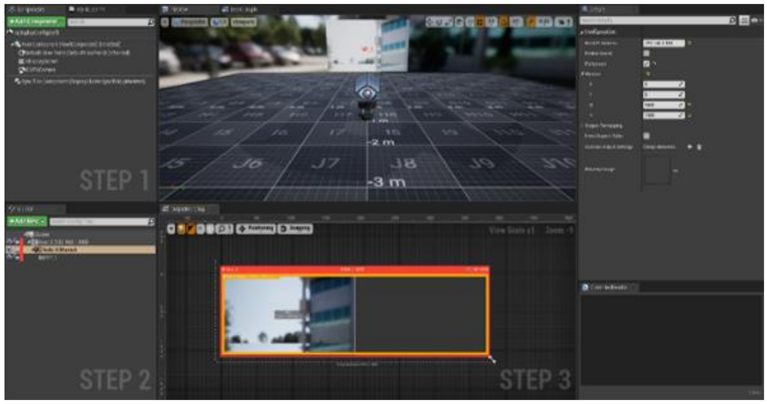
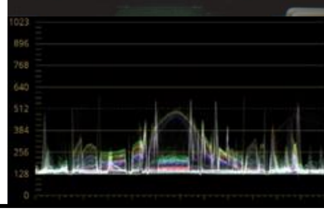
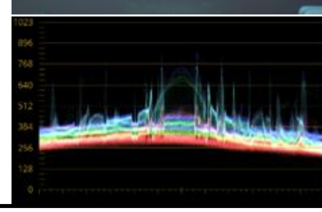
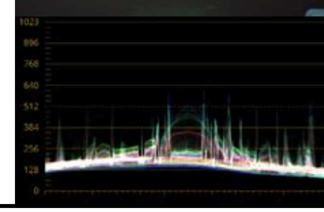


Figure 4. nDisplay Config in UE4

After completing the nDisplay Config, use the SwitchBoard plug-in to connect the scene and complete the shooting through the virtual camera tracking system. Table 4 is the comparison of the picture taken by the camera with the original picture and the picture after color correction.

The Blackmagic Raw codec method was used in this shooting. This codec method stores the metadata of the camera at the time of recording in the recording file , such as ISO, exposure, white balance, lens data and more.[10] The files recorded with the Blackmagic Raw codec can be finely adjusted in Davinci Resolve, with most of the parameters at the time of shooting being adjusted to get the desired picture.

Table 4. Image in In-camera VFX Process

	a. Origin	b. Camera Origin	c. Camera ColorCorrection
Capture			
Waveform			

From the waveform in Davinci Resolve of Table 4, compare b with a, due to the recorded Raw file has not been color converted to Rec. 709 standard, it can be seen that the image captured by the camera has poor performance in shadow, resulting in low contrast and chromatic aberration. After color correction in Davinci Resolve, compare c with a, there is still a lack of contrast in the picture, the color difference has been improved to some extent, and the final picture has a great usability.

4. Conclusion and future optimization

After the above analysis and experiments, we can see the possibility of using short-throw projection in In-camera VFX. First of all, the maturity of short-throw projection technology has also promoted the maturity of its market, the price of short-throw projectors will gradually decrease, and there will be more high-quality, low-priced products. Secondly, the extremely short projection distance solves the problem of the “blind spot” in front of the screen caused by the long projection distance of conventional projection technology, so virtual set can be built in a smaller space. In addition, the projection technology uses the principle of diffuse reflection to form images which solves the problems of moiré effect and flicker. In the experiment although there are some shortcomings in the picture performance, it can be made up for in this aspect through color grading in Davinci Resolve, finally got a relatively good picture. In this research, only a single short-throw projector is used to build the virtual set, but in practical application, multiple short-throw projectors can be used to build the virtual set, so as to provide more realistic reflection conditions for the subject.

Of course, there are still some shortcomings in using short-throw projection to build a virtual set. Since projection imaging is based on the diffuse reflection of the projection receiving medium, it cannot provide relatively high-brightness ambient lighting for the subject. The projection receiving medium used in this study is just an ordinary white wall, and its reflectivity and light resistance are relatively low. In future research, the study will start with the projection-receiving medium, and try to use materials with high reflectivity and high light resistance as the medium for receiving projection images to provide more realistic ambient lighting for the subject.

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