Real-Time Angular Color Shift Compensation for On-Set Virtual Production

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Abstract

On-set virtual production (OSVP) uses LED volumes to display real-time rendered backgrounds driven by camera pose and viewing direction. The camera-visible region, known as the inner frustum, is rendered at higher fidelity but is particularly affected by angular color shift at oblique viewing angles. Current calibration frameworks focus only on static angle-independent compensation of errors in color rendition. In our approach, we use a robogoniometric setup to measure the far-field colorimetric behavior of LED panels and derive a lightweight, angle-dependent color profile for the LED wall that can be directly used for real-time angular color shift correction.

CCS Concepts

• ***Human-centered computing*** → ***Visualization toolkits;*** • ***Computing methodologies*** → ***Graphics systems and interfaces;***

1. Introduction

In on-set virtual production (OSVP), LED volumes are used on film sets to display dynamically rendered real-time scene backgrounds. The wall content is typically generated from the camera pose and viewing angle using Unreal Engine. The camera is freely movable and captures only a portion of the LED wall [Fink and Sawicki(2023)]. This region, referred to as the inner frustum, is therefore rendered at increased fidelity. Angular color shift [Ng(2025)] here is particularly evident at certain camera viewing angles relative to the LED wall. This paper proposes an approach for dynamically compensating the angular color shift in real time directly within the rendering engine using a simplified far-field simulation model derived from goniometric measurements.

2. Related Works

The challenge of color rendition in OSVP is multifaceted. [Long et al.(2025)] outline the color management principles required to match the directors intent with the final camera capture, noting the difficulty of managing the narrow-band spectral nature of LEDs. Current open-source solutions like OpenVPCal [Payne and Giardiello(2022)] successfully effectively align LED panels to specific cameras using test patches. However, these frameworks typically generate static Color Correction Matrices (CCMs) or Look-up-Tables(LUT) based on on-axis measurements, leaving dynamic angular errors unaddressed. Characterizing angular color shift is well-established in display metrology. [Boher et al.(2016)] demonstrated methods using Fourier optics to analyze the full color volume (Lab) of displays across viewing angles. While highly accurate, these methods are data-intensive. For simulation, [Jacobs et al.(2015)] proposed using near-field goniophotometry to create spectral ray files. They noted that while near-field models are essential for optical design, extended sources can be approximated as point sources in far-field conditions. Our work leverages this far-field approximation to reduce computational complexity for real-time application, similar to how [Yu et al.(2025)] utilized pre-computed LUTs to drive multispectral lighting in real-time.

In terms of color rendition [Gudemann et al.(2022)] and metameric failures [LeGendre et al.(2016)] in OSVP settings, using RGBW panels with cold and/or warm white pixels are used for ceilings or backgrounds. Multi-primary or RGBW light sources also consist of higher pixel pitches, resulting in higher light output. As these panels are often used for lighting from above, they are not primarily used as an inner frustum. Further investigation of the angular color shift for RGBW panels is likely to be necessary. Aging phenomena are not considered in detail in our approach, as we assume that the effects of aging affect the whole panel or sub-pixel board equally. As manufacturers of receiver cards provide calibration data along new panels, the aging effects could be investigated and compensated by repeating the measurements for the individual pixels and correction of R,G,B primaries.

3. Methodology

Angular color drift of a $50 \times 50\,\text{cm}$ LED panel was characterized in the far field ($d = 8\,\text{m}$) using a robogoniometer, a spec-

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troradiometer and ARRI ALEXA 35 camera recording in RAW. Measurements conditions were adopted from [International Committee for Display Metrology(2025)], incorporating a 20-minute warm-up, 1500 cd/m^2 full white luminance, DCI-P3 gamut with D_{65} white point. Spectral power distributions (SPDs) were captured at 1 nm intervals as the panel was rotated in steps of 15° azimuth and 45° elevation. This initial characterization isolates full luminance; brightness-dependent color drift remains a subject for future investigation, assuming that the angular color show has it's maximum at full brightness.

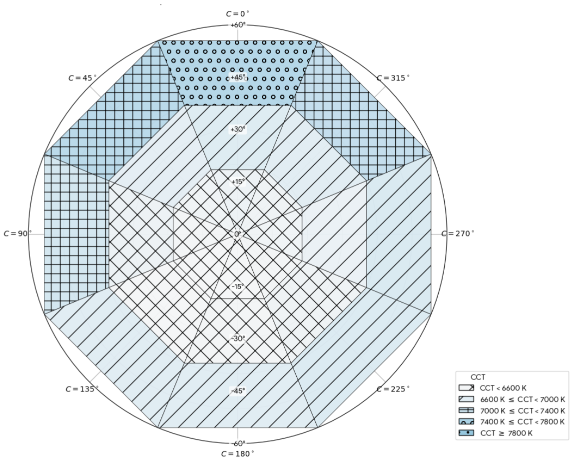

Figure 1: *Color over Angle shown for a 1.56 mm pixel pitch LED panel at 1500 nits, DCI-P3 Gamut and D_{65} white point showing full white without thermal calibration controlled by Brompton S8*

To visualize and correct for color drift, we first transformed the spectral power distributions (SPDs) into a polar plot, mapping the correlated color temperature (CCT) for each data point (see Figure 1). This angular color shift was then used to dynamically compensate for display inaccuracies in real time. The angular color shift is addressed by a shader that is applied to the nDisplay's inner frustum render node. This process uses OpenColorIO for the purpose of achieving precise color management. Real-time camera tracking data – specifically positional coordinates and rotational quaternions relative to the the display mesh's normal are dynamically computed by the viewing angel θ. This view-dependent compensation is executed per-pixel via the transformation:

$$\mathbf{RGB}_{out} = (\mathbf{I} + \theta \mathbf{K})\mathbf{RGB}_{in} \tag{1}$$

where $\mathbf{I}$ is the identity matrix and $\mathbf{K}$ is the 3×3 coefficient matrix scaled by θ. While the focus of the research was on collecting data regarding angular color shift, it is essential that the compensation pipeline undergoes comparative color rendering evaluation in a production environment with different implementations, including but not limited to look-up tables or high-level shading languages as an outlook.

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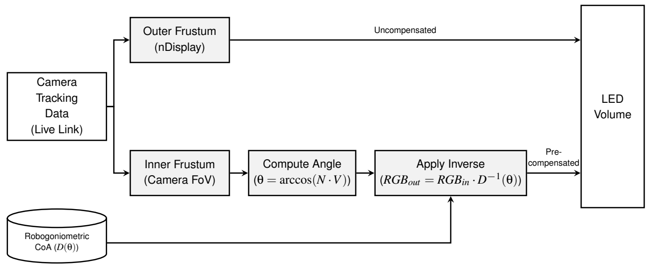

Figure 2: *Rendering pipeline for Color over Angle compensation in nDisplay LED Volume, illustrating outer frustum pass-through and inner frustum compensation driven by D and the inverse D^-1.*

References

[Boher et al.(2016)] Pierre Boher, Thierry Leroux, Thibault Bignon, and Véronique Collomb-Patton. 2016. 72-3: Optical Characterization of a Transparent LCD Using a Fourier-Optics Multispectral Viewing-Angle System. *SID Symposium Digest of Technical Papers* 47, 1 (2016), 982–985. doi:10.1002/sdtp.10891 1

[Fink and Sawicki(2023)] Noah Fink and Mark Sawicki (Eds.). 2023. *The VES Handbook of Virtual Production*. Routledge, New York. https://vesglobal.org/the-ves-handbook-of-virtual-production/ Visual Effects Society. 1

[Gudemann et al.(2022)] Laurent Gudemann, Jan Fröhlich, and Harald Brendel. 2022. Color Reproduction in LED Wall Virtual Production Stages. 30, 1 (2022), 109–117. doi:10.2352/CIC.2022.30.1.21 1

[International Committee for Display Metrology(2025)] International Committee for Display Metrology. 2025. *Information Display Measurements Standard* (1.3 ed.). Society for Information Display. doi:10.55410/HHXO3592 2

[Jacobs et al.(2015)] Valéry Ann Jacobs, Jan Audenaert, Johan Bleumers, Guy Durinck, Patrick Rombauts, and Peter Hanselaer. 2015. Rayfiles including spectral and colorimetric information. 23, 7 (2015), A361–A370. doi:10.1364/OE.23.00A361 Publisher: Optica Publishing Group. 1

[LeGendre et al.(2016)] Chloe LeGendre, Xueming Yu, Dai Liu, Jay Busch, Andrew Jones, Sumanta Pattanaik, and Paul Debevec. 2016. Practical multispectral lighting reproduction. 35, 4 (2016), 32:1–32:11. doi:10.1145/2897824.2925934 1

[Long et al.(2025)] David Long, Rod Bogart, Spencer Stephens, Catherine Meininger, Joseph Goldstone, Tim Kang, Kathryn Brillhart, and Jim Geduldick. 2025. Color Management Principles for LED Panels in On-Set Virtual Production. *SMPTE Motion Imaging Journal* 134, 2 (Apr 2025), 17–XX. doi:10.5594/JMI.2025/XEJK1138 1

[Ng(2025)] Kok Eng Ng. 2025. Investigation of Color-Over-Angle in Multi-Chip Array LEDs. doi:10.26180/30745235.v1 1

[Payne and Giardiello(2022)] Carol Payne and Francesco Luigi Giardiello. 2022. "OpenVPCal": An Open Source In-Camera Visual Effects Calibration Framework. In *ACM SIGGRAPH 2022 Talks* (New York, NY, USA, 2022-07-24) *(SIGGRAPH '22)*. Association for Computing Machinery, 1–2. doi:10.1145/3532836.3536265 1

[Yu et al.(2025)] Xueming Yu, David George, John Millward, and Paul Debevec. 2025. Real-Time Multispectral Lighting Reproduction. In *Proceedings of the Special Interest Group on Computer Graphics and Interactive Techniques Conference Posters* (New York, NY, USA, 2025-08-10) *(SIGGRAPH Posters '25)*. Association for Computing Machinery, 1–3. doi:10.1145/3721250.3743035 1