HDR Color Grading and Image Color Control Techniques in Video Post-Production: Postprint

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Abstract

Given that existing control technologies exhibit insufficient clarity enhancement effects for video frames and relatively low resolution, this paper proposes a novel HDR color grading frame color control technique for video post-production. Building upon an analysis of HDR color grading frame color control challenges in video post-production, we design a new control technology that calculates high dynamic range image information based on the nonlinear mapping relationship of image pixels to synthesize HDR color grading frames; scales the dynamic range of HDR color grading frames proportionally through tone mapping; and compensates for overall brightness and color to ensure clearer presentation of various information within video images. Experimental results demonstrate that the video resolution achieved with the proposed technology significantly surpasses that of conventional techniques.

Full Text

HDR Color Control Technology for Color Grading in Video Post-Production

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Abstract

Since existing control technologies offer insufficient improvement in video image clarity and resolution, this paper proposes a novel HDR color control technology for color grading in video post-production. Building upon an analysis of color control challenges in HDR grading, we design a comprehensive control framework that: (1) computes high dynamic range image information based on nonlinear pixel mapping relationships to synthesize HDR graded images; (2) proportionally scales the dynamic range of HDR graded images through tone mapping; and (3) compensates overall brightness and color to ensure clearer presentation of all image information. Experimental results demonstrate that the proposed technology achieves significantly higher video resolution than conventional methods.

Keywords: video post-production; HDR; color grading technology; image synthesis; color control technology

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The human eye can effectively recognize an extremely wide range of luminance, with recognition capability reaching up to 10^{10} orders of magnitude from night vision to intense light conditions. However, conventional digital video images typically exhibit a dynamic range not exceeding 100:1, and ordinary cameras' recognition capabilities fall far below that of the human eye, leading to inconsistencies [3]. Consequently, when different video segments are combined, significant disparities in contrast ratio and color temperature emerge. Additionally, variations in lighting and color between different camera positions create discontinuities and visual artifacts during subsequent video editing [4]. Color adjustment of video images can effectively compensate for the camera' s limited recognition range, thereby addressing issues of overexposure or underexposure as well as contrast and color discrepancies. During the grading process, it is essential to control and adjust different hierarchical and tonal relationships while preserving the intermediate detail relationships of the original image. Through minor corrections to luminance ratios, the overall quality of video images can be enhanced.

HDR (High Dynamic Range) in video post-production refers to high dynamic range imaging, a technique that can represent the full luminance variations of real-world scenes. In HDR images, pixel values can be directly proportional to the corresponding brightness values in the actual scene, enabling better preservation of details in both bright and dark regions. For highly saturated images, the video post-production process typically involves separate processing of the R, G, and B channels, which are then combined [2]. Current HDR image synthesis commonly employs tone mapping algorithms, which may substantially compress the color differences between the R, G, and B channels, resulting in color distortion that severely impacts the original image quality and reduces its fidelity to the actual scene. To address this issue, this paper investigates HDR color control technology for color grading in video post-production.

1. Analysis of HDR Color Control Challenges in Video Post-Production

1.1 Principles of Image Color Grading

Color control for HDR graded images in video post-production should follow both technical and artistic principles. Technical principles ensure that video image quality meets specified requirements by compensating for differences and artifacts between captured lens images and actual scenes. Since lighting conditions are affected by environmental factors and temporal variations during filming, and since shooting sequences differ from final edit sequences, color control must effectively remedy these issues. Artistic principles, meanwhile, serve the creative vision of the production, using color to convey intended emotions and narrative elements.

1.2 Overall Color Grading Control

For HDR graded images in video post-production, overall color grading control should address the distribution of bright and dark regions across the entire frame to ensure smooth subsequent color correction. Overall grading control can maximally rectify overexposure issues while maintaining color balance, and can combine with the creator' s artistic vision to convey the production' s conceptual intent through more vivid colors. During practical grading, the characteristics of the playback device should also be considered, with appropriate cool or warm tones added to enhance the emotional impact of the video image.

1.3 Local Color Grading Control

Local color grading control targets specific regions within HDR graded images. Before control implementation, specific areas should be delineated according to color variation patterns to prevent grading adjustments from affecting the entire image. Selection of local control regions is accomplished using chroma key and curve masking functions in editing software [5]. The effectiveness of color control is closely related to the quality of local region selection. Most current grading software employs HSL chroma keying to select similar hues within an image. Since local colors exhibit varying brightness and hue characteristics under different lighting conditions during filming, softer chroma keys should be used during control implementation to enable separate adjustments for different 明暗 areas of objects as needed. Specific control can be achieved through single-key single-point or multi-point accumulation methods [6]. Through collaborative parameter adjustments, regions requiring local grading can be selected with greater precision.

2. HDR Color Control Technology for Video Post-Production

2.1 HDR Graded Image Synthesis

Based on imaging principles during video capture, a nonlinear mapping relationship exists between actual scene brightness values and corresponding video image pixels. This mapping relationship constitutes the camera response curve, whose calibration is critical for HDR color control. Using the calibrated curve, the radiance values for each pixel in the corresponding channels of HDR graded images requiring color control can be calculated according to:

$$E_{i,j} = f(P_{i,j}, t_j) \tag{1}$$

where $E_{i,j}$ represents the radiance value of each pixel in the grading channel; $P_{i,j}$ denotes the pixel value of the i-th pixel in the j-th video frame; f is the smoothing curve objective function; and t_j represents the exposure duration of the j-th video frame. Since exposure times vary significantly across different video frames, some pixels perform better under short exposure while others benefit from long exposure [7]. To ensure optimal pixel quality in HDR graded images, multiple frames must be fused to calculate the radiance value for each pixel. Therefore, this paper introduces a triangular hat weighting function, yielding the radiance calculation formula:

$$E_{i,j} = \sum_{j=1}^{N} w(P_{i,j}) \cdot \frac{P_{i,j} - B_{i,j}}{t_j} \tag{2}$$

where $w(P_{i,j})$ represents the triangular hat weighting function. Using Equation (2), the radiance value corresponding to each pixel in the video frames is computed, and high dynamic range image information for the actual scene is derived from these calculations to complete HDR graded image synthesis.

2.2 HDR Graded Image Tone Mapping

Current display devices can only achieve a dynamic display range of 100:1 for video images. Even after obtaining HDR graded images through the aforementioned process, they cannot be properly displayed on conventional equipment. Therefore, this paper employs tone mapping to proportionally scale the dynamic range of HDR graded images to match the capabilities of display devices [8]. During luminance range compression, the contrast, brightness, and hue characteristics of the original scene should be fully preserved. Global tone mapping is used to compress the illuminance values of HDR graded images to obtain corresponding grayscale images, a process expressed by:

$$L_{out} = L_{max} \cdot \frac{L_{in} - L_{min}}{L_{max} - L_{min}} + \delta \tag{3}$$

where L_{out} represents the compressed grayscale value of the HDR graded image; L_{max} and L_{min} denote the maximum and minimum grayscale values; L_{in} is the illuminance value of the actual scene; L_{max} is the maximum illuminance of the actual scene; and δ represents the offset value. Manual control of the offset δ typically involves a trial-and-error process. To reduce errors from manual operation and save control time, an algorithm is required for automatic offset control. [Figure 1: see original paper] shows the RGB three-channel response curves for HDR graded images.

As demonstrated by the three RGB channel response curves in Figure 1, the average scene illuminance is typically used. However, in practical applications, illuminance values within a scene may be zero, potentially invalidating calculations. To minimize such issues, the offset is set to an optimal value of $\delta = 0.001$, which regulates the tone mapping process for HDR graded images.

2.3 Brightness and Color Compensation Control for HDR Graded Images

Following tone mapping control of HDR graded images, brightness and color compensation is necessary to ensure clearer presentation of all image information. This is accomplished using brightness curves, levels, and other commands in video post-production software. Based on the creator’ s requirements for the image, adjustments are made to brightness, levels, exposure, saturation, and color balance [9]. Color balance adjustment corrects color casts in the image. When over-saturation or under-saturation persists after color control, secondary color correction is performed using color adjustment curves and levels functions in the post-production software. The software’ s color balance function enables modification of individual colors within the video image.

Since changing a single color simultaneously affects surrounding colors in practice [10], the following requirements should be observed during compensation: First, residual color cast issues after color control typically affect not just one color but the entire image. Therefore, correction should consider the image as a whole. Second, when correcting color using post-production software, neutral gray should be employed, as it is usually the most effective means of compensating for color casts. Third, when using neutral gray for correction, human visual perception of color must be considered, as changes to other colors in the image can alter the perceived gray. In such cases, the eyedropper tool in the color panel dialog should be used to accurately read color values. Finally, when compensating brightness and color, complementary colors should be selected whenever possible.

3. Comparative Experiment

To verify the effectiveness of the proposed HDR color control technology, a comparative experiment was conducted against traditional methods. Five video clips of 10-minute duration each were selected, with original resolutions of 320$×240ppi, 480×240ppi, 800×600ppi, 1152×768ppi, and1400×$1200 ppi. Both the proposed technology and traditional technology were applied to these videos on a Windows 2008 operating system. The post-production color control process was recorded, and the resolution of videos after color control was measured. The experiment used post-control resolution as the metric, where higher resolution indicates clearer video images and lower resolution indicates poorer clarity. By comparing the resolution achieved by both control technologies, their applicability and effectiveness were analyzed. The experimental results are presented in .

Table 1 Comparison of Video Resolution After Applying Two Control Technologies (ppi)

<table>
<tr><th>Original Resolution</th><th>Traditional Technology</th><th>Proposed Technology</th></tr>
<tr><td colspan="3">320$×240|640×480|400×320||480×240|1024×800|650×480||800×600|1600×1200|1020×960||1152×768|2048×15</td></tr>
</table>

The results demonstrate that the proposed technology significantly improves video resolution, with enhancement values substantially exceeding those of traditional methods. The post-control resolution far surpasses that of conventional control technology, proving that the designed HDR color control technology can effectively improve video clarity and is more suitable for HDR color grading in video post-production, delivering superior control performance.

Conclusion

This study investigated HDR color control technology for color grading in video post-production. Addressing limitations of traditional methods, a new control technology was designed and experimentally validated for its high reliability and feasibility. The technology plays an important role in improving video color resolution and clarity while effectively controlling video quality, providing valuable reference for HDR color grading in video post-production. Although certain research achievements have been attained, individual capabilities are limited, and the proposed control technology still has certain shortcomings. Future work will require further investigation in this area to advance video post-production technology development.

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Note: Figure translations are in progress. See original paper for figures.