

Lumagen Tech Tip 2

Gamut Calibration

Introduction

Many displays have over-saturated colors. The primary and secondary color coordinates lie outside the CIE color triangle. The CIE diagram in Figure 1 shows an example of a display with over-saturated colors. Such a display will produce inaccurate colors, which are most noticeable in flesh-tones and natural colored objects such as grass. Many displays and projectors with this anomaly don't have a way to correct the problem. Other displays use an inappropriate method in an attempt to resolve this issue. In the Radiance series, Lumagen uses an advanced "3D color palette" to correct the primary and secondary color points. In the Radiance each primary, secondary, and white, color point is corrected independently including separate controls for the luminance values.

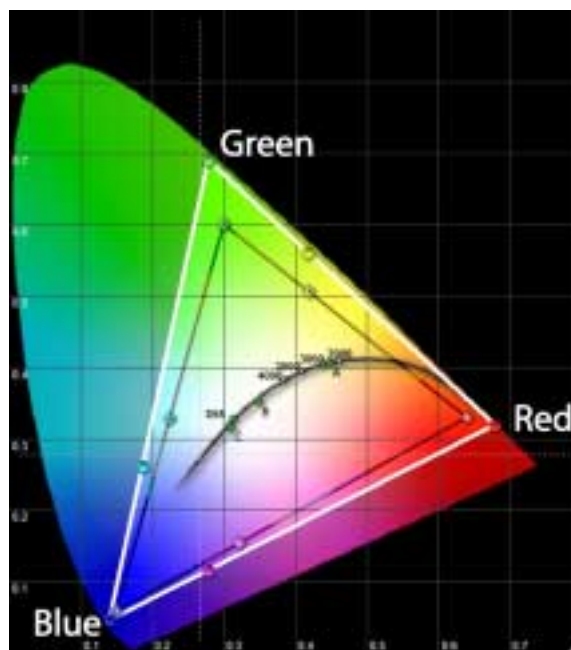


Figure 1: CIE chart with over-saturated colors

The solution

The Lumagen Radiance Series of processors has an advanced Color Management System (CMS). The CMS system can be used to correct the color-of-gray (often called grayscale), gamma, black level and white level. It can also be used to accurately and independently correct the primary and secondary color points on displays where the color points are outside the CIE color triangle. Note that the Lumagen Vision series has a simplified CMS system for primary color correction. While some concepts in this paper can be applied to the Vision series, the calibration procedure presented is specific to the Radiance series of processors.

Many displays and video processors claim to have primary color controls but, instead, they really only have Color/Hue/Offset controls. Color/Hue/Offset controls should not be used to try to correct the primary colors, because these controls operate in the wrong color space. Other manufactures attempt to calibrate the primaries using HLS color space. While this is an improvement over Color/Hue/Offsets, it is not as good as correcting in the RGB color space.

Lumagen uses RGB color space for primary color correction. Lumagen believes that RGB color space – the native color space for the primary and secondary colors – is the proper color space to use when correcting primary and secondary colors. This is because it allows the primary and secondary colors to be corrected, while maintaining the correct interpolation of colors. The Radiance performs this calibration in linear RGB color space to assure the best possible image quality. Figure 2 shows an example of corrected primary and secondary colors.

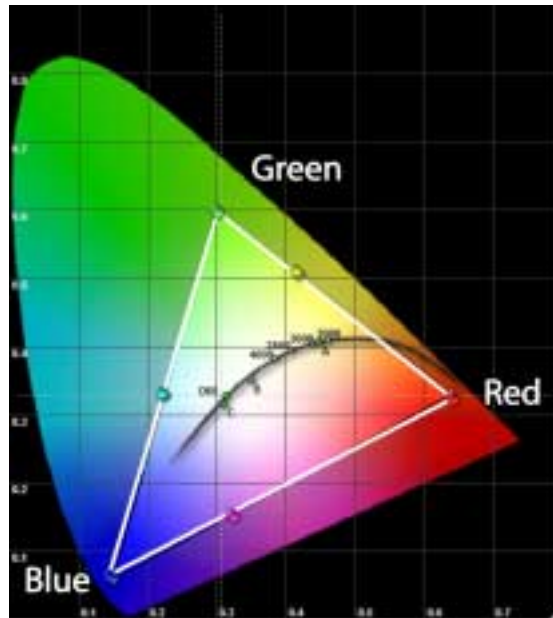


Figure 2: CIE chart after calibration

Primary/Secondary Calibration Procedure

This tutorial is intended for an experienced calibrator. If you don't have proper training and an accurate color probe, consider having your projector/display calibrated by an ISF calibration expert. Test patterns are required for each measurement in this procedure. The Radiance processor can generate all the necessary patterns, internally, in its frame buffer. An external pattern-generator can also be used to generate the necessary patterns. Lumagen strives to match the level of internally generated patterns to the level of externally generated patterns as much as practical. So, the results should be substantially the same whether you use internal or external generated patterns. However, there can be slight differences. Many experienced calibrators use an external pattern generator to ensure that the calibration will precisely match the source. After each calibration step, make sure you view real images to double check the calibration. Note that the Radiance must be in "Service Mode" (MENU 0910) to perform the following calibrations.

It is important to do the calibration steps in the appropriate order. While it is possible to vary the order and still achieve good results, Lumagen recommends the following:

- 1 Install the Radiance and connect it to the display. Set the Radiance output to the appropriate resolution (MENU> Output> Configs> [Config #]> Select Mode) and aspect ratio (MENU> Output> Configs> [Config #]> Aspect). For RGB output mode, also set the output level (MENU> Output> Configs> [Config #]> Other> Level).
- 2 Set the display controls to defaults as appropriate. Lumagen recommends disabling display features that are intended to enhance the image such as noise reduction and edge enhancement, since these can interfere with Lumagen enhancement features.

- 3 Lumagen recommends disabling Dynamic-Iris controls on projectors and rear projection televisions. A dynamic-iris tends to have a negative impact on overall image quality for real images. Mainly, the dynamic-iris increases the marketing numbers for contrast-ratio, while not improving contrast on real images that have any reasonable combination of light and dark areas. Also a dynamic Iris can “flutter” as it tries to choose an appropriate setting, or show a visible and distracting change in contrast for fast light-level changes. Consider putting the iris in manual mode and setting it to its minimal brightness position. This reduces the maximum white level, but remember that the black level is the most important factor in determining true contrast level. This setting darkens the black level and has a positive impact on overall real-image contrast-ratio. Of course in a brightly lighted environment you may need to leave the iris at a higher light level setting.
- 4 Measure the (x,y) points and (Y) luminance for the primary and secondary points. The Radiance Color-Gamut control can only bring color points on the display toward the center (i.e. toward the white point) of the CIE diagram. That is, the Color-Gamut control can't drive the display's color beyond its physical characteristics. It is important to note that many displays have a color temperature selection (e.g. default, warm, natural, etc.). These selections generally affect the primary and secondary (x,y) points. Before starting the color-gamut calibration, when possible, select a color mode for which all the primary and secondary points are at, or outside, the CIE color triangle for the desired color space.
- 5 Check the default gamma curve of the display. Specifications calls for a gamma of 2.2, but many professionals prefer a gamma of 2.4. Use either the display's gamma control function, or the Radiance's gamma-factor control to do an initial calibration of gamma. Depending on the display, it may be necessary to later use the Radiance's parametric gamma function to correct for non-linearities in the display gamma. This would be done after the gamut calibration is completed. The Gamma-Factor control (MENU> Output> Configs> [Config #]> Color Mgmt> Gamma Factor) allows either internal patterns, or an external pattern generator, to be used. The internal pattern can be set to small-window, normal-window, or full-screen. The small window patterns work best on plasmas and other displays where the result varies, depending on the area covered by the window pattern, due to power supply limitations. Measure the gamma curve of the display in either 5 or 10 IRE increments and calculate the actual gamma. Set the Lumagen gamma factor to achieve the desired display gamma. Note that in order to support whiter-than-white and blacker-than-black, Lumagen has chosen to include this entire range of values (i.e. 0 to 4095 with 12-bit pixel depth, where black = 256) in the gamma curve. This means that changes to the Radiance Gamma-Factor also changes the black and white levels. So black and white levels should be calibrated after setting the Radiance Gamma-Factor.
- 6 Set the black-level (brightness) and white-level (contrast) using the controls in the display. If an increase in the Gamma-Factor makes setting the black level in the display difficult, you can use the Radiance output–configuration black level to adjust the actual black output level from the Radiance before adjusting the display (MENU> Output> Configs> [Config #]> HDMI Format> Type). Later differences between sources can be calibrated using the Radiance per-input configuration memories. Proper black level is when a –2 or a –4 IRE bar cannot be differentiated from a 0 IRE black background, but a +2 or a +4 IRE bar can be barely seen against a 0 IRE black background. It is important to note that many displays will have different black levels depending on the average brightness of the image. Using a black full-frame image with a –4 and a +4 (e.g. Radiance Contrast 2 pattern) bar is recommended to insure that dark scenes have a good black level setting. Setting black slightly too dark is better than setting black slightly too bright. If black is too bright the image will look softer than it should. So, if you error, error on the side of setting the black-level slightly too dark.

- 7 If the display has a grayscale calibration feature, set the 100 IRE point grayscale using either Lumagen's internal window pattern or an external pattern generator. Some calibrators prefer to do the entire grayscale calibration using the display's controls when possible, while others only calibrate the 100% point and complete the calibration using Lumagen's parametric grayscale calibration function. Either method works well. If you are using the display's controls to do the entire grayscale calibration, do so at this point. It is recommended that, if needed, Lumagen's parametric grayscale calibration should be done after the color-gamut calibration.
- 8 The Radiance series uses a 3D RGB color-palette to allow both the primary and secondary color points to be independently calibrated for (x,y) and Y values. The 3D palette works in linear RGB color space. The Radiance processes the incoming values to remove the gamma pre-emphasis applied at the source, so the 3D palette can function in the linear color space. Next the 3D palette processes the image. Finally the gamma pre-emphasis is reinserted into the data. In order to support whiter-than-white and blacker-than-black, Lumagen has chosen to include the entire range of values (i.e. 0 to 4095 with 12-bit pixel depth, where black = 256) in the RGB color cube. So when the "100% point" is calibrated (i.e. 235/255, it is not the "fully saturated" point. The practical implication of this is that there will be some interaction between colors. This in turn will require iteration of all the primary and secondary points, including white.
- 9 Some comments on color probes: There is great debate about the accuracy of color probes in measuring primary and secondary colors. For tri-stimulus probes, the accuracy is mainly determined by the color filter's response curve. For spectral-radiometers, the number of sample-points mainly determines accuracy. Lumagen recommends caution when using the results obtained from color probes. A number of commercially available probes are not as accurate as many believe for measuring primary and secondary colors. The more accurate probes cost \$10K and up. It is better to error on the side of slight over-saturation rather than to allow any potential under-saturation of the primary or secondary points. Given that there is an unknown error in the probe's (x,y) point reading, having readings slightly outside the CIE triangle will likely provide better results than working to get a reading that exactly matches the CIE chart.
- 10 Measure the (x,y) and "Y" values for all primary and secondary colors including white.
- 11 Enter the measured white "Y" value into a calculator, such as the one available from the Accupel website. This calculator will output the expected (x,y) and "Y" values. Compare the actual measurements to the expected values
[http://www.accupel.com/Display%20Calibration%20Calculator%20\(PC\).zip](http://www.accupel.com/Display%20Calibration%20Calculator%20(PC).zip)
- 12 At this point you can work to get the (x,y) reasonably close to targets, or you can skip to step 12. If the Y values are reasonably close, or above their targets, work to get (x,y,) values closer. Start with white and then the points farthest from their target values. If the Y values are way below target, it may be best to skip to step 12. In either case there will be iteration between adjusting (x,y) and Y for each point.
- 13 Since the gamut starts with 100% of each color, the white "Y" may need to be reduced in order to be able to properly calibrate all the points, if other points have Y values below target. Find the Y point that has a measured value that is the smallest percentage of the calculated value. If this is above the calculated value, there is no need to adjust the white-point Y value. Reduce the measured white "Y" by editing the values in the color-gamut menu, using either by-color or matrix method, to match the new "Y" value entered into the calculator for white (MENU> Output> Configs> [Config #]> Color Mgmt> Color Gamut). While doing this make sure to maintain the proper R, G, B balance to hit the correct (x,y) point for white.

- 14 For each primary and secondary, edit the RGB color values to bring the (x,y) and “Y” values to their expected values. Start with the values farthest from the correct CIE points. Watch the (x,y,) and Y point locations and work to bring them closer to their expected values at the same time. There is a bit of art in this adjustment since the RGB calibration axis does not align with the (x,y) and Y axis of the CIE diagram.
- 15 Iterate through steps 12 and 13 as needed. It is probably best to work toward getting all the values close to the target, but slightly outside the CIE triangle, rather than precisely hitting the target values. The reasoning for this approach is:
 - a. To avoid any errors in the probe readings resulting in under-saturation.
 - b. Probe readings can actually change if you take another measurement later. This highlights the probe accuracy limits.
 - c. A small offset toward over-saturation is probably not observable. In contrast, a small error toward under-saturation may very well be observable. Use your own judgment on what level of accuracy is needed on a case-by-case basis.
- 16 Calibrate the black and white level again using the display controls.
- 17 Calibrate gamma and grayscale using the Radiance parametric gamma and grayscale calibration, if needed (MENU> Output> Configs> [Config #]> Color Mgmt> Color Temp).
- 18 If time permits, go through all the calibration steps again to check and refine the results. There is interaction between the various calibrations. Depending on how much correction was needed, there may be more adjustment needed to get everything dialed in properly.
- 19 **Remember to save your Radiance settings, or you will lose your work when the unit powers down! The command is MENU> Save> Save> Ok.**