HYBRID TARGETING FOR AUTOCAL

IMPROVED LUMINANCE RESPONSE FOR 1D LUTs

By Joel Barsotti and Tom Schulte

Grayscale imaging systems, often implemented with color displays, usually have rigorous luminance response model requirements to accurately render critical system images. With color being added to many critical imaging systems, luminance response requirements may be just as rigorous for those color imaging systems.

An interactive display calibration system that optimizes each grayscale or color calibration point to create a 1D correction LUT requires a calibration targeting metric to inform the system in its selection of the optimum luminance calibration solution for each calibration point.

This paper examines the utility of various luminance and chromaticity error metrics for use as a calibration targeting metric for an interactive display calibration system. We then present a new, hybrid targeting metric that combines the individual strengths of current luminance and color difference metrics to provide increased luminance calibration accuracy.

Imaging System Accuracy

Color imaging systems used for entertainment and information systems are calibrated to produce accurate color image rendering, with luminance, hue, and saturation contributing approximately equally to perceived color accuracy. The industry's best metric for specifying perceived color differences is currently the CIE dE2000 formula, which has approximately equal weightings for luminance, hue, and saturation differences.

Grayscale imaging systems for medical radiology, geospatial imaging, remote sensing, surveillance, etc. are calibrated differently from color imaging systems, however. These systems have very specific luminance response requirements for the electronic displays used to render the electronic grayscale images. Specialized luminance response models have been developed for grayscale systems, including DICOM and EPD, to assure optimal image tonal shading and detail resolution. In those cases where a color monitor is used to render the electronic grayscale images, chromaticity accuracy is secondary to the monitor's luminance accuracy.

It has been determined that a more rigorous luminance difference metric than CIE dE2000 is desirable to serve as the calibration optimization target for grayscale imaging systems. Plus, even in color imaging systems, the dE2000 formula often provides marginal performance for luminance calibration targeting, especially at low luminance levels.

Calibration Targeting Metrics

CIE dE2000 metric

The CIE dE2000 color difference formula contains a delta L* (L-star) value that represents the perceived luminance difference between two similar luminance levels. A delta L* value of 1 signifies a luminance difference that is just noticeable. In the CIE dE2000 formula, the luminance difference is summed with the hue difference and the saturation difference to create a single color difference value.

JND metric

The Just Noticeable Difference (JND) metric for quantifying luminance differences was developed from the Barten model of the human visual system. A JND is the smallest difference in luminance between two gray levels that the average observer can just perceive on a display system. The JND metric is used to rigorously evaluate luminance differences in grayscale imaging systems, disregarding any chromaticity differences.

Compared to L* increments, there are many more JND increments for a given luminance range. Also, compared to L*, a higher percentage of the JND increments occur at the low end of the luminance range.

Example:

For a luminance range of 100 cd/m^2, there are 100 L* increments, with 9% of the total L* increments in the bottom 1% of the luminance range. There are just 4 L* increments in the top 10% of the luminance range.

For the same luminance range, there are 476 JND increments, with 15% of the total JND increments in the bottom 1% of the luminance range. There are 14 JND increments in the top 10% of the luminance range.

With a greater number of error values for any given luminance range, compared to the dE2000 L* metric, the JND metric provides more resolution to detect luminance differences across the entire luminance range. The JND metric also produces higher error weighting for critical errors at low luminance levels.

Legacy CalMAN AutoCal Targeting

During the CalMAN AutoCal process, CalMAN uses a targeting error metric to guide its calibration optimization process. The calibration targeting metric serves three purposes during AutoCal:

1. The single value error metric is used to rank how close each measured grayscale or color point is to its desired target point. This allows CalMAN to pick RGB triplet signal drive values that get the grayscale or color results progressively closer to the desired target.
2. For each new RGB triplet, the error metric for the measured result is compared to the accuracy threshold to determine whether the desired accuracy has been achieved, or whether to continue to check other RGB triplet combinations for more accurate results.
3. When no RGB triplet achieves the desired accuracy, the error metric is used to rank each triplet for best fit. CalMAN then selects the RGB triplet with the lowest error ranking.

It is important, then, that the chosen targeting metric adequately informs the AutoCal system of luminance and chromaticity errors, so that the system can produce optimum calibration results.

In the past, when calibration results produced dE2000 values that were well within the desired threshold level, it was found that the luminance for that point could still have a marginally high JND value. A display’s luminance could be almost perfect at some signal drive levels, but the luminance could be at the edge of JND tolerance at adjacent drive levels.

With standard accuracy thresholds, CalMAN was achieving luminance accuracy that was just within the required threshold of many grayscale imaging systems. Also, even in color imaging systems, it was found that luminance errors often increased at low luminance values to be at or just above the desired threshold level.

The CIE dE2000 metric was not adequately informing the AutoCal system with stringent enough targeting information to select the RGB triplet combination that yielded the optimum luminance accuracy.

Single Pass Display Profiling

Calibration systems for grayscale imaging systems other than CalMAN use single pass display profiling with a single computation cycle to create calibration adjustment data. These systems do not use iterative measure/adjust cycles to optimize their calibration adjustment data and can’t correct many display nonlinearities, especially chromaticity errors.

Because single pass display profiling systems don’t perform interactive measurements and adjustments, they don’t utilize a calibration optimization target, as CalMAN does.

New Hybrid Targeting Metric

The design update goal was to produce a new AutoCal targeting metric that would continue to satisfy the chromaticity accuracy requirements of color imaging systems and would provide greater luminance accuracy for both grayscale and color imaging systems.

It was found that obtaining luminance accuracy within one JND was usually possible at all display luminance levels without sacrificing chromaticity accuracy. This was empirically proven by manually optimizing completed AutoCal calibrations to obtain lower JND luminance errors, while maintaining the chroma accuracy. The AutoCal targeting algorithm just needed to be informed of the tighter JND luminance standard.

The obvious solution seemed to be to include the more stringent JND luminance error metric as part of the AutoCal optimization target. The intent was to create a hybrid JND/dE2000 target that was in the same numeric range as the previous dE2000 target for low error points, with JND being used for luminance and dE2000 being used for chromaticity.

Just summing JND values with dE2000 values to create a new hybrid target didn’t work well, however, as the new error values were much higher than the previous, familiar dE2000 error values, requiring new, unfamiliar calibration threshold values.

Instead, since 1 JND and 1 delta L* both define a just perceptible luminance error, it was found that directly substituting JND values for delta L* values in the dE2000 formula worked very well. For low luminance errors near the perceptible threshold, the JND and delta L* values were similar. For larger luminance errors, however, the new JND error values were larger than the previous dE2000 delta L* error values.

The larger JND values in the new hybrid target algorithm cause AutoCal to limit higher luminance errors, without affecting the chromaticity threshold. A given chromaticity error still produces the same targeting effect with the new hybrid targeting algorithm in AutoCal that the standard dE2000 algorithm did previously.

The new hybrid targeting algorithm produces higher error values for any measured colors with significant luminance error, because the luminance error component has a higher value with JND weighting than it did with the previous L* weighting.

CalMAN uses this new hybrid JND/dE2000 targeting algorithm only for its AutoCal 1D LUT optimization target. In the future, the new hybrid error metric may also be made available for general grayscale and color measurements.

Conclusion

The CalMAN AutoCal 1D LUT calibration system uses an interactive measure/adjust process to optimize each point of display calibration adjustment data. It uses a targeting algorithm to inform the system in its selection of the optimum calibration data for each adjustment point.

To provide the highest level of luminance accuracy, both for grayscale and color imaging systems, CalMAN now employs a hybrid JND/dE2000 AutoCal targeting algorithm.

By combining the individual strengths of the JND and CIE dE2000 metrics, CalMAN continues to provide exceptional chromaticity accuracy, and now provides unparalleled luminance accuracy for both grayscale and color imaging systems.

About SpectraCal:

SpectraCal specializes in the tools and training necessary to achieve images representative of the content creator's intent for environments from low to high ambient light while achieving the colorimetry, contrast, and dynamic range necessary for the image to have the proper impact on the viewer.

SpectraCal CalMAN software was developed to support the display calibrator in the step by step process of screen optimization. The foundation of screen optimization through display calibration is to understand the elements in a display that require adjustment and how each element inter-relates to the others. From its inception, CalMAN has earned rave reviews and has become the preeminent display calibration software package on the market, compatible with virtually all color meters available today. As display technology evolves, CalMAN will continue to provide the first choice for display calibration solutions.

More Information:

For more information on CalMAN professional quality solutions for your displays:

Visit: http://studio.spectracal.com/store/calman-software/calman-studio.html,

Email: info@spectracal.com, or

Phone: +1 206 420 7514.

SpectraCal, Inc.
17544 Midvale Avenue N., Suite 100
Shoreline, WA 98133
www.spectracal.com

About the Authors:

Joel Barsotti is Head of Advanced Color Research at SpectraCal. He has been the primary architect of every version of CalMAN since version 4.0. Joel has designed several iterations of 3D LUT profiling code, each of which has significantly advanced the state of the art. His innovations include: CalMAN AutoCube technology, CalMAN Dynamic Profiling process, Dynamic Linearity Correction, Intelligent Resolution Profiling, Lightning LUT, 3D LUT Retargeting, the adaptation of volumetric interpolation to color science, grayscale priority interpolation, and grayscale tint reduction, making CalMAN one of the most sophisticated color management packages available.

Tom Schulte is Product Development Manager at SpectraCal. Tom has extensive experience in electronic systems test, calibration and service, as well as electronics test instrument design and usage and has authored numerous technical white papers. Tom was previously an Application Engineer at Sencore for over twenty years, where he was involved in video, audio, and RF test instrument design, plus training and support for electronic test equipment users.