Meta-Standards for Color Rendering Metrics and Implications for Sample Spectral Sets

CIE US / Canada Meeting

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Abstract

Paper #2
Consideration of Meta-Standards for Color Rendering Metrics

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There is compelling, largely agreed-upon evidence that the CIE Color Rendering Index (CRI) is not a sufficiently accurate measure of the fidelity of color rendering. This has become particularly evident with the consideration of white light sources employing several narrow band light emitters. Although there are numerous suggestions for improving the CRI, the CIE has had difficulty reaching agreement on this matter. In this presentation an approach is suggested for reducing the difficulty, which is first to agree upon meta-standards for evaluation of proposed replacement metrics. Most experts already agree with the most basic requirement, which is the need to avoid ranking error. That is, if one light source is perceived, by most people, to render colors more accurately than another light source does (when both are compared to the color rendering of a defined ideal source), then the metric should not reverse that ranking. However this meta-standard, when taken alone, is not very discriminating because of the diversity and variability of human perception. As a result, secondary supplemental meta-standards are needed to make a selection decision. To be helpful, they should ensure that any new metric will be sensible, practical and will not cause undesirable unintended consequences in the future optimization of light source spectra. There already are proposed metrics for color rendering that satisfy all of these meta-standards to some degree. Therefore, it is hoped that if such meta-standards can be agreed upon, it will be possible to make quicker progress toward a significantly approved, widely accepted, replacement metric for the CRI.
Color Concepts Are Confusing!

• Two strong views of color and light sources:
  – Color matters a lot
  – Color matters little

• Both statements are correct, sometimes:
  – Some aspects of color *do* matter a lot to people
  – Some aspects of color *don’t* matter all that much

• Confusion often leads to disagreement
An important case: “Flesh Tone”
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- Reflectance vs Wavelength (nm)
- Chromaticity Diagram (a* vs b*)
- Intensity vs Wavelength (nm)

- Skin Photo
- Skin Photo

Planckian 3 Narrow Bands
Key Ideas

• Different spectra can appear the same color
• But may *render* colors of surfaces differently
• We don’t adapt to poor color rendering
• This causes *some* people discomfort
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• Recommends an update for the current CIE CRI, including:
  • An updated calculation engine;
    • From Ronnier Luo’s collaborative group);
    • fixing “outdatedness”;
  • An updated sample set;
    • Eliminates spectral response non-uniformity;
    • As simple and “real” as possible.
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• Surveys literature supporting this general view;
• Highlights the CQS (there are differing view on how to do so);
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Color-Neutral Perturbation of Planckian
Average Curvature of the 8 CRI Samples
Average Curvature for 1000 Leeds Samples
Form of Representative Spectrum
\[ I_{c_i} = 550\text{nm} + 25\text{nm} \times (I - 9) \]

\[ M_i = 0.5 + 0.001\text{nm}^{-1} \times (I_{c_i} - 550\text{nm}) \]

A) If \( \text{ABS}(I - I_{c_i}) \geq [125\text{nm}] \):
   \[ R(I) = [0.01] \]

B) If \([125\text{nm}] > \text{ABS}(I - I_{c_i}) \geq [75\text{nm}] \):
   \[ R(I) = [0.01] + (M_i - [0.01]) \left[ \frac{1}{8750\text{nm}^2} \right] \times ([125\text{nm}] - \text{ABS}(\lambda - \lambda_{c_i}))^2 \]

C) If \([75\text{nm}] > \text{ABS}(I - I_{c_i}) \geq [25\text{nm}] \):
   \[ R(I) = [0.01] + (M_i - [0.01]) \times \left( \left[ \frac{8}{7} \right] - \left[ \frac{2}{175\text{nm}} \right] \times \text{ABS}(\lambda - \lambda_{c_i}) \right) \]

D) If \([25\text{nm}] > \text{ABS}(I - I_{c_i}) \):
   \[ R(I) = [0.01] + (M_i - [0.01]) \times \left( \left[ 1 \right] - \left[ \frac{1}{4375\text{nm}^2} \right] \times (\lambda - \lambda_{c_i})^2 \right) \]
HL17 Spectral Set
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HL17 “Natural Matches”
$b^* \text{ vs. } a^*$

$L^* \text{ vs. } a^*$

$L^* \text{ vs. } b^*$
Sensitivity of CRI to Perturbations vs. Wavelength
CRI values compared to Hybrid Leeds Data
CRI 14 samples
Non-hybrid 1000  $R^2 = 0.94$
HL17 set  $R^2 = 0.99$

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CRI values compared to Hybrid Leeds Data
Conclusions

- The HL17 set is proposed for CRI sample set
- This reduces CRI error from 5 points to <1
- The CRI will then work well with LEDs
- Work is still needed on color preference
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