White Paper #6

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ICC version 2 & version 4 display profile differences

Version 4 of the ICC specification requires that the media white point of all display profiles is D50. This White Paper explains the requirement for display tristimulus values to be chromatically adapted to the PCS white point and the use of the chromatic adaptation matrix to undo the chromatic adaptation and obtain the actual display tristimulus values.

Display white point adaptation

In version 2 of the ICC specification, the assumed state of viewer adaptation to the display white point was not specified. Consequently, the chromatic adaptation applied to display white point tristimulus values to produce the PCS media white point values can range from no adaptation (the actual display white point values are encoded as the media white point) to full adaptation (D50 tristimulus values are encoded as the media white point). The result of this ambiguity is that different profiles for the same display can produce different results, depending on the degree of adaptation that was assumed by the profile maker. These differences can cascade through the rest of a color management workflow, as the appearance of images on a display is often used as a basis for color adjustments.

To resolve this ambiguity, the version 4 ICC specification requires that v4 display profiles assume the viewer is fully adapted to the display white point. This means that display tristimulus values must be chromatically adapted to the D50 PCS white point when creating the profile. However, the v4 specification also requires the chromatic adaptation matrix used to be included in the chromatic adaptation tag if chromatic adaptation is needed (i.e. the display white point is not D50). This requirement makes it possible for CMMs to include the capability to undo the chromatic adaptation and obtain the actual display tristimulus values. Then, a capable CMM could re-introduce whatever degree of adaptation is desired.

Unfortunately, current CMMs do not offer a user selectable degree of display chromatic adaptation. For most applications, this control is not necessary - fully adapted values produce the desired results. However, if some use case requires partial or no adaptation to the display white point, it may be necessary to use the appropriate v2 profile until such time as CMMs with chromatic adaptation control become available. This approach requires a high degree of knowledge and skill, and should only be employed by expert users. It is the belief of the ICC that the vast majority of user needs are met by assuming complete adaptation to the display white point, which is why this assumption was selected to remove the ambiguity.

Also, it appears that some users utilised profiles that assume no viewer adaptation to the display to modify the white point of the display without adjustment of the hardware. When using the relative colorimetric rendering intent the display of the media white point of the source profile would be the white point set by the display hardware, whilst with the absolute colorimetric rendering intent the measured white point of an image seen on the display would be that of media white point of the source profile - typically similar to D50. With v4 profiles there will be no such differences and so the only differences when the absolute or relative colorimetric rendering is used is the difference between the media white of the source profile and D50 itself.

Questions have been raised by some users as to how they can now obtain a white with the chromaticity of D50 on their display. If full adaptation is assumed to occur it should only be necessary to provide D50 on a display when direct comparisons are made to hard copy and full adaptation to the display is not possible. In such a situation users are recommended to follow the guidance of ISO 12646 and directly set the hardware to provide this chromaticity. Otherwise they are recommended to follow the guidance of ISO 3446 and set the hardware to provide the chromaticity of D65. However, if there are users who require D50 chromaticity, without re-setting their hardware, their color management vendors should be encouraged to use the chromatic adaptation tag to provide this functionality in the CMM.

Rendering intents

ICC version 2 display profiles typically contain only one rendering intent, and this rendering intent is typically a mixture of perceptual and colorimetric rendering. For example, most display profiles assume a display black point luminance of zero (no light whatsoever), and scale the measured display transfer function accordingly, but then otherwise encode display colorimetry in the profile. This approach results from two v2 characteristics: the perceptual intent black point is assumed to be scaled to zero, and there is no defined perceptual intent reference medium.

The problems with the above approach are:

• Since real displays will not have a black point of zero, the display profile is not an accurate colorimetric profile. Furthermore, the scaling of the display black point will affect the encoded colorimetry of all the display colors except the display white point (even the display white point can be affected slightly by veiling glare).

• Since it is not possible to visualize and evaluate tone reproduction down to a luminance of zero, the ability to accurately view and control shadow detail is limited using v2 display profiles. Users can learn to compensate mentally for limited media in controlled situations, but this compensation is difficult to reliably communicate, or extend to arbitrary media.

• While in v4 there is a well-defined standard perceptual intent reference medium and associated gamut, there is no such medium defined for v2 and thus there is no way to color re-render the display colorimetry. The only opportunity for optimized color re-rendering is with proprietary situations where an output profile perceptual intent is tuned to receive the PCS colorimetry of a specific display profile.

The above issues result in limitations to the quality of images that can be produced using v2 display profiles. Historically, this has been less of an issue, because displays were less capable, and users realized their limitations and performed final adjustments based on actual printed output. Also, scaling of media black point tristimulus values is a way to achieve reasonable first-order color re-rendering. However, as displays improve and display-based color encodings (such as sRGB) are widely used, it becomes important to know the true display colorimetry, to enable optimal quality color re-renderings to be produced.

The ICC v4 specification solves these problems, because it clarifies the inclusion of multiple rendering intents in display (and color space) profiles, and includes a well-defined perceptual intent reference medium with associated color gamut. Display profiling tools vendors are encouraged to encode accurate display colorimetry in colorimetric intents, and to perform appropriate color re-rendering in perceptual intents where present. Color re-rendering art is difficult to model mathematically to the extent required to create perceptual rendering intents automatically without user intervention. An example of a source-to-PRMG perceptual rendering can be found in the ICC preference sRGB v4 profile.

Many display profiling measurement devices do not record the ambient illumination which must be included to obtain accurate measurements of veiling glare. Accurate colorimetric intents are straightforward to construct using suitable measurement devices, and several manufacturers have shown profiles with high quality (hand-tuned) display to print reference medium perceptual rendering intents.