International Color Consortium®

White Paper #1

Level: Advanced

Fundamentals of the Version 4 Perceptual Rendering Intent

ICC Version 4 differentiates clearly between perceptual rendering and colorimetric rendering so that the applications appropriate for each of these rendering intents are clarified. Improved workflows can be achieved by exploiting these clarified rendering intent definitions.

An understanding of image state concepts will assist in understanding and applying the ICC perceptual rendering intent.[1] Essentially, image state conveys information content potential – pertaining to encoded color information. As color scientists we know that scenes in general have certain extents of color and tone information, scanned hardcopy originals in general have certain different extents of color and tone information, etc. From this general understanding, the image state semantic allows us to categorize encoded color information – based on real-world algorithm and encoding capabilities and constraints. A color object encoded in a particular image state is appropriate for the uses and output modes associated with that image state. Furthermore, the concept of image state allows us to clarify our understanding of the image processing relationships between different color information content potentials – that is between different image states, e.g., the fundamental processing required when transforming a scene to an image suitable for reflection print output.

In general, recently developed color image encodings are each identified with a particular image state, with an associated color space white point, and viewing environment. A color gamut, with a particular volume and luminance range, can be a part of a particular image state condition. Note, however, that while, in a sense, image state is an attribute of a color image encoding, an image state is in fact a representation of what can be done with any color object encoded for that image state. Several image encodings are valid for use with each of the standardized image states: scene-referred, original-referred, reference-output-referred, and actual-output-referred.

[1] Image state is defined in ISO 22028-1, “Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange — Part 1: Architecture and requirements”

With these image state concepts in mind, the ICC perceptual rendering intent can be defined. The ICC perceptual rendering intent is provided to accomplish a *preferential* adjustment in concert with an image state image processing transition.

A comparison look at the colorimetric rendering intents can help to further position the perceptual rendering intent. The media-relative and absolute colorimetric rendering intents provide a means to transition from one color space encoding to another, adapting for color space white point differences while maintaining colorimetric measurement accuracy for in-gamut colors. Image data is re-encoded, via any of the colorimetric renderings, but is not adjusted preferentially for image state differences. The only image state constraints that are incorporated via colorimetric renderings are gamut volume (when a particular gamut volume is associated with the target image state condition) and color space white point. Essentially, either of the colorimetric intents can be used to re-encode image data, *while maintaining a current image state*, e.g., capture-referred, output-referred. In addition, either of the colorimetric intents may be appropriate for transitioning between two closely related image states, such as reference-output-referred (e.g., ICC Profile Connection Space (PCS) Reference Medium) and actual-output-referred, e.g., when the actual output condition is similar to that of the reference output condition.

The distinction in the perceptual rendering intent is now explained; the perceptual rendering intent provides a means to transition from one image state to another image state, preferentially adjusting color appearance for differences in any or all image state characteristics. In transition, colors are adapted to achieve a preferred color appearance within reference- or device-constraints, and out-of-gamut colors, that cannot be represented in the destination image state, are adjusted using one of many gamut mapping strategies. Note that if a reference-output-referred and an actual-output-referred image state are essentially identical, then a perceptual rendering intent transforming between those states can be thought of as performing a NULL image state transition. In this case the perceptual intent can be identical or similar to a media-relative colorimetric intent. Given this background, one understands that the preferential nature of any *particular* perceptual rendering intent is image state transition dependent. For example, the preferential nature of a perceptual rendering intent used to transition from a raw digital camera RGB into ICC PCS should be different from the preferential nature of a perceptual rendering intent used to transition from ICC PCS to a printer CMYK. The image state transition from raw digital camera RGB to ICC PCS Reference Medium is Scene-referred to Output-referred (reference). [*Note that this initial image processing from scene-referred to output-referred occurs inside almost all digital cameras – the image written from the camera is output-referred.*] The image state transition from ICC PCS Reference Medium to a printer CMYK is Output-referred (reference) to Output-referred (actual-device-constrained). One part of the difference between a ‘scene-referred-to-output-referred transition’ and an ‘output^{B}-referred-to-output^{A}-referred

transition' is that color-rendering from a natural scene to an image requires specific preferential handling, adapting the color information from the three dimensional world to the two dimensional imaging environment.

Given that a perceptual rendering intent transform applies a preference adjustment, a perceptual rendering can be understood to target a particular image state color appearance, i.e., "color aim." A color aim is the color appearance goal of a preference adjustment or adaptation. A color appearance "color aim," dependent on source and destination image states, is inherent in all ICC perceptual rendering intent transforms. However, due to the nature of ICC profiles, the inherent color aim in perceptual rendering intent transforms is not visible to or tunable by the users of ICC profiles.

Color-rendering of scenes (scene-referred image state) to create reproductions (output-referred image state) typically includes a chroma and contrast boost. This is an example of an image state appearance preference adjustment. This boost must be done only in the Device to ICC PCS perceptual transform of an input (scene-referred-to-output-referred) ICC profile. This boost is by nature a non-convergent operation, i.e., if it is applied repeatedly it produces unacceptable results. The ICC PCS Perceptual Intent Reference Medium output-referred image state serves as a target for this scene-referred-to-output-referred perceptual color-rendering. Output^{B}-referred-to-output^{A}-referred ICC PCS to Device perceptual transforms (e.g., perceptual rendering intent transforms in printer profiles) should not implement this particular chroma and contrast boost.
For general purpose pictorial reproduction, perceptual rendering intent transforms are applied in both the input to ICC PCS (scene-referred-to-output-referred) and ICC PCS to printer (output^{B}-referred-to-output^{A}-referred) image state transitions. When a perceptual rendering intent transform has been used to color-render into ICC PCS, the intermediate ICC PCS 'image' is the media-relative colorimetric (reference medium output-referred) representation of an idealized color appearance visualization appropriate to the constraints of the Reference Medium. In ISO 22028-1 terms, the ICC PCS is a color space encoding and the perceptual rendering intent result *in ICC PCS* is a color image encoding. The general purpose pictorial reproduction is completed when the ICC PCS color image encoding is perceptually color-re-rendered to an actual visualization (actual output output-referred).

Alternatively, in cases when the digitization (capture) goal is to accurately retain the image state of a limited gamut source image (e.g., is the source image gamut ~288:1 linear dynamic range from a reflection print scan), media-relative colorimetric rendering from capture to ICC PCS can be followed by perceptual (capture-referred-to-output-referred image state transition) or media-relative colorimetric (capture image state is essentially preserved) rendering to visualization. In this case ICC PCS holds capture-referred media-relative colorimetric values. Preferential image state transition dependent adjustments to output conditions (capture-referred-to-output-referred) are handled through the

output profile. Note that this places a particular constraint on the ‘color aim’ to be achieved in the output profile ICC PCS to Device perceptual rendering intent transform. Media-relative colorimetric intents may be appropriate for each of the encoding transitions from original reflection print digitization to reproduction printing, given that the information is consistently related to reflection print color capability.

In any ICC PCS to Device transition, resulting in an actual-output-referred image state, the selection of perceptual rendering intent versus one of the colorimetric rendering intents must take into account the image state of the image in ICC PCS (e.g., how was the image ‘encoded’ into ICC PCS) and the similarities and differences between that ICC PCS image state and the targeted actual-output-referred image state. The differences and similarities are judged in terms of the image state attributes: color space encoding, color space white point, viewing environment, appearance aim relative to a reference medium, and color space gamut – having a particular volume shape and luminance range.