International Color Consortium®

White Paper 24

Level: Introductory

ICC Profiles, Color Appearance Modeling, and the Microsoft Windows™ Color System

This is the first in a planned series of tutorial white papers the ICC will provide to help applications and systems developers understand run-time color rendering and color appearance modeling.

Microsoft has announced that the new Microsoft Windows™ Color System (WCS) will use the CIECAM02 color appearance model, and run-time color rendering, in which the color transforms to be applied to source [input] files are determined after the output devices are known.

When using standard ICC profiles in WCS the software developer will have a choice of processing, either run-time color rendering with CIECAM02 -or- color rendering using predetermined transforms from the ICC profiles.

First, let's define what we mean by color rendering, gamut mapping, and color appearance models. A gamut mapping operation takes the code values from a source image and converts those to the code values of a reproduction [output image] in a way that compensates for differences in the input and output gamut volume shapes. [In printing, gamut volume shape is the result of colorants, media, half toning, etc.]. Gamut mapping does not include adjusting for preferred colors or adapting colors for different lighting [viewing] conditions.

On the other hand, a color rendering operation begins with an encoded representation of a scene [raw capture] and converts that scene representation to a reproduction in a way that includes gamut mapping and image preference adjustments, and also compensates for differences in viewing conditions, tonal range, etc. Color re-rendering is similar to color rendering, except that it starts with a source image that is already a reproduction, and produces a new different reproduction, typically for a different kind of display. If you would like more information about these operations, refer to the white papers dealing with rendering intents that are posted on the ICC website at www.color.org.

A color appearance model uses a parameter set and an algorithm to compute colors encoded in a color appearance color space. The value of a color appearance color space is that it provides a way to represent colors as a human would see them under a particular defined viewing condition. CIECAM02, the color appearance model in WCS, is familiar technology. CIECAM02, and other color appearance models, are commonly used in the construction of ICC profiles.

The idea of run-time color rendering is that the complete color transformation is constructed at run-time from various available components, and that the complete transform is specific to the imaging conditions required at that time. ICC member companies have provided various kinds of run-time color rendering solutions to market as far back as the mid- to late-1990s. Scitex's Profile Wizard is one example. Enhanced support for run-time color rendering was one of the design objectives in the ICC version 4 revision work, completed in 2001.

Although ICC profiles can be used to construct run-time color rendering transforms, and some ICC-based applications are available, the dominant modes of ICC operation have used predetermined transforms. This is because quality, predictability, and repeatability have generally been more important to ICC users than run-time output flexibility. Across the markets that the ICC serves, there are business-critical use cases that require the specification of predetermined color behavior, e.g., conversion rules to be carried from the design approval point in a workflow to the later implementation stages, and to be archived with digital color files for later matching reproduction. Predetermined transforms encoded in ICC profiles provide this capability.

It is important to keep in mind that a typical color conversion transform, whether it is constructed at run-time, or predetermined, will incorporate a number of features. Color appearance models deal with viewing adaptation adjustments between source and destination, but do not address optimization for a variety of output condition particulars, e.g., gamut reshaping from monitor to print, printing ink limit, etc. In many cases the quality of output is determined by such particulars. ICC profiles include pre-optimized transform elements that deal with all aspects of cross-media reproduction. E.g., the predetermined perceptual rendering intent transforms in ICC Version 4 profiles are pre-optimized for print production gamut mapping. Version 4 profiles ensure correct interconnection between the predetermined transforms in source and destination profiles through the use of a common well-defined reference print color gamut.

The ICC has chosen not to lock-in color management systems to a particular version of a color appearance model due to the rapid pace of advancement in color appearance and color rendering research. ICC color management, and virtually all color appearance models, are based on CIE colorimetry, which has remained stable since 1931. Basing color source interpretation on CIE colorimetry does not limit quality, and maintains a consistent color conversion basis for any color rendering algorithm that may be used. For ICC profile users, flexibility in choosing gamut mapping to convert between similar color encodings, color rendering to create an image from a scene, or color re-rendering, e.g., to create an optimized print from a monitor display image, is provided through the predetermined [and pre-optimized] rendering intent transforms in ICC profiles, and the colorimetric encoding of the PCS. When a run-time color appearance adaptation is required, support is provided by the chromatic adaptation and viewing conditions tags in ICC profiles. It is often the case that the predetermined transforms in ICC profiles are the result of extensive expert optimization.

Whenever digital color data is stored or archived, regardless of the processing methods, each image and/or digital color file should be stored using a well-defined color encoding and should be tagged with a standard ICC ‘source’ profile that matches the well-defined color encoding. Note that this profile stored with the digital color data is called a ‘source’ profile, because it will be used to interpret that color information at a later time. Saving images and documents tagged

with standard ICC profiles will ensure that they can be interpreted correctly on any system, for any use, in the future.

Let's review the encoding benefits of the ICC profile encoding format. ICC profile data is encoded in a machine readable form rather than in a human readable form such as XML. As a consortium, the ICC recognizes that there is a significant installed base of ICC profiles worldwide. A change from the current efficiently encoded format would place an undue burden on systems and applications providers, and their customers, while increasing file size and adding no new functionality. The key ICC objective of continuously improving interoperability across open systems motivates against changing the profile format encoding, particularly given that numerous editing and inspection tools that work with the current format are readily available.

Microsoft has stated that WCS will support Version 4 ICC profiles. ICC profiles have become the standard way to interpret the meaning of color values held in digital files and are recognized and processed in hundreds of applications and millions of devices worldwide. The ICC welcomes the new Microsoft Windows™ Color System support for this community and applauds the work by Microsoft and Canon to advance the state of Windows color management.

If the WCS approach is successful, the ICC anticipates broader implementation of run-time color rendering in ICC-compliant color management software and devices, along with continuing support of predetermined transforms.