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Poynton's Vector

14 Colour management systems (CMS) in video

I've discussed *colour management systems* tangentially in previous issues, but it seems timely to dedicate an issue to the topic.

Virtually all commercially deployed imaging systems are based upon *R'G'B'* colour components. Several "flavours" of *R'G'B'* are in use. By *flavours* I mean that the colours of the pure primaries – technically, the *chromaticities* of red, green, and blue – differ. SD and HD today both use the chromaticities of ITU-R BT.709, adopted 20 years ago. Fifteen years ago, the BT.709 primaries were adopted in the sRGB standard; that coding is now ubiquitous in computing and digital still photography. In graphics arts, sRGB is common, but Adobe RGB 1998 is sometimes used, and Pro Photo RGB is occasionally used.

R'G'B' components may be transformed into different colour representations. $Y'C_BC_R$ is used for digital video and HD; *X'Y'Z'* is used for digital cinema distribution; and the CMYK – cyan, magenta, yellow, and black – system is used for graphics arts.

About 15 years ago, several companies active in graphics arts, computer graphics, and digital photography collaborated to devise an architecture and a standard to enable predictable mathematical colour transforms among devices. This scheme evolved into the International Color Consortium (ICC) standard for *colour management system* (CMS). Device-specific colour data is stored in *profiles.* The transform for a display ("monitor") is a fairly simple combination of 1-D lookup tables and coefficients of a 3×3 matrix. The profile for a CMYK printer is a combination of 1-D lookup tables and one or more 3-D lookup tables, usually large and complex. Even without looking inside a profile, you can guess whether you have a monitor profile or a printer profile by simply examining the file size: A matrix profile for a display is typically a few KBytes; a 3-D LUT for a CMYK printer is typically a few hundred KBytes.

If image data encoded to one set of *RGB* primaries is naïvely "plugged-in" to a display having different primaries, colour is not displayed correctly. In the ICC approach, an image data file can contain an embedded profile that specifies the colour space of the image data. An ICC-savvy receiving application can potentially process the image data and transform it appropriately for the display primaries. In some cases, out-of-gamut colours may result. A 3D LUT profile can incorporate gamut mapping to accommodate such situations.

Video has historically used no such technology. Apart from troublesome but fairly minor variations (SMPTE, EBU, BT.709), video has historically "locked-down" its primary chromaticities in paper standards. Consistent colour display has been enabled with no cumbersome processing at the receiver and no requirement for metadata.

During the last decade, the ease of incorporating VLSI into television receivers has led many CE manufacturers to wonder what additional colour adjustments could be offered to entice consumers. A "colour management system" (CMS) offers such additional adjustments. Perhaps the term CMS was adopted from graphics arts colour management, perhaps it was independently contrived; either way, the CMS scheme now fairly common in video displays and video processors bears no resemblance to the ICC's CMS scheme.

In video, a *colour management system* (CMS) enables independent control of hue and saturation – and sometimes also luma (or luminance) – of red, green, blue, yellow, cyan, and magenta. As far as I can tell, CMS circuits are always situated in the $Y'C_BC_R$ path, prior to $Y'C_BC_R$-to-$R'G'B'$ matrixing and prior to the display's EOCF.

You might ask, why are black and white missing from the list of colours above? Well, they're accounted for elsewhere. The luminance of white is already controlled through CONTRAST. Hue and saturation of white are already controlled through choice of colour temperature. The luminance of black is already controlled through BLACK LEVEL. Hue and saturation of black are already indirectly controlled through RGB-BIAS (sometimes called RGB-SCREEN, RGB-OFFSET, or RGB-LOW).

But back to red, green, blue, cyan, magenta, and yellow. You think, "Great! With a CMS, I can control everything!" Not so great, I argue.

The studio reference displays upon which professional content is mastered exhibit near-perfect additive behaviour. At content mastering, cyan is always exactly the sum of blue and green. Magenta is exactly the sum of blue and red, and yellow is exactly the sum of green and red.

As a home theatre calibrator, how can you recreate the director's experience at mastering if cyan isn't the sum of blue and green? You can't. You must seek additivity. You must bypass the CMS (if that is possible), set the CMS to pass $Y'C_BC_R$ unchanged (if the display implements that option), or make sure the CMS settings achieve additive mixing (in the absence of detailed documentation from the manufacturer). Clearly, you're faced with a challenge. You may require individual control of *R, G,* and *B* chromaticities to attain the BT.709 primaries; however, is it reasonable that CE manufacturers force you to use CMS controls to achieve that goal?

In computer graphics and consumer digital photography, "colour management systems" provide a way for image receiving equipment to effect colour transforms to deliver the colour intended by the content originator. In video, it's exactly the other way around: "colour management systems" features defeat the goal of additive mixture, and thereby defeat the content originator's colour intent!

It's no wonder that content creators shun proposals to originate wide gamut colour to CE equipment, proposals such as using xvYCC to deliver digital cinema's P3 RGB gamut. Movie makers think, "The CE industry can't even present today's BT.709 colour content correctly. How can we trust them with theatrical-quality colour?"

Your comments are welcome!