On the Desktop Color System Implied by the ICC Standard

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Abstract

The International Color Consortium (ICC) [1] has established a standard for the format for “color” profiles used in managing color in computer systems. The ICC’s work, although quite limited in its scope, has been very successful since all major desktop computer operating system vendors that have included color management in their operating systems have specified the use of the ICC format for profiles. In addition, support among desktop computer application developers and desktop color management tool creators has been very high.

Historical Notes

The history of the ICC and its standard profiles was presented at the 5th Color Imaging Conference by Michael Stokes[2]. We only emphasize a few points in that history that seem relevant to where we find ourselves today. The predecessor to the ICC was the “ColorSync® Consortium” started by Apple® Computer to help promote and support its ColorSync[3] product. ColorSync provides an addition to the Apple Macintosh Operating System (MacOS) for calibrated color processing

It is to Apple Computer’s credit that they allowed a consortium of companies to take over the definition of these color profiles to be open and not closely held by Apple. Apple has continued to support the standard by keeping ColorSync compatible with it.

So, at least at one point in time, there was a desktop operating system that had a thought-out color management architecture that used the ICC profiles as an essential component in its design. However, the ICC profiles have certainly taken on a life of their own independent from ColorSync. This has become a little of the tail wagging the dog instead of the tail being an essential and useful component of a dog.

Another historical note. In this paper we have repeatedly used the term “desktop” to emphasize that the discussion is about “desktop computers.” The reason this is important is because there have been several color management systems developed in the past that we will not be discussing. They were usually proprietary systems delivered as a package by one vendor. The reason we must mention this previous activity is that many of the concepts and basic principles we are “discovering” today as we develop color techniques for desktop computers are actually being rediscovered. At least some recognition of the earlier systems work is warranted.

Another reason it is worth mentioning that the previous systems were delivered as one product by a single vendor, is that today no one owns our desktop computer systems design. There is no single company from which you buy all components (hardware and software) of your desktop computer system nor is there a group or company that defines how those computer systems should work. It is amazing that a system works at all when we buy the main computer from company W, a display from company X, a scanner from company Y and software from company Z.

It is about time that we have some detailed and explicit discussions of how colors should be processed in a desktop computer system and what role the ICC profiles play in such systems. We should discuss the color architecture in an open and inquisitive manner. Perhaps some common understanding of what is a workable architecture for desktop computers can be defined, and some agency like the ICC could document the basics. I offer this paper as a feeble first draft to be openly criticized and improved upon.

Back to Basics

There are diverse and varying views on what needs to be done on desktop computers to get better results when dealing with colored data. We hear that color is too complex to be handled easily with simple tools, that the current products have too many controls or not enough controls, and that color management should be built-in or not built-in to the computer operating systems. We hear that color management is only good enough for casual users and we hear that color management is only useful to the expert.

Whenever one hears such conflicting views on a subject it is useful to go back to the root issues and work outward to the more complex ones a step at a time. The basic issue in dealing with colors in computers is twofold: 1) the color of objects is defined by varying and complex human perception including things outside of the computer's control and 2) each of the numerous devices that reveal colored data to humans operates very differently from the others.

Cathode ray tube displays devices (CRTs) respond to numerical controls that meter the intensities of the red, green and blue of the screens to create colors. Other devices, like scanners and printers, deal with colors as numbers also. The problem is, all of these devices need different numbers to represent colors. Here is the first basic truth:

If the same numbers are sent to different devices the usual result is different colors, and

if similar colors are desired then different numbers must be sent to each device.

(You are free to define "similar colors" in any way you wish.)

So to get similar colors on two different devices the numbers must be converted for the second device as shown in Figure 1. This is an essential starting point for any architecture. Two basic approaches to fill the "Custom Transformation" box are supported in the ICC architecture: additive linear transformations using 3x3 matrixes and table lookup. Of course countless other techniques can be used, but at this point in time, the industry seems to have settled on these two basic techniques.

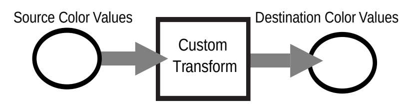

Figure 1. Transforming Color Values

Refinement of the Basics

The difficulty with the simple approach shown in Figure 1 is that it is very device dependent and specialized. For each pair of devices such a transformation has to be done. A more general approach is "device independent" and is shown in Figure 2.

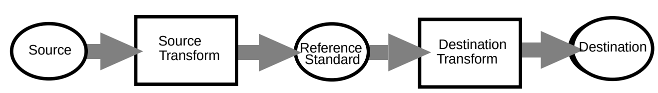

Figure 2. Device Independent Transformations

In the flow shown in Figure 2 the notion of a "reference standard" color space is introduced. The ICC specification calls this the "Profile Connection Space" or PCS. The advantage to introducing a standard is that for each device the only color spaces that are of concern are that of the device and that of the standard. So the creation of the transforms is per device. The next step in this evolution is to realize that the transform algorithms do not have to be created new for each device but can be derived from a generic transform that is specialize by some, hopefully small amount of parametric data that "characterizes" the particular device. This is shown in Figure 3.

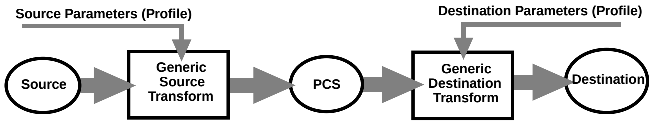

Figure 3. Parameterized Device Independent Transforms

Following this step an optimization can take place where the two independently defined transformations are "smashed" together to be executed as one step. Note, however, that the definitions of these two transforms and the profiles that control them are still created and maintained as separate device independent pieces of information. This provides for efficiency in processing yet independence in definition. This is shown in Figure 4.

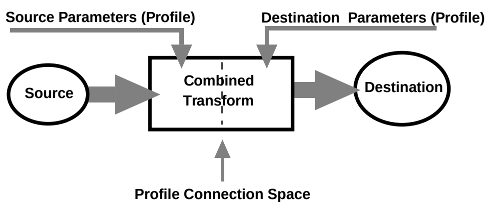

Figure 4. "Smashing" the Processing into One Step

Its More Than Images and Devices

Much of the development of color conversion or color management has been done on pictures or images. In addition, the original ColorSync product had a strong emphasis on color devices and their management. These two sources of the work have had a lasting influence on the architecture. But the architecture must be more general than that. First, the world of computers processes complete documents not just pictures. Sometimes these are called "compound" documents. A compound document is represented in Figure 5.

This example document or page contains text, graphics (line art) and image or picture data. Optimally each different type of information is preserved in a format suited to that type of information. For example the text is preserved as

Figure 5. A Compound Document

strings of ASCII characters, the graphics is saved as colored and filled shapes and lines and the image is preserved as sample data. Tools like Adobe PageMaker® can be used to draw together such material from diverse sources.

The color data of each object may have been developed using one or more colorspaces and it is best to preserve that original diversity in the compound document. So instead of thinking of a document as a picture and containing only one ICC color profile, one must extend that thinking to compound documents that contain one or more ICC color profiles, in the extreme case one source profile for each distinct object in the compound document. For example, the page shown in Figure 5 might have four profiles, one for the flower picture, one for the bar chart, one for the logo and one for the text.

It is true that we would like to have ICC profiles corresponding to the devices attached to our computer. When we print to a printer or display to a screen, the applications need to understand the colorspace of those devices in order to do the proper transformations on the data. However, when we save data that has been created to look correctly on one device we must also save with the data that device's profile so that the data can be used later, possibly with another device. The original device's profile is needed to do the transform to the second device. So ICC profiles are not just device profiles but when saved with an image, or graphics or text become "data" profiles as well. In addition, one might process data that is in some device independent color space such as L*a*b* and data profiles are needed in this case as well.

The analogy to taking distance measurements and sharing them works well to understand the basic requirements. If you were to receive the number "33" alone and were told it was the measurement of a distance you still would not know enough to make use of the number. However, if you were also told that the number was in a measurement space that had 11 units to the meter you would know how to convert that number to the metric system as 3 meters. And from there it could be converted to any other measurement system if the conversion factor for that system was also known.

The final Figure 6 is intended to represent an instance of a "chain of calibration" that the desktop computer system must maintain of the color spaces used in documents while the document and its pieces flow through the system. It isn't so much an issue of "color correction" or "color management" but preservation of calibration.

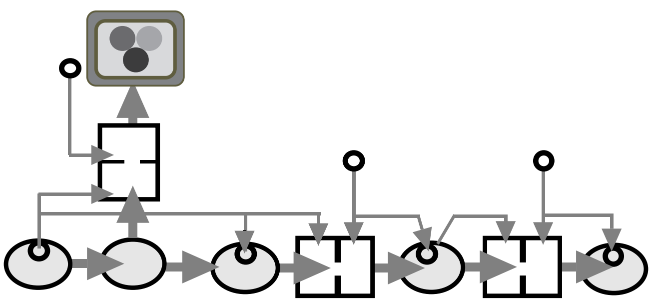

Figure 6. A Typical Chain of Calibration on the Desktop

The small circles represent profiles, the boxes represent transforms and the larger ovals represent data or objects within documents. Each transform requires colorspace profiles for the data flowing into it and profiles for the desired colorspace for the outgoing data. In addition, the outgoing data must have the profiles imbedded with it.

New Refinements

In Figure 7 we show in diagram form some changes in the ICC architecture currently being discussed.

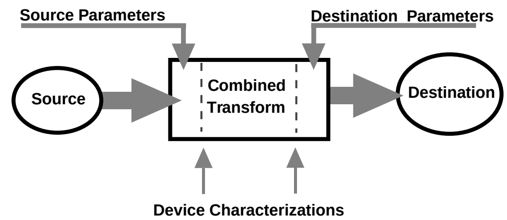

Figure 7. New Architecture Ideas

This introduces the idea that colorspaces can be characterized in ways other than how to transform them to a standard PCS. In this technique we simply define the colorspace in terms that allow a conversion algorithm to do its job. This new architecture would allow more power and intelligence to be incorporated into the "Combined Transform" component usually called the "Color Matching Method" or "CMM." It does not change the ideas of device independence or the overall architecture. It does imply that an explicit PCS is not necessary.

Summary

This paper is intended to begin a discussion about the proper desktop computer color processing architecture. It is based on the author's perception of the architecture implied by the ICC standard for color profiles. It is hoped that this will trigger a public discussion of what the correct architecture should be and perhaps the ICC or some other body will later publish a system architectural guideline.

References

1. International Color Consortium (ICC), http://www.color.org (1998).
2. Michael Stokes, History of the ICC, Color Imaging Conference, IS&T, 5, (1997).
3. Apple Computer, ColorSync 2.5, http://www.apple.com/colorsync (1998).