Summary of Comments on ColorMgmtTutorial_010622.ppt

Page: 1

Sequence number: 1
Author: jking
Date: 9/29/2001 11:36:12 AM
Type: Note

I have typed annotation notes on each or nearly each of the slides in this presentation.
You might want to use the Tools-> Comments->Summarize feature of Acrobat to collect them and print them out. Then you can read along without sharing screen space between the notes and the pictures.
Have fun!
Jim King

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Sequence number: 1
Author: jking
Date: 6/26/2001 7:09:21 PM
Type: Note

Desktop Color Management has had a shady past. It is believed to be very difficult, hard to understand, and possibly not a good thing to attempt.
I don't believe any of that and after this presentation, I hope that you will have a better, more clear understanding and will become a believer as I am.
Jim King -- 6/26/2001

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Sequence number: 1
Author: jking
Date: 6/26/2001 7:10:03 PM
Type: Note

We believe that people are looking for predictability and consistency. They would like a colored page to be reproducible on a variety of technologies with consistent results.

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Sequence number: 1
Author: jking
Date: 6/26/2001 7:11:14 PM
Type: Note

This is real simple stuff. If when the same numbers are sent to two different displays we get different colors, then we must send different numbers to the second display to get results similar to the first display.

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Sequence number: 1
Author: jking
Date: 6/26/2001 7:12:00 PM
Type: Note

Again, this may be quite obvious but we say it clearly anyway. If the same values are sent to different devices (say the same RGB values are sent to different displays, or the same CMYK values are sent to different CMYK printers) the results are usually quite different. In order to get similar results, different values need to be sent to the different devices.

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Sequence number: 1
Author: jking
Date: 6/26/2001 7:13:15 PM
Type: Note

To get the same results on different devices the color values each have to be altered or transformed. This is done by using tables, equations, or other tricks. The quality of today's products are judged, in part, by how they perform these transformations. We talk of taking some given "source" values and transforming them to a modified set of values appropriate to a different "destination" device.

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Sequence number: 1
Author: jking
Date: 6/26/2001 7:14:40 PM
Type: Note

If we were to create a transformation to map from each of N sources to each of M destinations, we would have to create M times N unique transformations. If we were to add a new destination device to the list we would have to add N new transforms, one for each source. Conversely, a new source would dictate that we make M new transforms, one for each destination.

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Sequence number: 1
Author: jking
Date: 6/26/2001 7:15:07 PM
Type: Note

A common way to simplify the situation is to introduce a fixed standard color space. One transform per source is all that is needed to produce the standard and one transform per destination is all that is needed to conform to each destination.
This is now an additive problem and the introduction of a new device only requires the introduction of one new transform either to or from the standard.
The use of this principle is a major part of what the CMS vendors are referring to as "device independent color."

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Sequence number: 1
Author: jking
Date: 9/29/2001 11:36:31 AM
Type: Note

The current technology used by most of us is to have a generic transform mechanism (CMM) that is customized by what we here call "colorspace definitions."
Note in the diagram that the colorspace definitions are a small amount of information compared to the large amount of data that might need to be transformed (the sources color values) as in a large color image. Also note that the generic engine (CMM) is common to all transforms.
The International Color Consortium has standardized the "colorspace definitions" and has called them "profiles". The format chosen matches that of Apple's ColorSync Profiles and nearly all major operating system and color system vendors have agree to use that format.
One other powerful idea, that most of the current systems share, is an optimization that is introduced by "smashing" the two transforms into one. The definition for what has to be done is provided in terms of the PCS, gaining the benefits as noted earlier. However, no sacrifice in processing efficiencies need be made.
Separating the definition from the execution is key.

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Sequence number: 1
Author: jking
Date: 9/29/2001 11:36:44 AM
Type: Note

Here is an example of a color managed workflow that you might find while using Adobe Photoshop. Note that there is a "working colorspace" in which the current job is kept. In order to update the display color values in the working space needs to be converted to values in the display color space. This is constantly being done as the image is updated.
The conversion from the working space to the display space requires a profile for each. The monitor profile is supplied by the operating system since the display is used across all applications and is a component of the basic machine.
The working colorspace is established by the user by choosing among several available with Photoshop.
If the source colors are in a colorspace that is other than the working colorspace then usually upon opening that input it will be converted to the working colorspace. This requires that the input has a colorspace profile associated with it to define what the color values in the input mean.
If the work is saved it is saved in the working space colorspace and the profile for that space is saved with the data.

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Sequence number: 1
Author: jking
Date: 9/29/2001 11:14:51 AM
Type: Note

The gamut of a colorspace is the total set of colors that can be represented within that colorspace.

Different colorspaces can have quite different gamuts; they can have a different set of colors which values within that colorspace can represent.

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Sequence number: 1
Author: jking
Date: 9/29/2001 11:18:06 AM
Type: Note

Typically a device CMYK colorspace will be able to represent less saturated and fewer colors than an RGB colorspace. In this slide we simulate the changes that are forced upon us as we convert some colors from an RGB colorspace to a CMYK colorspace. Matches for the bright red and purple are just not available in a typical printing press CMYK colorspace.

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Sequence number: 1
Author: jking
Date: 9/29/2001 11:37:04 AM
Type: Note

When the gamut of the source and destination colorspaces differ a "gamut mapping" needs to be performed. Those colors that cannot be represented in the destination need to be altered to colors that can be represented.

If one is working with a company logo or any other object where it is important to preserve the colors colorimetrically, then one will want to colorimetrically match source colors to matching colors in the destination. For those colors that have no match some "closest possible" match should be found. This type of gamut mapping is called "colorimetric".

Experience has shown that colorimetric gamut mapping of pictures can be improved upon and so a "perceptual" method of gamut mapping is preferred for pictures. Usually these mappings make changes even to the colors that can be matched. The human visual system is more sensitive to relative color differences than it is to absolute differences so changing the mapping to preserve those differences yields better looking results.

When producing a business graphic or other schematic material, it may be more important to have the best solid saturated colors that a device can produce than to have an accurate color that the device produces in a poorly rendered way. So for these kinds of objects one uses a "saturated" gamut mapping.

There is a correspondence between gamut mapping methods and what has come to be called "rendering intents". More about rendering intents a little later.

The ICC has agreed to a basic set of four of rendering intents shown here. For the perceptual and saturated intents considerable latitude is allowed in the interpretation and implementation since no one has demonstrated a single best method to do the gamut mapping.

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Sequence number: 1
Author: jking
Date: 9/29/2001 11:28:43 AM
Type: Note

This sample page shows the need to have three of the classic rendering intents used on a single

page. The processing desired is object based. The logo requiring the best possible colorimetric mapping, the picture a perceptual mapping and the graph a saturated mapping.

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Sequence number: 1
Author: jking
Date: 9/29/2001 11:37:17 AM
Type: Note

This slide shows a simulation of what changes will take place in the appearance of the top original graduated shading when process through Adobe Photoshop using the intents listed.

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Sequence number: 1
Author: jking
Date: 9/29/2001 7:37:46 PM
Type: Note

With the ICC method for color management, the gamut mapping is accomplished by the color conversions being done and controlled by the source and destination profiles. Typically gamut mapping is performed when translating from the Profile Connection Space (PCS) to the destination colorspace. Different profile data is needed for different gamut mappings.
A minor dilemma arises because the gamut mapping or "rendering" is determined by the source objects yet effects the output profiles. We do not want to carry output profiles with our source data since that would tie that source to only one destination. Carrying a large variety of destinations is also not a good design. So a clever trick is used. We associate one of four "rendering intent" values with each source object. They tag the source objects as to which of the basic four gamut mappings is most appropriate for that object but do not specify anything further that might involve an output or destination device.
When this source material is finally converted to a particular destination device one of four different gamut mappings can be performed on any given object provided the output profile contains the data required to do any of four different gamut mappings. So, ICC output files do require four different sets of mapping data, one for each rendering intent. (Actually, since it is possible to obtaining one colorimetric mapping from the other only three independent sets of data are required.)

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Sequence number: 1
Author: jking
Date: 9/29/2001 7:40:03 PM
Type: Note

This diagram shows how the rendering intent chosen by the user effects the processing done by Photoshop while outputting an image to a printer. In this case, the whole Photoshop workspace is considered to be one object and it is all rendered with a single intent chosen by the user.

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Sequence number: 1
Author: jking
Date: 9/29/2001 7:41:12 PM
Type: Note

This diagram shows how color management and the various profiles and conversions are used to do what is typically called "soft proofing".
Soft proofing refers to producing an image on the monitor that closely resembles the gamut-reduced image that might be produced on a gamut limited output device (think CMYK printer).
The color values are first converted as if they were going to be sent to the printer, and then they are converted back to the monitor colorspace. During the conversion to the printer values, any important gamut mapping is performed. Then care is taken when converting those printer values to ones for the display not to do any further gamut mapping and thus preserving the reduction in gamut in the overall display.

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Sequence number: 1
Author: jking
Date: 9/29/2001 7:43:24 PM
Type: Note

So what do these color transformations really do and what are the controlling parameters provided by the ICC profiles?
For Cathode Ray Tubes (CRTs) the following 3x3 matrix conversions are quite good and form the basis for one version of ICC transformations.

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Sequence number: 1
Author: jking
Date: 9/29/2001 7:54:23 PM
Type: Note

CRTs are linear additive devices. That means that the RGB colors produced are done in a way that they do not interact with each other and that in a linear setup the values sent to the display can be added to predict the additive output.
Linear additive devices obey basic linear algebra so that color transformations can be done by simple linear (3x3) matrix transformations.
Since most real devices are not linear with respect to the CIE XYZ values the transformation algorithms used begin with a linearization step that converts the non-linear values to ones that are linear with respect to CIE XYZ. These linearizations are represented in the diagram by the component-wise boxes.
The linearized values are then fed into a 3x3 matrix that transforms the values between linear spaces.
The central portion of this diagram represents the PCS reference colorspace. The inverse operations are performed on output; the PCS values are linearly transformed and then adjusted to the non-linear output world.

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Sequence number: 1
Author: jking
Date: 9/29/2001 9:04:38 PM
Type: Note

Gamma adjustments and linearizations are transformation that usually look like the diagram shown. These stem from the fact that doubling the power sent on one of the signals to the CRT does not necessarily double the effect seen by the human visual system. Usually one has to more than double the power sent to the face of the CRT in order to double the effect on the human visual system.

The term "gamma adjustment" comes from the use of the greek mathematical symbol used in the formula to represent the curve:

out = in (to the power) gamma.

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Sequence number: 1
Author: jking
Date: 9/29/2001 7:59:08 PM
Type: Note

If you have read any material about color management you no doubt have encountered phrases like: "one can convert those color values by use of a 3x3 matrix". This refers to the fact that a matrix with three rows and three columns is a convenient way to represent the 9 coefficients needed for the linear conversion equations shown by example on this slide. The output value x is some weighted linear combination of the three inputs a, b and c. Likewise for the outputs y and z.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:00:27 PM
Type: Note

As noted earlier, the 9 values represented by both of the large boxes in this diagram are used to provide the coefficients to the linear equations used to do the conversions.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:05:57 PM
Type: Note

The device CMYK found in real life are far from linear additive colorspaces. The subtractive nature of CMY or CMYK colorspaces and the potentially complex interactions between the translucent ink drops placed on paper make these colorspaces very hard to model theoretically. Because of this the transformations to CMY or CMYK are usually done by table lookup.

Certainly, if one had the time and patience to build an exhaustive table mapping proper values of the CIE XYZ PCS colorspaces into the output colorspace, the proper results would be captured and the table could be used for conversions.

Since such tables can be excessively large, smaller tables are produced and interpolation is used to guess intermediate values not directly represented in the tables.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:08:00 PM
Type: Note

So this is the complete schematic diagram of the color conversion flow from an RGB device to a CMYK device. The PCS connection space is represented as CIE XYZ in this diagram.
A 3x3 matrix is used to convert the linearly additive RGB values into CIE XYZ and a table lookup is used to convert the CIE XYZ values into proper CMYK values.

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Sequence number: 1
Author: jking
Date: 9/29/2001 9:05:18 PM
Type: Note

The color of all white paper is not the same. We have all experience the realization of this as we notice that one piece of paper looks rather pink whereas another looks very bright and blueish.
There are a lot of issues revolving around what is white and what is black in color management systems. I believe that most of the problems in this area are created by oversimplification and misunderstandings. Here are some of the issues surrounding white and black:
The human visual system is always a relative adaptive system and hence adjust the sensation of white depending upon what appears to be the background white.
The paper white is often used as the image white and hence plays a role as one of the imaging inks. The other colors in the images may have to be adjusted to compensate for the white provided by the paper.
The white illumination determines what light is available to reflect off of a surface and so greatly influences the colors seen when looking at a reflective surface.
When viewing a CRT or other emissive display the white color provided as a reference by the surrounding environment effects the impression of colors on the CRT.
When converting from one colorspace to another the appearance of a neutral white or a neutral gray color is very important to the impression presented by the human visual system to the rest of the intelligent brain. It is often difficult in using one of the transformation systems to assure that what looks like a neutral color in one colorspace maintains that neutral look in the destination colorspace.

Page: 31

Sequence number: 1
Author: jking
Date: 9/29/2001 9:05:38 PM
Type: Note

Typical carriers of colored material through digital workflows are some of the Adobe defined data formats: PostScript and PDF.
Both of these file formats support the use of ever changing colorspaces and per object rendering intents.
They both support ICC model for color management. In fact, PostScript color management preceded the ICC developments and had a positive influence on the ICC architecture.

PDF and PostScript use different syntax and terminology for representing essentially what is the same data contained within an ICC profile. Both of these file formats treat input profiles and output profiles as different things whereas the ICC has profiles that contain data so that they can be used for input or output. In PDF a source profile is called a "Color Space Resource" or CSR.
In PostScript the source profiles are called "Color Space Arrays" or CSAs.
In PostScript an output profile is called a "Color Rendering Dictionary" or CRD.
There are more detailed technical differences but they are not important enough to detail here.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:26:34 PM
Type: Note

Here is an example of a page represented in PDF and PostScript and using different colorspaces for different objects drawn on the page.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:30:14 PM
Type: Note

This is the exact display of the PDF file that produced the preceding page.
Notice that the page description shown in the middle column refers to colorspace resources by name (e.g. /CS1) that are then defined in the page's resource object (3 0 obj) shown in the third column. Two colorspaces are defined, /CS1 is the L*a*b* colorspace and /CS2 is a calibrated RGB colorspace with gamma, 3x3 matrix and whitepoint values as shown.

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Sequence number: 1
Author: jking
Date: 9/29/2001 9:05:55 PM
Type: Note

These are just the other details needed to make all of this text a legitimate PDF file. If you were to copy all of the text out of this presentation and make a file out of it, when presented to a PDF viewer it would produce the page shown earlier.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:34:50 PM
Type: Note

In this example we show how a PDF file can include an ICC profile instead of its own CSR representation for defining a colorspace. The colorspace /CS2 is "/ICCBased" and refers to object 7 0 which literally contains the ICC profile as a stream of length 345 bytes.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:36:06 PM
Type: Note

This is the equivalent PostScript file that contains "setcolorspace" operators which accept CSAs. The CSAs are very similar to the PDF CSRs shown previously.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:37:17 PM
Type: Note

There are too many situations where the ICC workflows don't produce as good as results as one would hope for and rightfully expect. What accounts for these less than expected results?

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:37:53 PM
Type: Note

I have listed 5 areas where things can be improved.

Page: 40

Sequence number: 1
Author: jking
Date: 9/30/2001 6:07:09 AM
Type: Note

If someone mentions that your color data may have been quantized, then run the other direction.
This term has been inherited from the world of analog to digital conversion where analog data has to be broken in to digital representations with fixed precision and range and hence "quantized". However, in color management the term refers to what computer scientists would more likely call "truncation" or "loss of data".
It usually means dropping lower order (right most) digits in a result in order to allow the result to be represented in a certain number of binary digits.
It is somewhat unfortunate for color management that the computer industry standardized on the 8-bit byte as a basic computer storage and computational unit. With 8-bits one can represent or code 256 distinct values. For many situations 256 levels or colors or variations per color channel matches the human visual system reasonably closely.
However, if the coding of data into the 8-bit bytes is done without regard for the way that the values to be represented spread themselves out in a coding scheme the 8-bit representation can become very lossy when representing color values.
We would have seen far fewer bad color conversions had the computer industry standardized on

12-bit bytes or early color products had just use 16-bit values.

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Sequence number: 1
Author: jking
Date: 9/29/2001 8:49:10 PM
Type: Note

Since the most notorious color gamut compressions involve reducing the total number of colors that can be represented going back to the original values is usually impossible. What has been lost is lost.

So it is best to delay any steps where gamut compression can occur to avoid reducing the gamut of the data we have. It must be done for output to gamut reduced devices but it is best to reduce your data in this way only in the last step.

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Sequence number: 1
Author: jking
Date: 9/29/2001 9:06:22 PM
Type: Note

The International Color Consortium (ICC) is now a group of more than 60 companies working on and agreeing to a standard profile specification, and implicitly through that, agreeing to a standard way in which to perform color management and color conversion.

The clarity of the agreements hasn't always been perfect and the specification has several places where the explanation and wording can be greatly improved. The ICC is working on this and will soon come out with a revised specification that is much improved.

There is also other more long term work being done within the ICC to change some of the fundamental assumptions of the current architecture with hopes of making bigger advancements. This is also work in progress.

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Sequence number: 1
Author: jking
Date: 9/29/2001 9:06:41 PM
Type: Note

It is both surprising and expected that some programmers don't do a very good job of having the programs that they produce to good arithmetic. Any time when one does computation on a computer she has to worry about loss of significance and magnified error creeping into our computations.

In the early days of computer development "numerical analysis" was a strong discipline where one learned in excruciating detail how to do computations that maintain the maximum amount of useful information.

People writing color management software should at least pay a passing glance at this older establish discipline.

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Sequence number: 1
Author: jking
Date: 9/29/2001 9:06:48 PM
Type: Note

Interpolation is a simple process of guessing a result value intermediate between two know values. For smooth functions this is a very effective way to reduce table sizes when functions are to be computed by simply looking up the proper answer in a table. For many functions the table would be required to have an impractical number of entries so tables with fewer entries are provided and the smoothness of the function is relied upon to make computation of intermediate results meaningful.
However, given that rounding and/or truncation are used to make the table values, and then averaging calculations are made to determine intermediate values it becomes clear that the table entries have to be represented to a higher precision than that required of the output.
This is an observation that has generally been overlooked by the ICC and others and if corrected could result in slightly more precise results.

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Sequence number: 1
Author: jking
Date: 9/30/2001 4:20:12 AM
Type: Note

Many of the pages or screen views that are created are made from many individual elements. They are compound documents. What if each of the contributing elements have been created with their own different colorspace?
This diagram shows how this is typically handled in Photoshop. Photoshop maintains the idea of a working colorspace and as each contributing element is opened and included into the final document, it is converted to the working colorspace.
Each input is expected to come with its own appropriate input profile and the profile associated with the working colorspace is used as the output or destination for the color transformation.

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Sequence number: 1
Author: jking
Date: 9/30/2001 4:24:28 AM
Type: Note

In a layout application like PageMaker, a different strategy is possible. All conversions are deferred and the colorspace and associated profile are kept with each element.
As the document is being displayed on the monitor many different color transformations are setup, one for each different element of the compound document.

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Sequence number: 1
Author: jking
Date: 9/30/2001 4:27:54 AM

Type: Note

During the output of the final document all element may then be converted to a common output colorspace as shown here.

Or if the output device is a PostScript device the compound document, including all of its various input profiles can be sent on to allow the colorspace conversions to be done within the PostScript device.

Notice that each element of the compound document has a rendering intent associated with it. This allows each of the elements to chose the appropriate type of gamut mapping from the output profile.

Page: 50

Sequence number: 1
Author: jking
Date: 9/30/2001 6:07:24 AM
Type: Note

At the start of this talk we tried to emphasize that color management is a requirement because devices produce color differently and require different color values to produce similar results. This part seems inevitable.

However, we seem to be pushing too much of the work needed to accomplish color management onto the computer user.

Let me give you an analogy. Early automobiles had a lever that the driver had to adjust that is no longer seen on automobiles today. It was called a spark advance. The exact timing of when the spark plug is to fire and cause the gasoline to explode in each engine cylinder has to be adjusted depending upon how fast the engine is running and upon how much load is being drawn from the engine.

Drivers of early cars had to learn the exactly how to set this spark advance as the car is accelerating, decelerating and especially when starting the engine.

The fact that drivers no longer use these controls isn't that the spark doesn't need advancing on modern engines. It just means that engineers have figured out how to do the spark advance automatically and more accurately than the human driver can do it.

We need to find which of the various things we are asking our computer users to do with respect to color management are to become spark advances. Which things can we do in our systems automatically and better than the user can?

Page: 51

Sequence number: 1
Author: jking
Date: 9/30/2001 6:07:27 AM
Type: Note

Our color management strategy may have things backward. It is designed around the notion that documents use the colorspace of some display or printing device.

When that document is to be displayed on some other different display or printer it must be completely transformed.

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Sequence number: 1
Author: jking
Date: 9/30/2001 6:00:17 AM
Type: Note

A classic design decision is when two things are related to one another which one is the base and which one is the modification.

Page: 53

Sequence number: 1
Author: jking
Date: 9/30/2001 6:03:33 AM
Type: Note

I believe that a model that would be more intuitive for people is to have our documents be fixed using some universal standard colorspace. When viewing or printing this document on some particular device a temporary translation is made for that purpose but then discarded. The original standard document is always the one we work from.

There are considerable technical barriers to making such a system work since we now feel compelled to make adjustments to device specific representations, but if such a system were to be made workable it should be much more easily understood and controlled.

Page: 54

Sequence number: 1
Author: jking
Date: 9/30/2001 6:04:17 AM
Type: Note

Inherent in this idea is the requirement for a universal colorspace with the properties noted on this slide.

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Sequence number: 1
Author: jking
Date: 9/30/2001 6:05:33 AM
Type: Note

One of the difficulties in making this model work is if editing is allowed in one of the device representations, then how is this editing reflected back into the document that uses the universal colorspace.

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Sequence number: 1
Author: jking
Date: 9/30/2001 6:06:23 AM
Type: Note

Thanks for staying with me. I hope you found this session educational. I certainly learned a great deal preparing it.

Jim King--June 25, 2001.