everywhere you look

Adobe
Why Color Management?

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Outline

- Introduction to Color Management
- Basics of Conversions
- Color workflow issues
- Conversion Glitches
  - Where do things go wrong?
- A user’s perspective -- Some thoughts on a better way
Introduction to
Color Management

Just the basics
The Root Issue

Devices Do Color Differently
Consistency

Same results require different values

Conversion of values

Numbers

Numbers
Consistency

- Same values produce different colors
- Same colors require different values
Color Value Conversions

- **Transform:**
  - Table and interpolations
  - Device model formulae
The n by m Problem

- (n x m) Transforms required
  - Both source and destination must be known for each

n Sources    m Destinations
Device Independence

- \((n + m)\) not \((n \times m)\) Transforms
  - Each source and destination handled independently

A Standard

\(1\) \(2\) \(\vdots\) \(n\) Sources

\(1\) \(2\) \(\vdots\) \(m\) Destinations
Basic ICC Diagram
(International Color Consortium)

- Composite conversion “compiled”
- ICC Profiles define colorspace

Source Profile (Colorspace Definition) → Color Matching Method (CMM) → Destination Profile (Colorspace Definition)

Source Color Values → Profile Connection Space (PCS) → Destination Color Values
Photoshop: Basic Workflow

- Monitor profile supplied by system
- Workspace profile set by user
Rendering Intents

- "gamut mapping"
  - Destination colorspace "smaller" than source colorspace
  - Shrinking the range of colors in an object
Gamut Differences

RGB (Original)

CMYK (Photoshop Swop Coated)
Gamut Mapping

- Four situations identified
  - Perceptual (pictures)
  - Saturated (graphics)
  - Relative Colorimetric (logos)
  - Absolute Colorimetric (strict conversions)
Rendering Requirements

Logo-Colorimetric

Graph-Saturated

Picture-Perceptual
Rendering Intents

- RGB Original
- CMYK-Perceptual
- CMYK-Saturated
- CMYK-Relative Colorimetric
- CMYK-Absolute Colorimetric
Rendering Intents

- Intent is property of the source
- Action happens during output
Rendering Intents

- Monitor profile supplied by system
- Workspace profile set by user

- Two way conversions while displaying and editing

- Sent to Imagesetter, Proofer or Desktop Color Printer
Soft Proofing

- What would it look like on my printer
Basics of Conversions
Device Models

- e.g., CRT Displays
Device Models (CRTs)

- Linear Additive Devices

1-IN 1-OUT
Component Modification

3-IN 3-OUT
Linear Transform

1-IN 1-OUT
Component Modification

3-IN 3-OUT
Linear Transform
Single Component

- Things like Gamma adjustments
- “Linearize” the components

1-IN 1-OUT Component Modification
The Famous 3x3

3-IN 3-OUT Linear Transform

\[
\begin{pmatrix}
1.0 & 1.4 & 0.8 \\
0.0 & 2.5 & 0.6 \\
1.3 & 1.4 & 1.3
\end{pmatrix}
\]

3 x 3 Matrix

x = 1.0 \cdot a + 1.4 \cdot b + 0.8 \cdot c
y = 0.0 \cdot a + 2.5 \cdot b + 0.6 \cdot c
z = 1.3 \cdot a + 1.4 \cdot b + 1.3 \cdot c
Device Models (CRTs)

- Linear Additive Devices

1-IN   1-OUT
Component Modification

3-IN   3-OUT
Linear Transform

1-IN   1-OUT
Component Modification

3-IN   3-OUT
Linear Transform
Table Lookup

- E.g., Printers

1-IN 1-OUT
Component Modification

3-IN 4-OUT
Lookup Table
White & Black Points
Color Workflow Issues
Both PostScript and PDF have what it takes

- **PostScript**
  - Color Space Arrays (CSA) -- source profiles
  - Color Rendering Dictionaries (CRD) -- destination profiles
  - No direct support for ICC profiles but converters available

- **PDF**
  - Color Space Resources (CSR) -- source profiles
  - No destination profiles
  - Supports ICC profiles as option in addition to PostScript like source profiles

- **Both support**
  - Intents
  - Compound documents -- multiple colorspace per page/document
Star -- **filled** with L*a*b* Yellow  ///  Star -- **stoked** with Calibrated RGB Blue

---

2 0 obj
<< /Length 51 >>
stream
BT
/F1 24 Tf
1 0 0 1 260 600 Tm
/CS1 cs
63 127 127 sc
(Hello World)Tj
ET
ENDSTREAM
endstream
endobj

---

3 0 obj
<< /ProcSet[/PDF/Text] /Font <</F1 4 0 R>> /ColorSpace
<</CS1
[ /Lab << /Range
[-128 127 -128 127]
/WhitePoint
[ 0.951 1 1.089]
>> ] >>
<</CS2
[ /CalRGB <<
/Gamma
[2.222 2.222 2.222]
/Matrix
[0.412 0.213 0.019
0.358 0.715 0.119
0.181 0.072 0.951]
/WhitePoint
[0.951 1 1.089]
>> ] >>
>>
endobj
Star -- **filled** with L*a*b* Yellow  ///  Star -- **stroked** with Calibrated RGB Blue

```plaintext
4 0 obj
<<
/Type /Font
/Subtype /Type1
/Name /F1
/BaseFont/Helvetica
>>
endobj

6 0 obj
<<
/Type /Catalog
/Pages 5 0 R
>>
endobj

5 0 obj
<<
/Type /Pages
/Kids [ 1 0 R ]
/Count 1
/MediaBox
[ 0 0 612 792 ]
>>
endobj
```
Star -- filled with L*a*b* Yellow /// Star -- stroked with Calibrated RGB Blue

2 0 obj
<< /Length 51 >>
stream
BT
/F1 24 Tf
1 0 0 1 260 600 Tm
/CS1 cs
63 127 127 sc
(Hello World)Tj
ET

100 0 127 sc

/CS2 CS
0 0 1 SC
315 572 m
299 528 l
339 554 l
291 554 l
331 528 l
b
endstream
endobj

3 0 obj
<< /ProcSet[/PDF/Text]/Font <</F1 4 0 R>>
/ColorSpace
<</CS1
[ /Lab << /Range
[-128 127 -128 127]
/WhitePoint
[ 0.951 1 1.089]
>> ] >>

<</CS2
[/ICCBased 7 0 obj]
>>

>>
endobj

7 0 obj
<</Length 345
/N 3 >>
stream
... (ICC Profile) ...
endstream
endobj

Example 08
A PostScript File Equivalent to Example 8

%!PS
% PostScript file that generates same output as example 08

Helvetica findfont
24 scalefont setfont
260 600 moveto

/CIEBasedABC <<
/RangeABC
[0 100 -128
127 -128 127]
/DecodeABC
[16 add 116 div]
bind {500 div}
bind {200 div}
bind
/MatrixABC
[1 1 1 1 0 0 0 0 -1]
/DecodeLMN
[{dup 6 29 div ge
{dup dup mul mul}
{4 29 div sub 108
841 div mul} ifelse
841 div mul} ifelse}
bind
{dup 6 29 div ge
{dup dup mul mul}
{4 29 div sub 108
841 div mul} ifelse}
bind
{dup 6 29 div ge
{dup dup mul mul}
{4 29 div sub 108
841 div mul} ifelse
1.0890 mul} bind
{dup 6 29 div ge
{dup dup mul mul}
{4 29 div sub 108
841 div mul} ifelse
0.9505 mul} bind
{dup 6 29 div ge
{dup dup mul mul}
{4 29 div sub 108
841 div mul} ifelse
1.0890 mul} bind
/WhitePoint
[0.9505 1 1.0890]
>>
setcolorspace
63 127 127 setcolor
(Hello World) show

100 0 127 setcolor
315 572 moveto
299 528 lineto
339 554 lineto
291 554 lineto
331 528 lineto

gsave

fill

grestore

/CIEBasedABC <<
/DecodeLMN
[{1 0.45 div exp}
bind dup dup]
/MatrixLMN
[0.412 0.213 0.019
0.358 0.715 0.119
0.181 0.072 0.951 ]
/WhitePoint
[0.9505 1 1.0890]
>>
setcolorspace
0 0 1 setcolor

Example 08.ps
closepath
true setstrokeadjust
\textcolor{red}{stroke}

showpage
Conversion Glitches

Where do things go wrong?
Limited Places for Error

- Quantization (truncation)
- Gamut compression
- White Point/Black Point Compensation
- Bad arithmetic
- Interpolation errors
Quantization

- 8-bits isn’t really enough
  - No room for mistakes
  - Some colorspaces not spaced right

- Move to 16-bits per component
  - It only doubles color value sizes
Gamut compression

- Avoid it
- Delay it
- Do it only once at the end
White Point/Black Point

- ICC Specification hasn’t been clear
- Change ICC model
  - To be more like PostScript
Bad arithmetic

- Don’t do it
- Get help
Interpolation errors

- Adjust table size for more accuracy
- Tables need fractional values
  - Get ICC to change
Compound Documents

It gets complicated!
Compound Documents
(more than one colorspace)

- Photoshop

Embeded input profiles

Monitor profile

Two way conversions while displaying and editing

Working Colorspace

Source Color Values

One time conversions upon input

Workspace profile
Compound Documents
(more than one colorspace)

- PageMaker
Compound Documents
(more than one colorspace)

- PageMaker or In the RIP

Each Object may have its own intent

Compound Document

Individual Objects (each with own colorspace)

Printer Color Values

Sent to Imagesetter, Proofer or Desktop Color Printer

Printer profile

Rendering Intents

Each Object may have its own intent
A User’s View

And some thoughts on a better model
A User’s View

- What does a user want?
  - This red color
  - What is a colorspace?
  - Why do I care?

- Users don’t ask for:
  - a monitor colorspace
  - an ICC profile

- They just want this red
Now is Device Centric

- We move colors through device colorspaces
We have it backwards!

- Should A slide over B
- Or should B slide under A
Fixed Colored Data
Just have Windows onto it

- Only Change the view of it

Device 1  Device 2  Device 3  Device 4

Adobe  Adobe  Adobe  Adobe

On the fly Transforms  On the fly Transforms

One Fixed Object
Fixed Colored Data

- A universal colorspace
  - Extend the idea of workspace
- All colors visible by humans
- Enough bits to allow flexibility
  - Precision
  - Range
Homework

- How do you edit using this model?
everywhere you look

Adobe