joshua pines
chief trouble maker and luddite
technicolor digital intermediates

“…from scene to screen…”

color enhancement and rendering
in film and game production

siggraph july27, 2010 los angeles, california
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Cave painting, Lascaux, France, 15,000 to 10,000 B.C.
real world dynamic range

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camera acquisition dynamic range

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display dynamic range

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2001: A SPACE ODYSSEY
### Real World Dynamic Range

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first approach - 
scale full acquisition dynamic range into display dynamic range
### Real World Dynamic Range

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marcie - 10 bit log film scan
exr -> 10bit log conversion
marcie - converted to “radiometric linear”
“typical” display response
compensation for display response
marcie - converted to “radiometric linear”
full range acquisition scaled to display dynamic range (and gamma corrected)
second approach -
extract display’s dynamic range
from full acquisition dynamic range
### Real World Dynamic Range

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### Display Dynamic Range
match display dynamic range instead of full acquisition dynamic range
full range acquisition scaled to display dynamic range (and gamma corrected)
match display dynamic range from acquisition preserving relative intensities
limiting to the display’s dynamic range while preserving relative intensities is an improvement - but still looks “low contrast” - why?
limiting to display’s dynamic range while preserving relative intensities is an improvement - but still looks “low contrast” - why?

- stevens effect - perceived contrast decreases at lower luminance
- hunt effect - perceived “colorfulness” also decreases at lower luminance
limiting to display’s dynamic range while preserving relative intensities is an improvement - but still looks “low contrast” - why?

- stevens effect - perceived contrast decreases at lower luminance
- hunt effect - perceived “colorfulness” also decreases at lower luminance
- display flare characteristics reduce contrast - sequential contrast vs. simultaneous contrast
limiting to display’s dynamic range while preserving relative intensities is an improvement - but still looks “low contrast” - why?

- stevens effect - perceived contrast decreases at lower luminance
- hunt effect - perceived “colorfulness” also decreases at lower luminance
- display flare characteristics reduce contrast
- bartleson-breneman effect - a “dark” surround decreases perceived contrast
“normal surround” - (office)

“dim surround” - (living room)

“dark surround” - (theatrical)
“normal surround” - (office)
display gamma = 2.2

“dim surround” - (living room)
display gamma = 2.4

“dark surround” - (theatrical)
display gamma = 2.6
limiting to display’s dynamic range while preserving relative intensities is an improvement - but still looks “low contrast” - why?

- stevens effect - perceived contrast decreases at lower luminance
- hunt effect - perceived “colorfulness” also decreases at lower luminance
- display flare characteristics reduce contrast
- bartleson-breneman effect - a “dark” surround decreases perceived contrast
solution - increase contrast!
match display dynamic range from acquisition preserving relative intensities
match display dynamic range
add contrast (1.25 - 1.50)
...but now we’ve added clipping artifacts

- add “toe” and “shoulder” to reduce clipping artifacts
- ...which also brings back some shadow and highlight detail
solution - increase contrast + add toe and shoulder (the infamous “S-curve”)
display dynamic range + add contrast (1.25 - 1.50)
display dynamic range + add contrast +
add toe and shoulder
display dynamic range + add contrast
+ add toe and shoulder (b&w)
real film print emulation (b&w)
i cheated - this “simple S-curve” is the real film emulation tone mapping curve
display dynamic range + add contrast +
add toe and shoulder (b&w)
real film print emulation (b&w)
display dynamic range + add contrast +
add toe and shoulder
real film print emulation
a little color science never hurt anybody...
\[ x = \frac{X}{X + Y + Z} \]
\[ y = \frac{Y}{X + Y + Z} \]
\[ z = \frac{Z}{X + Y + Z} = 1 - x - y \]
Figure 5. Color gamut comparison of real-world objects with color gamut of various technologies.
display dynamic range + add contrast +
add toe and shoulder
real film print emulation
mapping “middle grey” from scene to display
0.18 -> 0.10

1.0 (max display white)

0.10 (~3.33 stops below max display white)

display “black”

1.0 (100% diffuse reflector)

0.18 (18% diffuse reflector
~2.5 stops below 1.0)
ASC “STeM” movie
”standard evaluation material”
ASC “STeM” movie
mean rgb linear intensity = 0.11  0.09  0.11
mapping “middle grey” from scene to display

0.18 ➔ 0.10

1.0 (max display white)

0.10 (~3.33 stops below max display white)

0.004 (8 stops below max display white)

1.0 (100% diffuse reflector)

0.18 (18% diffuse reflector ~2.5 stops below 1.0)
how to build your own rendering transform
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
- place a "middle gray" 0.18 diffuse reflector "gray card" in scene
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
- place a "middle gray" 0.18 diffuse reflector "gray card" in scene
- scale image accordingly (i.e. "properly set the scene exposure")
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
- place a "middle gray" 0.18 diffuse reflector "gray card" in scene
- scale image accordingly (i.e. "properly set the scene exposure")
- transform to log
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
- place a "middle gray" 0.18 diffuse reflector "gray card" in scene
- scale image accordingly (i.e. "properly set the scene exposure")
- transform to log
- choose dynamic range of "interest" (requires knowledge of display)
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
- place a "middle gray" 0.18 diffuse reflector "gray card" in scene
- scale image accordingly (i.e. "properly set the scene exposure")
- transform to log
- choose dynamic range of "interest" (requires knowledge of display)
- increase contrast in log space around middle gray (log(0.18))
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
- place a "middle gray" 0.18 diffuse reflector "gray card" in scene
- scale image accordingly (i.e. "properly set the scene exposure")
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- choose dynamic range of "interest" (requires knowledge of display)
- increase contrast in log space around middle gray (log(0.18))
- add toe and shoulder to taste (requires knowledge of display)
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
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- darken saturated colors to taste (i.e. to emulate subtractive-color reproduction)
how to build your own rendering transform

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- transform back to lin
how to build your own rendering transform

- light scene with cgi linear-light (or obtain linear-light image)
- place a "middle gray" 0.18 diffuse reflector "gray card" in scene
- scale image accordingly (i.e. "properly set the scene exposure")
- transform to log
- choose dynamic range of "interest" (requires knowledge of display)
- increase contrast in log space around middle gray (log(0.18))
- add toe and shoulder to taste (requires knowledge of display)
- darken saturated colors to taste (i.e. to emulate subtractive-color reproduction)
- transform back to lin
- xform to display space - mapping 0.18 to 0.10 of display maximum
traditional film workflow
“real world” on-set scene → original film negative elements → traditional film colour correction → film positive release prints → film projection
colour grading optical system

Color grading optical system. Schematic view.
colour grading optical system
“ppt” secret decoder ring
“ppt” secret decoder ring

“…i never met a data i didn’t like…”
print +0.0 stops
print -2.0 stops
print -1.5 stops
print -1.0 stop
print -0.5 stop
print +0.0 stops
print +0.5 stop
print +1.0 stop
print +2.0 stops

KODAK Digital LAD Test Image
digital intermediate workflow
“null” colour correction
“bleach bypass” colour correction
(extreme hicon + desat)
Idealized System
scene space vs. display space
scene space vs. display space

- “input referred”
- “output referred”
scene space vs. display space

- “input referred”
- cgi "rendering"
- “output referred”
- photoshop
scene space vs. display space

- “input referred”
-cgi "rendering"
- the laws of physics

- “output referred”
- photoshop
- the talents of artists
scene space vs. display space

- “input referred”
- cgi "rendering"
- the laws of physics
- high dynamic range

- “output referred”
- photoshop
- the talents of artists
- limited dynamic range
scene space vs. display space

- “input referred”
- cgi "rendering"
- the laws of physics
- high dynamic range
- 18% diffuse reflector

- “output referred”
- photoshop
- the talents of artists
- limited dynamic range
- 10% of max intensity
scene space vs. display space

- “input referred”
-cgi "rendering"
-the laws of physics
-high dynamic range
-18% diffuse reflector
-werewolves(powerful)

- “output referred”
-photoshop
-the talents of artists
-limited dynamic range
-10% of max intensity
-vampires(sexy)
real film print emulation
vampire film print emulation
The End