Color and the Display of Information:

Yes, this is still Computer Science

Mike Bailey
mjb@cs.oregonstate.edu
Oregon State University

What's Wrong with this Picture?

Source: Scientific American, June 2000
Physiology of the Human Eye

Rods

- ~115,000,000
- Concentrated on the periphery of the retina
- Sensitive to intensity
- Most sensitive at 500 nm (~green)

Cones

- ~7,000,000
- Concentrated near the center of the retina
- Sensitive to color
- Three types of cones: long (~red), medium (~green), and short (~blue) wavelengths
What Makes a Good Contrast?

- Many people think that simply adding color onto another color makes a good contrast
- In fact, a better measure is the $\Delta$ Luminance
Color Alone Doesn’t Cut It!

I sure hope that my life does not depend on being able to read this quickly and accurately!

Luminance Contrast is Crucial!

I would prefer that my life depend on being able to read *this* quickly and accurately!
The Luminance Equation

\[ Y = 0.30 \times \text{Red} + 0.59 \times \text{Green} + 0.11 \times \text{Blue} \]

Luminance Table

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>G</th>
<th>B</th>
<th>Y</th>
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<tr>
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<tr>
<td>Green</td>
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<tr>
<td>Blue</td>
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<td>1.0</td>
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<tr>
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<td>1.0</td>
<td>0.70</td>
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<tr>
<td>Magenta</td>
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<td>0.41</td>
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<tr>
<td>Orange</td>
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<td>0.5</td>
<td>0.0</td>
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<tr>
<td>Yellow</td>
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### Contrast Table

<table>
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<th>Green</th>
<th>Blue</th>
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<th>Magenta</th>
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<th>Yellow</th>
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<td>0.41</td>
<td>0.60</td>
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<td>0.70</td>
<td>0.41</td>
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Do Not Attempt to Fight Pre-Established Color Meanings

Red:
- Stop
- On
- Off
- Dangerous
- Hot
- High stress
- Oxygen
- Shallow
- Money loss

Green:
- On
- Plants
- Carbon
- Moving
- Money

Blue:
- Cool
- Safe
- Deep
- Nitrogen

What in the World was The Oregonian Thinking When They Chose This Color Scale?

Source:
The Oregonian, January 11, 2006

Shouldn’t lush-green colors represent wet and sand-colors represent dry?
This one is better

Source:
The Oregonian, October 31, 2006

Not a bad choice of colors, but the Dynamic Range needs some work
Be Aware of Color Vision Deficiencies (CVD)

- There is actually no such thing as “color blindness”
- CVD affects ~10% of Caucasian men
- CVD affects ~4% of non-Caucasian men
- CVD affects ~0.5% of women
- Most common type of CVD is red-green
- Blue-yellow also exists

Q: Why are more men affected by CVD than women?

A: A common CVD is carried on the X Chromosome

http://www.bio.miami.edu/~cmallery/150/mendel/c7.15.X.Y.jpg
Be Aware of CVD: Code Information Redundantly

Four score and seven years ago, our forefathers brought forth upon this continent a new nation...

Four score and seven years ago, our forefathers brought forth upon this continent a new nation...

Four score and seven years ago, our forefathers brought forth upon this continent a new nation...

Use a Black or White Line as the Boundary Between Colored Regions
Do Not Display Fast-moving or High-detail Items in Color, Especially Blue

Watch the Use of Saturated Reds and Blues Together

Reds and Blues are on opposite ends of the color spectrum. It is hard for your eyes to focus on both.
Be Aware of the Difference in Color Gamuts between a Monitor and a Color Printer (and a Projector)

I’m really happy that analog video is on its way out!

NTSC Cycles-of-Encoding per Scanline

<table>
<thead>
<tr>
<th>What</th>
<th>Cycles/Scanline</th>
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<tbody>
<tr>
<td>Intensity</td>
<td>267</td>
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<tr>
<td>Orange-Blue</td>
<td>96</td>
</tr>
<tr>
<td>Purple-Green</td>
<td>35</td>
</tr>
</tbody>
</table>
Sometimes You Have to Try Goofy Color Experiments Just Because You Can

Beware of Lots of Other Stuff
The Ability to Discriminate Colors Changes with Surrounding Color
Afterimages
Afterimages

Beware of Mach Banding
Beware of Mach Banding

Actual Intensity

Perceived Intensity

Beware of Mach Banding

Perceived Intensity

Actual Intensity