Vision, Color, and Illusions

Vision: How we see…

- The human eye allows us to see colors from red (low frequency) through violet (high frequency).
- Light passes through the front of our eye and focuses onto the retina.

One of many optical illusions…
- http://www.physics.uc.edu/~sitko/LightColor/19-Perception/19-Perception.htm
The Eye: Overall structure…

Some parts of the eye…

- Light comes in through the cornea and crystalline lens to reach the retina.
- Brightness and color are detected respectively by the rods and cones on the retina.
- The fovea has the highest concentration of cones.  
  - an inspiration for the name of the Foveon sensor perhaps
- The iris opens/closes the pupil to determine how much light gets through.
- The lens can change its shape to help focus.  
  - some small camera lenses do this with liquid lenses
Rods and Cones

The human eye has approximately 120 million rods but fewer than 10 million cones (between 6 and 8 million).
- This makes a question such as “how many megapixels does the human eye have” a tricky one.

There are three types of cones, each with a sensitivity to light of a different wavelength (short, medium, long). They are essentially red, green, and blue. We have around twice as many red cones and green, and around eight times as many green as blue.

Eye -vs- Camera

The cornea, crystalline lens, and ciliary muscles can be seen as the lens and focal ring on a camera.

The iris and pupil can be seen as the diaphragm and aperture on a camera.

The rods and cones on the retina can be seen as the sensor or film inside the camera body.
How colors are captured and created…

Recall that most digital camera sensors are built so that each photosite captures a value in one color channel (red, green, or blue).

– The most common pattern is the Bayer pattern.

The “missing” pixels in each color are filled in using algorithms to make a mathematically intelligent guess at what shade of the color in that spot would be based on the shades of the pixels around it.

– The three monochromatic images are then combined to create a single, full-color image.

Base 2, Base 10, Base 16

Information is generally stored on digital media as binary information (base 2).

– Values are often represented using hexadecimal (base 16) to make things more human-readable (you can represent 4 bits of information using a single hexadecimal digit). A collection of 8 bits (a byte) is a common group size.

When we encounter terms such as “24 bit RGB color” that means that 24 bits (0/1 values) are available for use in representing the color.

– These bits are typically distributed as 8 for RED, 8 for GREEN, and 8 for BLUE even though our eyes do not perceive all three colors with the same ranges.
Example from dpreview.com:

As you can see, the combined image isn't quite what we'd expect but is sufficient to distinguish the colors of the individual items in the scene. If you squint your eyes or stand away from your monitor your eyes will combine the individual red, green, and blue intensities to produce a (dim) color image.

Example for specific camera at https://www.dpreview.com/reviews/sigmasd10

### Pointillism

Seurat used additive color theory to create one of the best-known neo-impressionist works.

*Un dimanche après-midi à l'Ile de la Grande Jatte*
Interpolation

If there is an information gap between two dots, our brain can interpolate what it thinks it should see there.

– In digital image processing, in addition to the earlier sensor-to-photo example, this same type of operation can smooth out what might otherwise be a jagged curve or blocky image when enlarging a picture.

Some Interpolation Algorithms

Nearest neighbor: a “missing” pixel’s color will simply be a copy of the exact color from a neighboring pixel.

Bilinear interpolation: a “missing” pixel’s color can be generated using the average of the colors of the pixels immediately above, below, left, and right of it.

Bicubic interpolation: a “missing” pixel’s color can be generated by taking the weighted average of the colors of the pixels in a 4x4 grid around it.

• Example approach for dealing with the Bayer filter’s data.
## Perception: HSL

Colors can also be described in terms of the **hue** (pure base color), **saturation** (how “thick” the color should be), and **luminosity** (brightness of the color).

- This can be a useful way to think about colors if you want to be able to say something such as “make it a little brighter”.

You can easily convert between HSL and RGB using mathematical formulas.

- Note: A red hue with 0 luminance and a blue hue with 0 luminance are both going to appear as black.

## “Primary Colors”: YRB

The color system associated with mixing paint.

- This is generally an example of a subtractive color system like CMY used by many color printers, and unlike RGB which is additive.

Why do you think neither monitors nor printers use this color system?

- Let’s do some quick online research…
How We Perceive

When we look at an image, our eyes and brain have a large amount of data to process (estimates are in the hundreds of megapixels range).

- Many optical illusions and visual effects are achieved by understanding how the brain processes visual information (e.g. how it interprets light and shadow, how it views colors within different contexts).
- Consider the two button images here:

```
  UP
  DN
```
- One is a “depressed” button. The other is not. Why?

Optical Illusions: Color

In the picture below, the cell with the A in it and the cell with the B in it have the same background color.

http://persci.mit.edu/gallery/checkershadow

I still can not convince my eyes of this, even done as a video.

http://www.youtube.com/watch?v=z9Sen1HTu5o
Photomosaics

We can make use of how we see colors, how context affects perception, how our eyes can interpolate information, and how distance can cause blur to create an interesting type of optical illusion.

- Imagine taking each pixel of an image and replacing it with an image whose overall color scheme roughly matches that one pixel’s color.

www.cs.umd.edu/~egolub/HDCC208N/TestudoMosaic.html

Perspective matters...

Found on many web pages.
Not sure where the original is.
Search on: rooms painted to look 3d
Some resources:

http://www.photo.net/photo/edscott/vis00010.htm
http://wfc3.gsfc.nasa.gov/MARCONI/sensitive.html
http://www.visionchannel.net/anatomy.shtml
http://www.rgbworld.com/color.html
http://www.cecs.csulb.edu/~jewett/colors/index.html
http://www.quadibloc.com/other/cfaint.htm
http://www.clarkvision.com/imagedetail/eye-resolution.html
http://www.cem.msu.edu/~reusch/VirtTxtJml/Spectrpy/UV-Vis/spectrum.htm
http://www.physics.uc.edu/~sitko/LightColor/19-Perception/19-Perception.htm
https://www.amazon.com/Photomosaic-Mona-Lisa-Jigsaw-Puzzle/dp/B000S0VL4Q
http://www.nikon.co.jp/main/eng/feelnikon/kumon/11e.htm
https://www.youtube.com/watch?v=UhDPWtCEa7U
http://www.technologyreview.com/computing/21449/