

Images and Color

Multimedia Systems (Module 1 Lesson 2)

Summary:

- Basic concepts underlying Images
- Popular Image File formats
- Human perception of color
- Various Color Models in use and the idea behind them

Sources:

- Course text
- Dr. Ze-Nian Li's course material at:
<http://www.cs.sfu.ca/CourseCentral/365/li/>
- Follow this link for a great read on color:
<http://www.adobe.com/support/techguides/color/colortheory/>

Graphics: Terminology

- **Pixels** -- picture elements in digital images
- **Image Resolution** -- number of pixels in a digital image (Higher resolution always yields better quality.)
 - Most common Aspect ratio: 3:4 (lines:columns)
- **Bit-Map** -- a representation for the graphic/image data in the same manner as they are stored in video memory.
- **Bits/pixel** - also contributes to the quality of the image

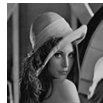
Monochrome vs. Grayscale

Monochrome:

- Each pixel is stored as a single bit (0 or 1)
- A 640 x 480 monochrome image requires 37.5 KB of storage.

Grayscale:

- Each pixel is usually stored as a byte (value between 0 to 255)
- A 640 x 480 grayscale image requires over 300 KB of storage.



Dithering

Dithering is often used for displaying monochrome images

- Creating the illusion of new colors and shades by varying the pattern of dots. Newspaper photographs, for example, are dithered. If you look closely, you can see that different shades of gray are produced by varying the patterns of black and white dots. There are no gray dots at all. The more dither patterns that a device or program supports, the more shades of gray it can represent.
- In printing, dithering is usually called **halftoning**, and shades of gray are called halftones. Note that dithering differs from gray scaling. In gray scaling, each individual dot can have a different shade of gray.

Color Images (24 vs. 8 bit)

24-bit:

- Each pixel is represented by three bytes (e.g., RGB)
- Supports 256 x 256 x 256 possible combined colors (16,777,216)
- A 640 x 480 24-bit color image would require 921.6 KB of storage
- Many 24-bit color images are stored as 32-bit images, the extra byte of data for each pixel is used to store an alpha value representing special effect information

8-bit:

- One byte for each pixel
- Supports 256 out of the millions colors possible, acceptable color quality
- Requires Color Look-Up Tables (LUTs) -- *Palette*
- A 640 x 480 8-bit color image requires 307.2 KB of storage (the same as 8-bit grayscale)



← 24-bit color
(60KB jpeg)

8-bit color
(30KB gif) →



System Independent Formats

GIF(GIF87a, GIF89a):

- Graphics Interchange Format (GIF) devised by the UNISYS Corp. and CompuServe, initially for transmitting graphical images over phone lines via modems.
- Uses the Lempel-Ziv Welch algorithm (compression).
- Supports only 8-bit (256) color images.
- Supports interlacing
- GIF89a supports simple animation

JPEG:

- A standard for photographic image compression created by the Joint Photographic Experts Group
- Takes advantage of limitations in the human vision system to achieve high rates of compression
- Lossy compression which allows user to set the desired level of quality/compression

...Contd

TIFF:

- Developed by the Aldus Corp. in the 1980's and later supported by the Microsoft
- Tagged Image File Format (TIFF), stores many different types of images (e.g., monochrome, grayscale, 8-bit & 24-bit RGB, etc.)
- TIFF is a lossless format (when not utilizing the new JPEG tag which allows for JPEG compression)
- It does not provide any major advantages over JPEG and is not as user-controllable it appears to be declining in popularity

Graphics Animation Files:

- FLC -- main animation or moving picture file format, originally created by Animation Pro
- FLI -- similar to FLC
- GL -- better quality moving pictures, usually large file sizes

Postscript/ PDF:

- A typesetting language which includes text as well as vector/structured graphics and bit-mapped images
- Used in several popular graphics programs (Illustrator, Free-Hand)
- Does not provide compression, files are often large

System Dependent Formats

Windows(BMP):

- A system standard graphics file format for Microsoft Windows
- Used in PC Paintbrush and other programs
- It is capable of storing 24-bit bitmap images

Macintosh(PAINT, PICT):

- PAINT was originally used in MacPaint program, initially only for 1-bit monochrome images.
- PICT format is used in MacDraw (a vector based drawing program) for storing structured graphics

X-windows(XBM):

- Primary graphics format for the X Window system
- Supports 24-bit color bitmap
- Many public domain graphic editors, e.g., xv
- Used in X Windows for storing icons, pixmaps, backdrops, etc.

PNG: The Future

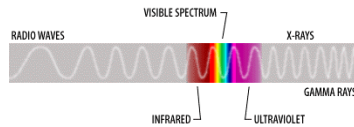
- The Portable Network Graphics (PNG) format was designed to replace the older and simpler GIF format and, to some extent, the much more complex TIFF format.
- Advantages over GIF:
 - Alpha channels (variable transparency)
Also known as a *mask channel*, it is simply a way to associate variable transparency with an image.
 - Gamma correction (cross-platform control of image brightness)
 - Two-dimensional interlacing (a method of progressive display)
GIF uses 1-D interlacing. (see the difference in the example at <http://data.uta.edu/~ramesh/multimedia/examples/interlacing.html>)
 - Better Compression (5-25% better)
- Features:
 - Supports three main image types: *truecolor*, *grayscale* and *palette-based* ('8-bit'). JPEG only supports the first two; GIF only the third.
- Shortcomings:
 - No Animation

Color in Images and Video

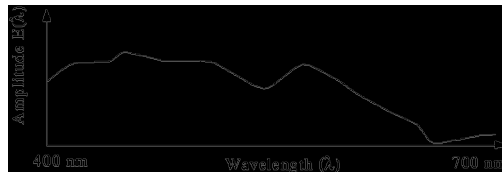
Basics of Color

□ Light and Spectra

- Visible light is an electromagnetic wave in the 400 nm - 700 nm range.



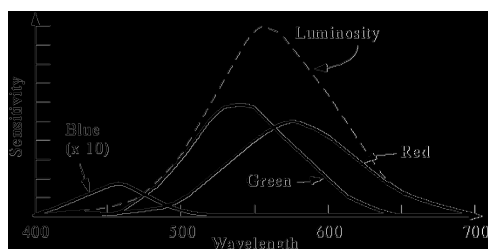
- Most light we see is not one wavelength, it's a combination of many wavelengths.



Basics of Color (...Contd)

□ The Human Retina

- The eye functions on the same principle as a camera
- Each neuron is either a rod or a cone.
- The rods contain the elements that are sensitive to light intensities. Rods are not sensitive to color.
- Cones come in 3 types: red, green and blue. Each responds differently to various frequencies of light. The following figure shows the spectral-response functions of the cones and the luminous-efficiency function of the human eye



Cones and Color

- The cones provide humans with vision during the daylight and are believed to be separated into three types, where each type is more sensitive to a particular wavelength
- The color signal to the brain comes from the response of the 3 cones to the spectra being observed. That is, the signal consists of 3 numbers:

$$R = \int E(\lambda) S_R(\lambda) d\lambda$$

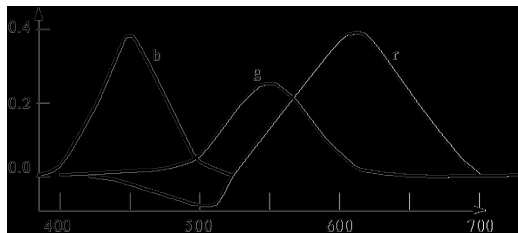
$$G = \int E(\lambda) S_G(\lambda) d\lambda$$

$$B = \int E(\lambda) S_B(\lambda) d\lambda$$

where **E** is the light and **S** are the sensitivity functions

Color Composition

- A color can be specified as the sum of three colors. So colors form a 3 dimensional vector space.
- The following figure shows the amounts of three primaries needed to match all the wavelengths of the visible spectrum.



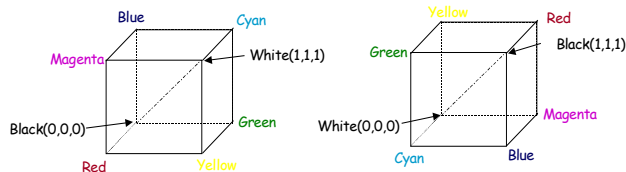
Color Models for Images

RGB Additive Model

- A color image is a 2-D array of (R,G,B) integer triplets. These triplets encode how much the corresponding phosphor should be excited in devices such as a monitor.
- CRT displays have three phosphors (RGB) which produce a combination of wavelengths when excited with electrons

CMY Subtractive Model

- Cyan, Magenta, and Yellow (CMY) are complementary colors of RGB.
- CMY model is mostly used in printing devices where the color pigments on the paper absorb certain colors (e.g., no red light reflected from cyan ink).



Color Models for Video

YUV Model

- Human perception is more sensitive to brightness than chrominance. Therefore, instead of separating colors, one can separate the brightness info. from the color info.
- Y is luminance
 - $Y = 0.299R + 0.587G + 0.114B$
- Chrominance is defined as the difference between a color and a reference white at the same luminance. It can be represented by U and V -- the color differences.
 - $U = B - Y$
 - $V = R - Y$
- Eye is most sensitive to Y. Therefore, any error in the resolution of the luminance (Y) is more important than the chrominance (U,V) values.
- In PAL, 5 (or 5.5) MHz is allocated to Y, 1.3 MHz to U and V.
- CD-I and DVI also use the YUV model

YIQ Model

- YIQ is used in NTSC color TV broadcasting, it is downward compatible with B/W TV where only Y is used.
- Although U and V nicely define the color differences, they do not align with the desired human perceptual color sensitivities. In NTSC, I and Q are used instead.
 - $I = 0.74(R - Y) - 0.27(B - Y) = 0.596R - 0.275G - 0.321B$
 - $Q = 0.48(R - Y) + 0.41(B - Y) = 0.212R - 0.523G + 0.311B$
- Eye is most sensitive to Y, next to I, next to Q. In NTSC broadcast TV, 4.2 MHz is allocated to Y, 1.5 MHz to I, 0.55 MHz to Q.

Color Models for Video (...Contd)

$YCbCr$ Color Model

- The $YCbCr$ model is closely related to the YUV, it is a scaled and shifted YUV.
 - $C_b = ((B - Y) / 2) + 0.5$
 - $C_r = ((R - Y) / 1.6) + 0.5$
- The chrominance values in $YCbCr$ are always in the range of 0 to 1.
- $YCbCr$ is used in JPEG and MPEG.

Summary: Color

- Color images are encoded as triplets of values.
- RGB is an additive color model that is used for light-emitting devices, e.g., CRT displays CMY is a subtractive model that is used often for printers
- Sometimes, an alternative CMYK model (K stands for Black) is used in color printing (e.g., to produce darker black than simply mixing CMY).
 $K := \min(C, M, Y); C := C - K; M := M - K; Y := Y - K.$
- Two common color models in imaging are RGB and CMY, two common color models in video are YUV and YIQ.
- YUV uses properties of the human eye to prioritize information. Y is the black and white (luminance) image, U and V are the color difference (chrominance) images. YIQ uses similar idea.