Multimedia Software Systems
CS4551

Before Learning

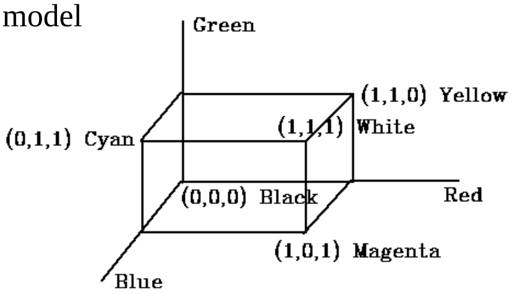
JPEG Image Compression Algorithm

Color Spaces (Coordinate Systems)

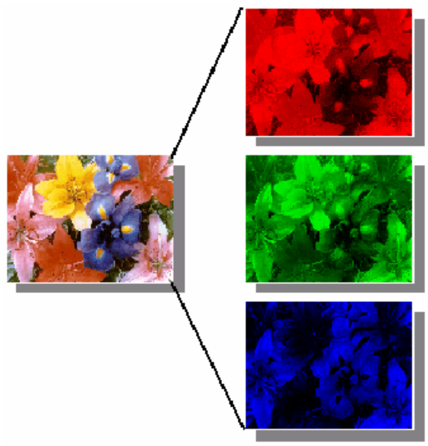
- RGB
- CMY/CMYK
- YIQ
- YUV
- YCbCr
- HSL/HSV
- …

Color Models in Images - RGB

- RGB color model for CRT displays
  - stores color information in directly in RGB form
  - device-dependent
  - additive color model

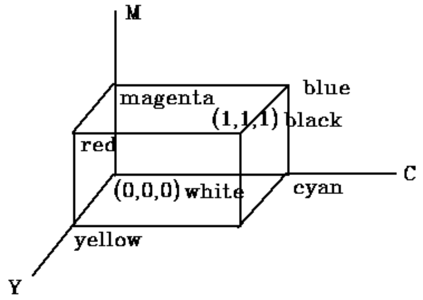


Color Models in Images - RGB



Color Models in Images - CMY

- *CMY* for printing
  - primary colors : Cyan, Magenta, Yellow
  - subtractive model
  - C = 1-R
  - M = 1-G
  - Y = 1-B



Color Models in Images - CMYK

- Using truly black ink for black is cheaper than mixing C, M, and Y to produce black.
- *CMY*K: like *CM*Y, uses black *(*K) as fourth color.
  - Given *(C, M, Y),*
  - K=min(C, M, Y)
  - C=C-K
  - M=M-K
  - Y=Y-K

Color Models in TV/Video - YUV

- YUV color model was used for PAL and SECAM video.
- PAL, short for Phase Alternating Line, is a color video signal format used in broadcast television systems in Europe.

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ -0.299 & -0.587 & 0.886 \\ 0.701 & -0.587 & -0.114 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$

Y' is called "luma".

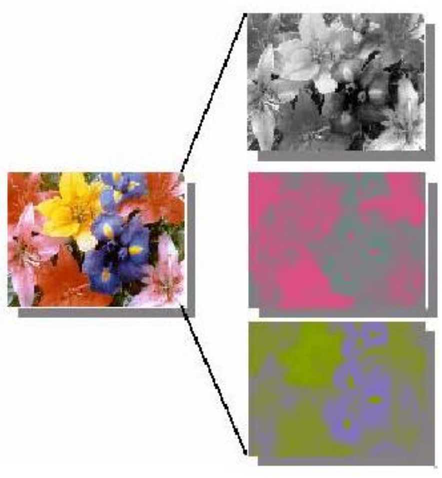
$\mathrm{U = B'\text{-}Y'}$ is "chrominace "

$\mathrm{V = R'\text{-}Y'}$ is also "chrominanc e"

R', G', B' : gamma corrected R, G, B

- Color TV signal can be displayed on a black-and-white television by using Y' signal.

Color Models in TV/Video - YUV



Color Models in TV/Video - YIQ

- YIQ color model is used in NTSC (short for the National Television Standards Committee) color TV broadcasting in North America and Japan.

$$\begin{bmatrix} Y' \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.595879 & -0.274133 & -0.321746 \\ 0.211205 & -0.523083 & -0.311878 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$

Y' *is called "luma".*

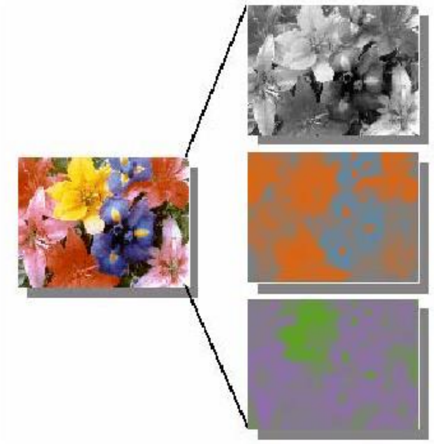
I *is for "in-phase chrominace"*

Q *is for "quadrature chrominance"*

R', G', B' : gamma corrected R, G, B

- UV of YUV are more simply defined. But they do not capture the most-to-least hierarchy of human perceptual color sensitivities compared to IQ of YIQ.

Color Models in TV/Video - YIQ



Color Models in TV/Video - YCbCr

- YCbCr is the international standard for component(three-signal) digital video recommended by ITU (International Telecommunication Union). Used for JPEG and MPEG standards.

$$\begin{bmatrix} Y' \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.418588 & -0.081312 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} + \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix}$$

Y' *is called "luma".*

Cb is blue chrominance

Cr is red chrominance

R', G', B' : gamma corrected R, G, B

- YCrCb is closely related to YUV. However, YUV is an analog system with scale factors different than the digital YCbCr system

Why RGB is not used for Video?

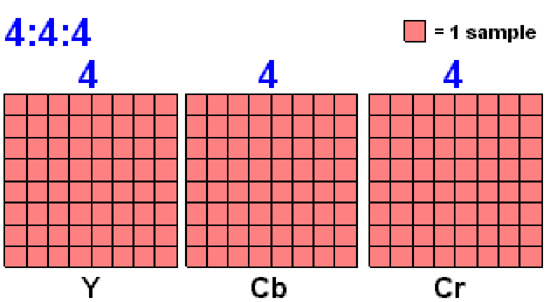
- Human visual system is more sensitive to luminance than chrominance.
- YUV, YIQ and YCrCb represent color with *luminance (*Y) and *chrominance*(the other 2 channels).
- Advantages:
  - We can subsample the chrominance channels(e.g., 4:2:2, 4:2:0 subsampling schemes)
  - We can quantize the chrominance channels more coarsely (with fewer bits)

Chrominance Subsampling Schemes

- Human visual system is less sensitive to the *Chrominance* channels than to *Luminance* channel
- We can *subsample* the chrominance channels without noticeable loss of detail
- Color subsampling schemes:
  - *4:1:1*: 1 sample of each chrominance channel every 4 samples of luminance
  - *4:2:0*: 1 sample of each chrominance channel every 4 samples of luminance
  - *4:2:2*:1 sample of each chrominance channel every 2 samples of luminance

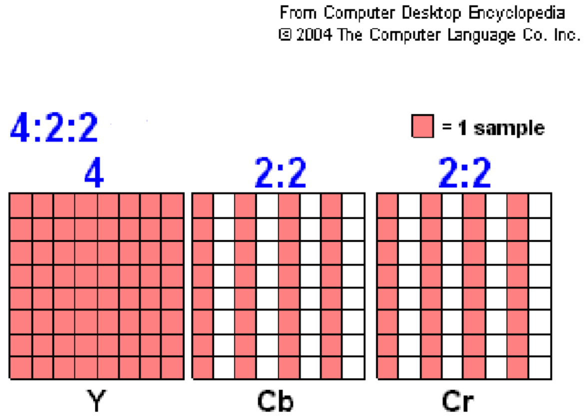
Chrominance Subsampling Schemes

- 4:4:4 : Cb/Cr Same as Luma



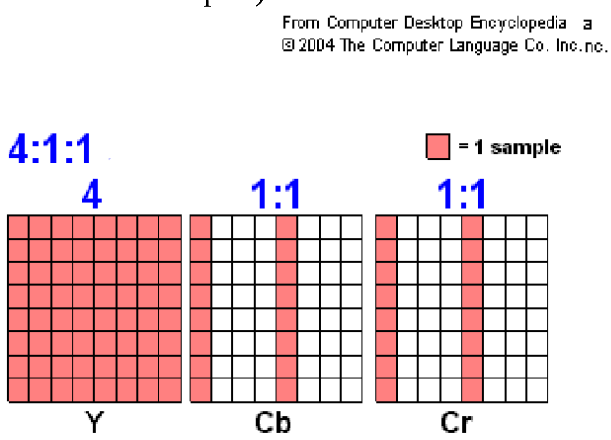
Chrominance Subsampling Schemes

- 4:2:2 (1/2 the Luma Samples)



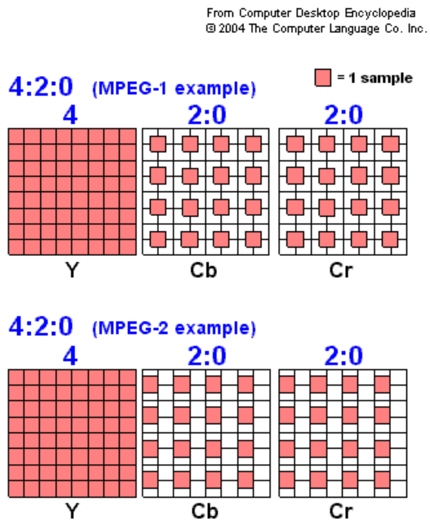
Chrominance Subsampling Schemes

- 4:1:1 (1/4 the Luma Samples)



Chrominance Subsampling Schemes

- 4:2:0 (1/4 the Luma Samples, The zero in 4:2:0 means that Cb and Cr are sampled at half the vertical resolution of Y.)



Sample Questions

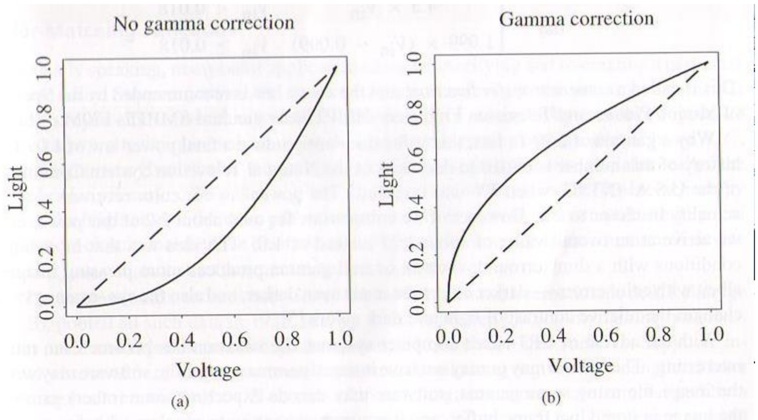
- What are the advantages of using a different color space than RGB (e.g., YCrCb) for the sampling and compression of color images and video?
- Consider a video format with 325 lines/frame, 490 pixels/line, 30 frames/s, color subsampling scheme 4:2:2, image aspect ratio: 4:3. Compute the bit-rate of the system (assuming each luminance and chrominance sample is quantized with 8 bits).

  Ans: 76.44 Mbits

Gamma Correction

- The RGB number in an image file are converted back to analog and drive the electron guns. For each gun, the power of the emitted light is a function of the *control voltage*. Ideally, the emitted light is would be linearly proportional to the voltage. In practice, the relation is *not linear* and the emitted light is roughly linearly proportional to the voltage raised to the γ (gamma) power.
- So if the file value in the red channel is R, the screen emits light proportionally to R^{γ} (unwanted distortion). We need to correct the output by raising to the power ($1/\gamma$) so that the given input R will be displayed as it is by going through $(R^{1/\gamma})^{\gamma}$ -> R. This transformation is called *gamma correction*.
- TV systems pre-correct for this situation by applying inverse transformation before transmitting TV signals. So it transmits $R^{1/\gamma}$.

Gamma Correction



Effect of gamma correction: (a) no gamma correction — effect of CRT on light emitted from screen (voltage is normalized to range 0 .. 1); (b) gamma correction of signal.

Gamma Correction

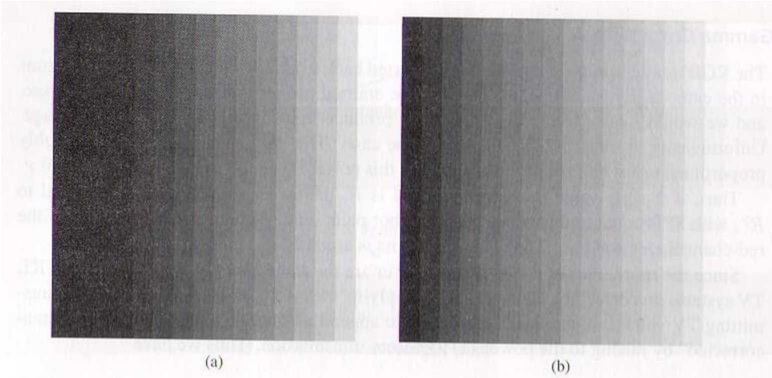


FIGURE 4.7: Effect of gamma correction: (a) display of ramp from 0 to 255, with no gamma correction; (b) image with gamma correction applied.