How to Compute Bandwidth $\Delta\nu$

- Count Number of Pixels scanned and displayed per Second

  = Number of pixels per line $\times$

  Number of lines per frame $\times$

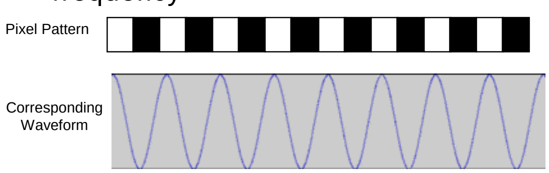
  Number of frames per second

  (= rows $\times$ columns $\times$ frames per sec.)
- Divide by 2

  = Number of pixels per cycle at maximum

Why Divide by 2?

- Two pixels (one bright + one dark) can be represented by one cycle that oscillates at the maximum frequency



Bandwidth of NTSC "Luminance" Signal

- "Black-and-White" Image
- Minimum Oscillation Frequency is:

  0 cycles per second = 0 Hz
- Maximum Oscillation Frequency is:

  525 spl × 525 lpf × 30 fps ÷ 2 spc (spots per cycle`)

  = 4,134,375 Hz $\cong$ 4 MHz

"spl" = "spots per line" (number of pixels per scan line)
"lpf" = (scan) "lines per frame"
"fps" = frames per second
"spc" = "spots per cycle" (2 spots per cycle at maximum frequency ν)

What About Color Video?

- Color Image Made from 3 Monochrome Images (“channels”)
  - Red, Green, Blue
- Might Expect to Need 3 × B&W Bandwidth

$$\Delta\nu \cong 12 \text{ MHz}$$

- BUT: this assumes that the color images are completely independent (unrelated)!

Image Channels ARE NOT Independent!

RGB Channels Often Are Very Similar!

Red

Green

Blue

Sum

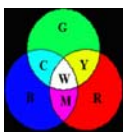
Don’t Need All Information in All Images

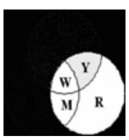
- Some Image Data Can Be “Thrown Away” Without Noticeable Effect on Image
- Just as in Image Compression
  - Color video transmission uses color image compression

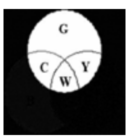
Compute 3 Different Images

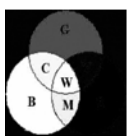
- Current Method: Compute the following numbers from the RGB values at each pixel
  - Luminance: ***Y = 0.299 R + 0.587 G + 0.114 B***
    - (all weights are positive and add to 1)
    - produces a "weighted sum"
  - Chroma 1: ***U = -0.147 R – 0.289 G + 0.436 B***

RGB Color

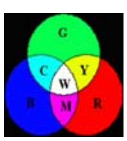


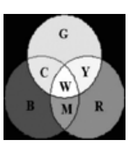

Red Channel


Green Channel

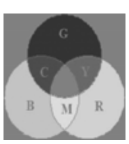

Blue Channel

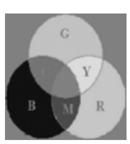
Luminance-Chrominance Color





Lightness
= Monochrome Image


Chrominance 1


Chrominance 2

Three “New” Images

Red Yellow Blue

Monochrome Luminance = Y | Chrominance U | Chrominance V

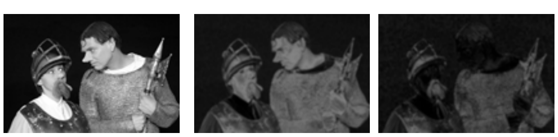
Imaging Science Fundamentals

Now Add Knowledge of HVS

- Spatial Response of Human Visual System to “Details and Edges”
  - Sensitive in monochrome (luminance) image
    - Edges in monochrome image must be sharp
  - Less sensitive in chrominance image
    - Edges in color part of image may be “fuzzy”
- Same principle used in movie “colorization”
  - Artists don’t need to “color within the lines” when colorizing a B&W movie

Imaging Science Fundamentals

Three “New” Images



Monochrome Luminance = Y | Chrominance U | Chrominance V

Imaging Science Fundamentals

Strategy to Transmit Color Video with Reduced Bandwidth

- Transmit **Luminance Image *Y*** with **Full** Resolution (full bandwidth)

  525 spl × 525 lpf × 30 fps ÷ 2 spc (spots per cycle`)

  = 4,134,375 Hz ≅ 4 MHz

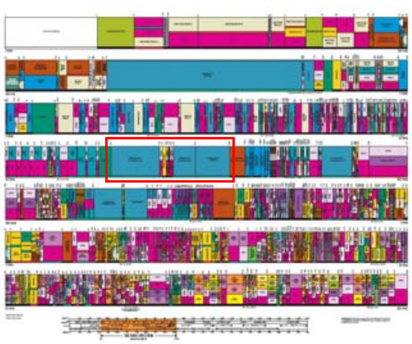
- Transmit **Chrominance Images *I,Q*** with **Less** Resolution (less bandwidth)

  (≤ 1 MHz per Image ⇒ ≤ ¼ of Pixels)

⇒Total signal requires **6 MHz** of Band

  - Interval between TV Channels in Frequency (MHz)

Allocation of Electromagnetic Spectrum for Different Uses



TV Spectrum