جامعة اللاذقية
كلية الهندسة المعلوماتية

Multimedia Systems

Graphics and Image Data Representation

Lecture 4

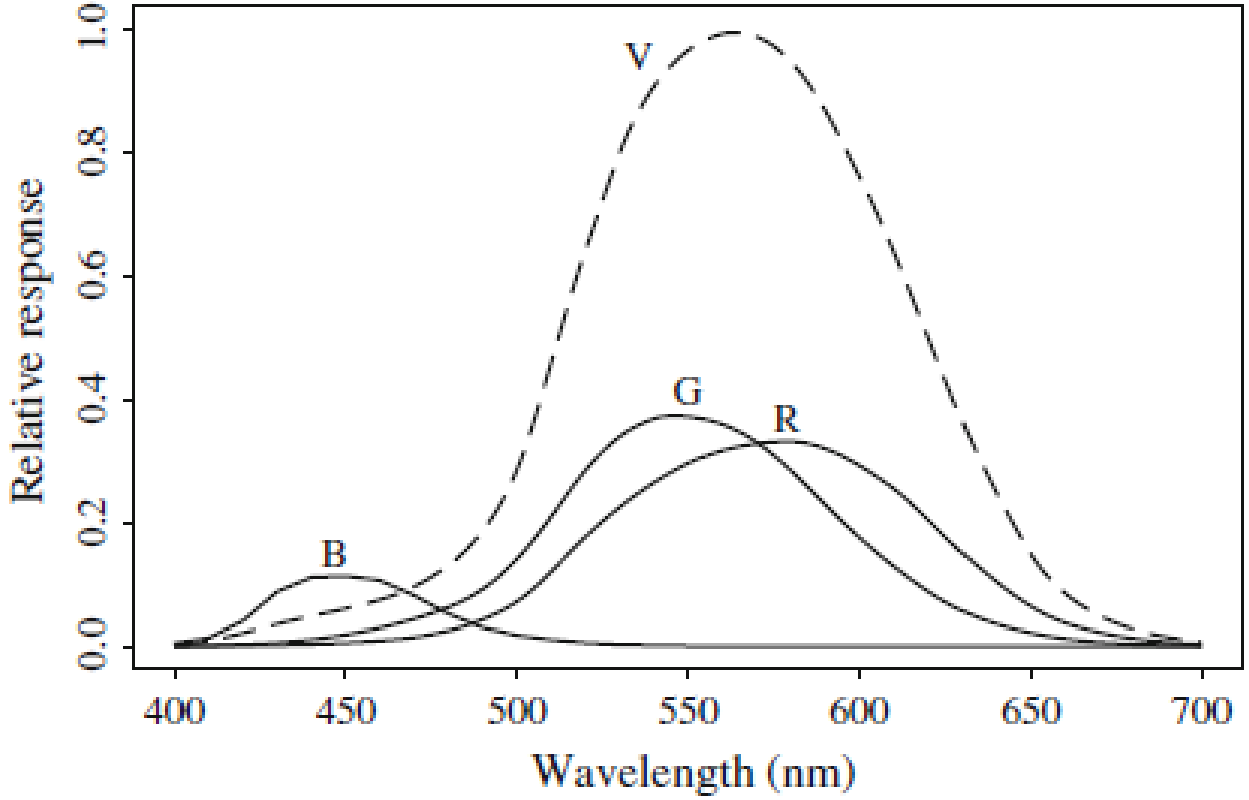
Human vision

- The eye works like a camera, with the lens focusing an image onto the retina (upside-down and left-right reversed).
- The retina consists of an array of rods and three kinds of cones.
- The **rods** come into play when light levels are **low** (night vision) and produce image in shades of gray. they do not contribute to color differentiation.

- For higher light levels, the **cones** each produce a signal. Because of their differing pigments, the three kinds of cones are most sensitive to red (R), green (G), and blue (B) light.
  - S-cones (sensitive to blue light, **s**hort wavelengths, 400-500 nm).
  - M-cones (sensitive to green light, **m**edium wavelengths, 500-600 nm).
  - L-cones (sensitive to red light, **l**ong wavelengths, 600-700 nm).

Spectral Sensitivity of the Eye :

- The eye is most sensitive to light in the middle of the visible Spectrum.
- The sensitivity of our receptors is also a function of wave-length



R,G, and B cones, and luminous-efficiency curve V*(λ)*

Spectral Sensitivity of the Eye :

- Rods are sensitive to a broad range wavelengths and they produce the signal that generates the perception of Black-White scale only
- Previous figure shows the overall sensitivity as a *dashed line* – this important curve is called the **luminous efficiency function**
  - is formed as the sum of the response curves for Red, Green, and Blue.

- The eye has about 6 million cones, but the proportions of R, G, and B cones are different.
- They likely are present in the ratios 40:20:1
- So the achromatic channel produced by the cones is thus something like 2R + G + B/20.

Image formation

The image formation situation is thus as follows: light from the illuminant with SPD E(λ) impinges on a surface, with surface spectral reflectance function S(λ), is reflected, and is then filtered by the eye's cone functions q(λ).

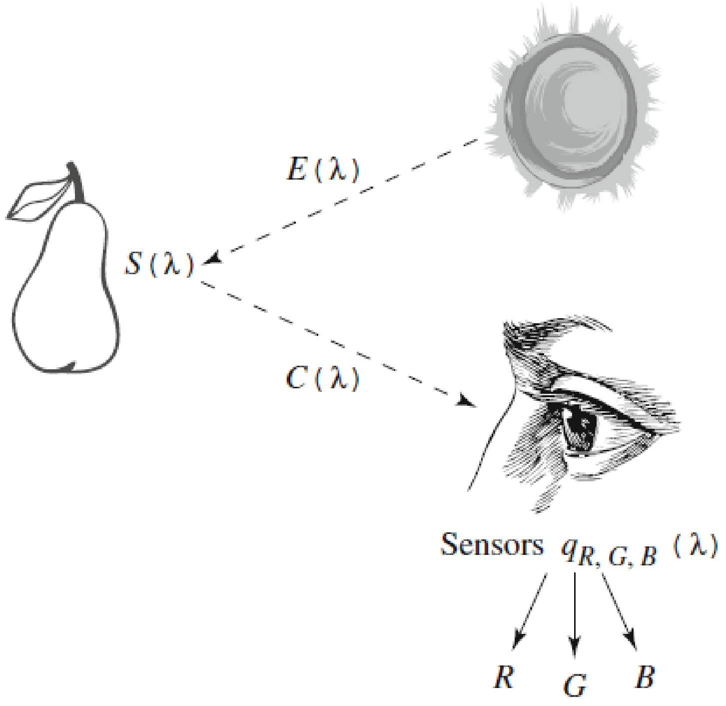
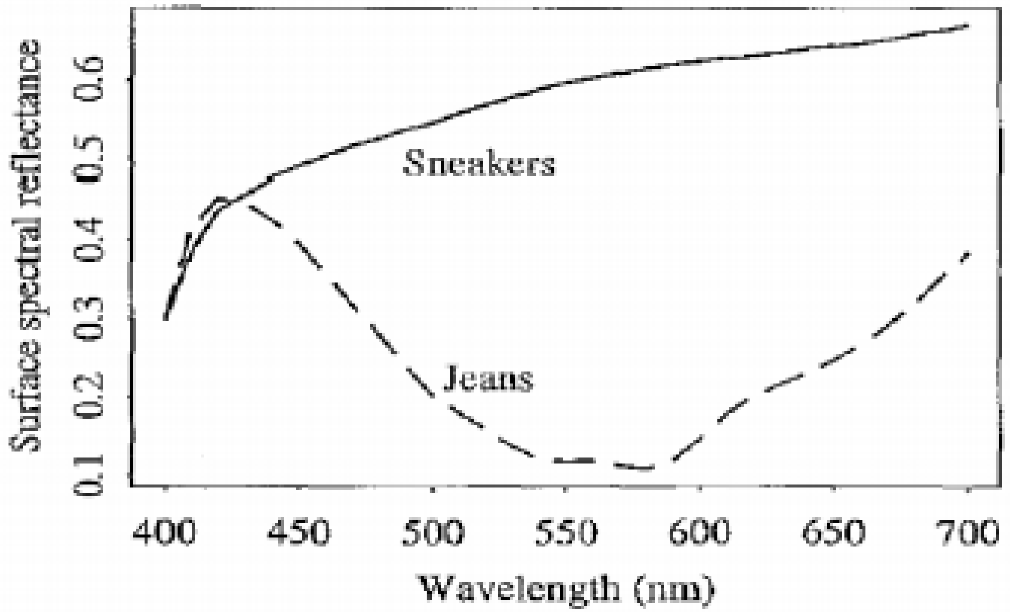


Image formation

Surfaces reflect **different amounts** of light at **different wavelengths**, and dark surfaces reflect less energy than light surfaces.

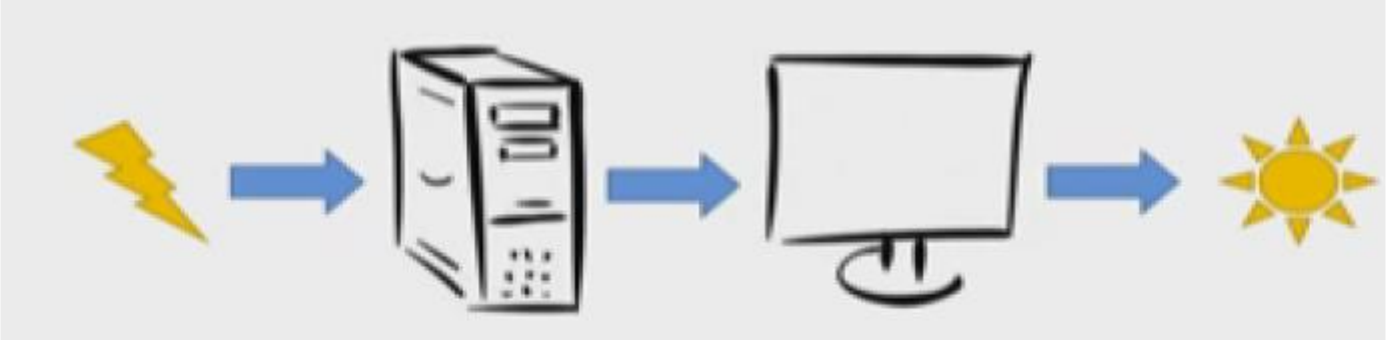
- The reflectance function is denoted $S(\lambda)$.



CRT display – gamma correction

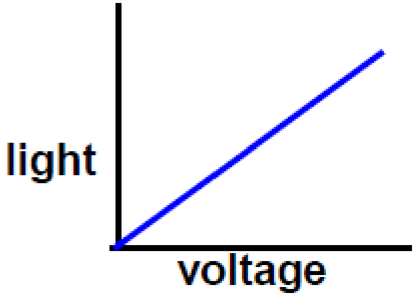
To display images in a monitor screen, an input voltage is applied

What is gamma ??



This voltage outputs as light intensity on the screen

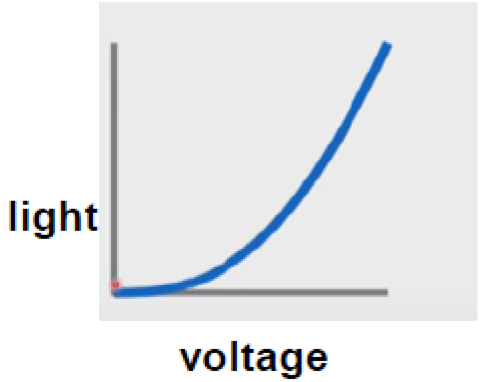
In a *perfect* world, input would equal to output linearly



What is gamma ??

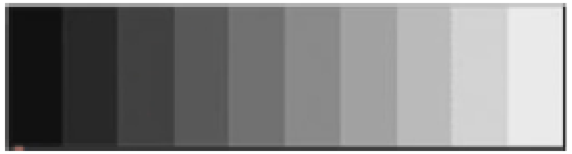
But monitor's response is closer to an exponential curve and this exponent called gamma

$$\text{Luminance} = \text{voltage}^{\gamma}$$

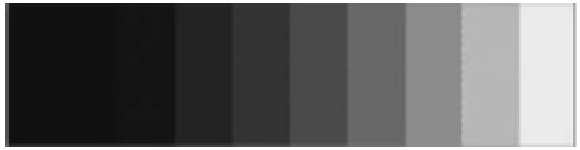


How color is affected ??

Linear ramp → Easy to distinguish each step

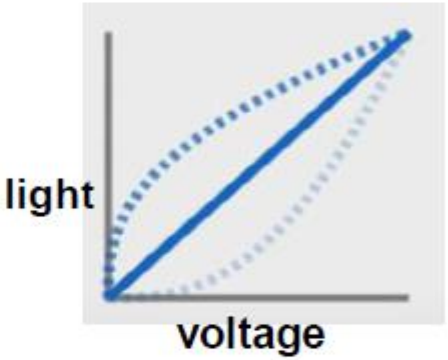


Gamma curve of 2.2 → darkens part of image



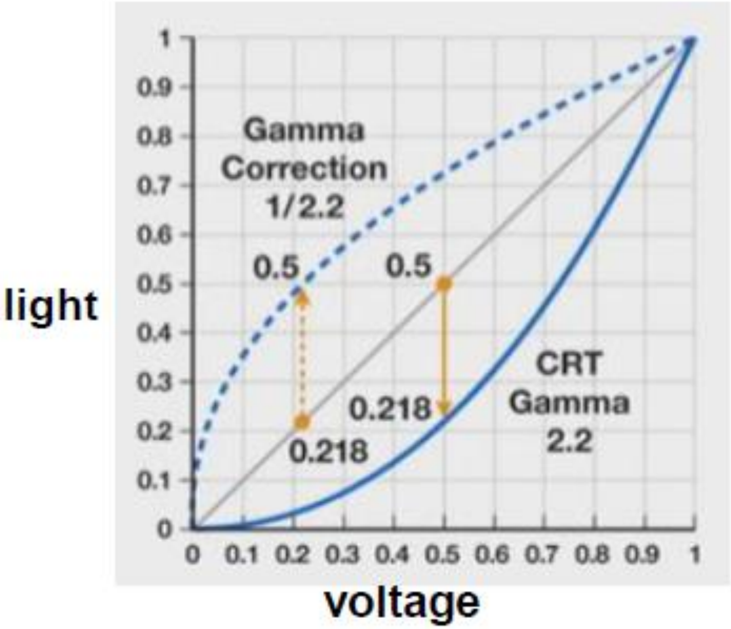
What is gamma correction

If you apply an inverse 2.2 gamma curve to a 2.2 gamma curve ,you will get the source image



Applying the inverse of the monitor transformation to image pixels before display them

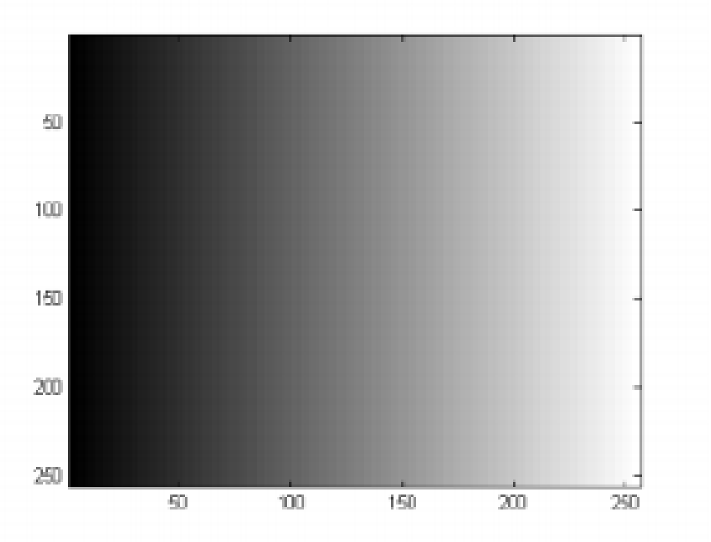
Example: gamma=2.2



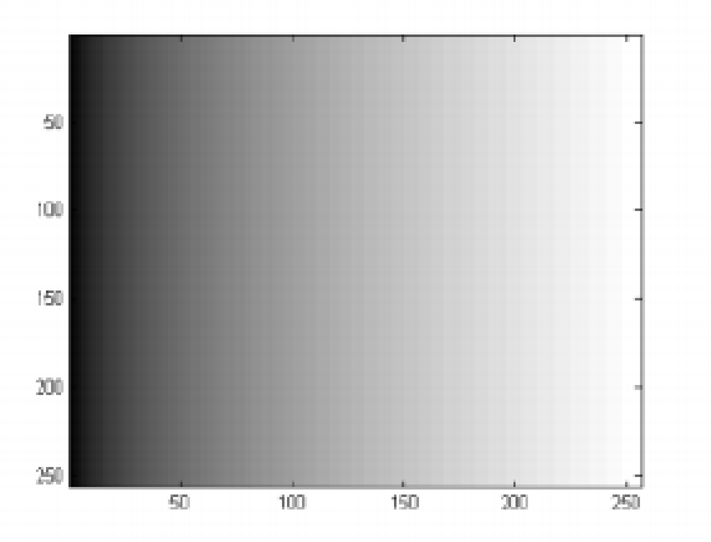
What is gamma correction

Display of ramp from 0 to 255

- White still white
- black still black



With no gamma Correction



Applying gamma correction

Color Space

A color space is a mathematical model that represents colors in a way that can be manipulated and analyzed.

What color space should I use? That depends on what you want to do

1. RGB (Red Green Blue)
2. CMY(K) (Cyan Magenta Yellow (Black))
3. HSL (Hue Saturation and Lightness)

Color Space – RGB model

an **additive** color system based on **tri-chromatic theory**.

when two light beams impinge on a target, their colors add; when two phosphors on a CRT screen are turned on, their colors add.

-So, for example, red phosphor + green phosphor makes yellow light.

-Often found in systems that use a CRT to display images.

-RGB is easy to implement but non–linear with visual perception.

-RGB is very common, being used in virtually every computer system as well as television, video etc.

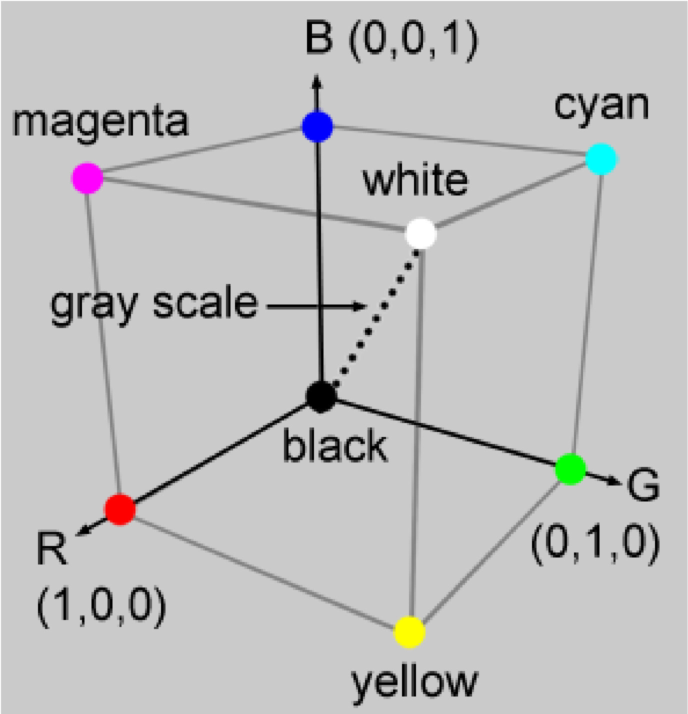
Color Space – RGB model

- We can specify colors by a combination of

$$\text{Color} = r\mathrm{R} + g\mathrm{G} + b\mathrm{B}$$

$$= [\mathrm{R}, \mathrm{G}, \mathrm{B}] \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

  - R, G, B color primaries are basis vectors
  - (r, g, b) tristimulus values specify 3-D coordinates



- Each color can be specified by its (r, g, b) coordinates

$$\mathrm{Red} = \mathrm{R} \Leftrightarrow (r, g, b) = (1, 0, 0)$$
$$\mathrm{Green} = \mathrm{G} \Leftrightarrow (r, g, b) = (0, 1, 0)$$
$$\mathrm{Blue} = \mathrm{B} \Leftrightarrow (r, g, b) = (0, 0, 1)$$

- Cyan, Magenta, and Yellow can each be specified by their (r, g, b) coordinates

$$\mathrm{Cyan} = \mathrm{G} + \mathrm{B} \Leftrightarrow (r, g, b) = (0, 1, 1)$$
$$\mathrm{Magenta} = \mathrm{R} + \mathrm{B} \Leftrightarrow (r, g, b) = (1, 0, 1)$$
$$\mathrm{Yellow} = \mathrm{R} + \mathrm{G} \Leftrightarrow (r, g, b) = (1, 1, 0)$$

Color Space – CMY(K) model

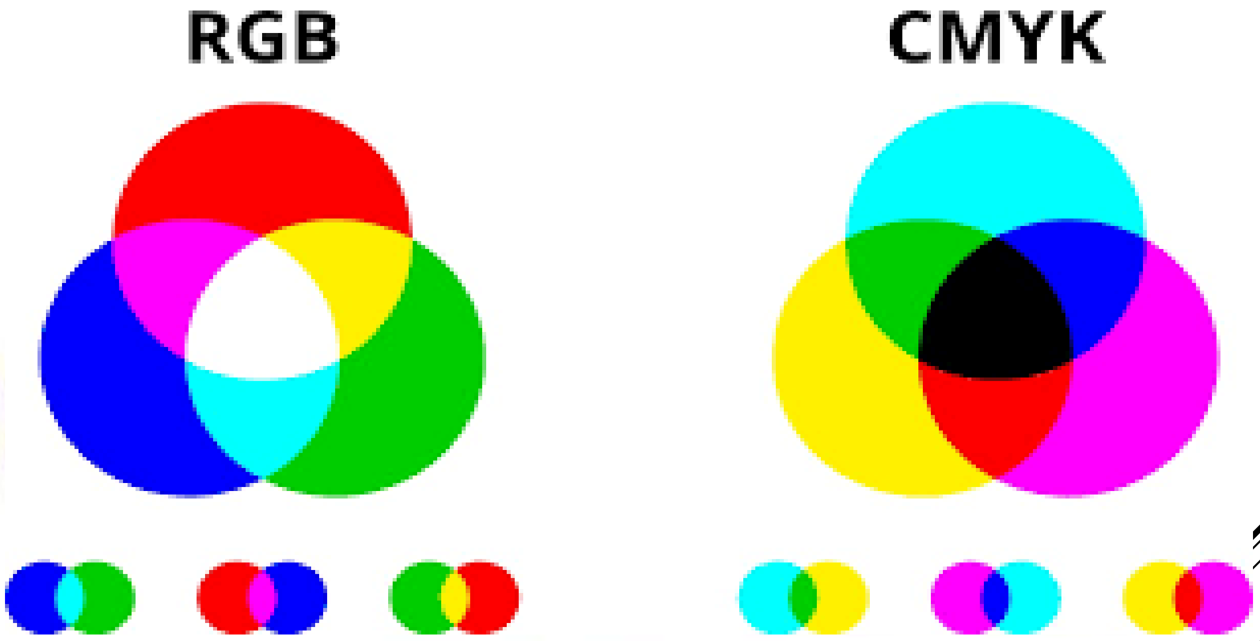
- a subtractive based color space and is mainly used in printing
- we have effectively been dealing only with additive color, But for **ink** deposited on paper,
- The opposite situation holds: **yellow** ink subtracts blue from **white** illumination but reflects (red and green); which is why it appears yellow!
- So, instead of red, green, and blue primaries, we need primaries that to subtract R, G, or B (CMY).
- Simple Comparison :
  - In the additive (RGB) system, black is "no light", RGB = (0,0, 0).
  - In the subtractive CMY system, black arises from ,subtracting all the light by laying down inks with (C ,M ,Y) = (1,1,1).

Transformation from RBG to CMY:

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

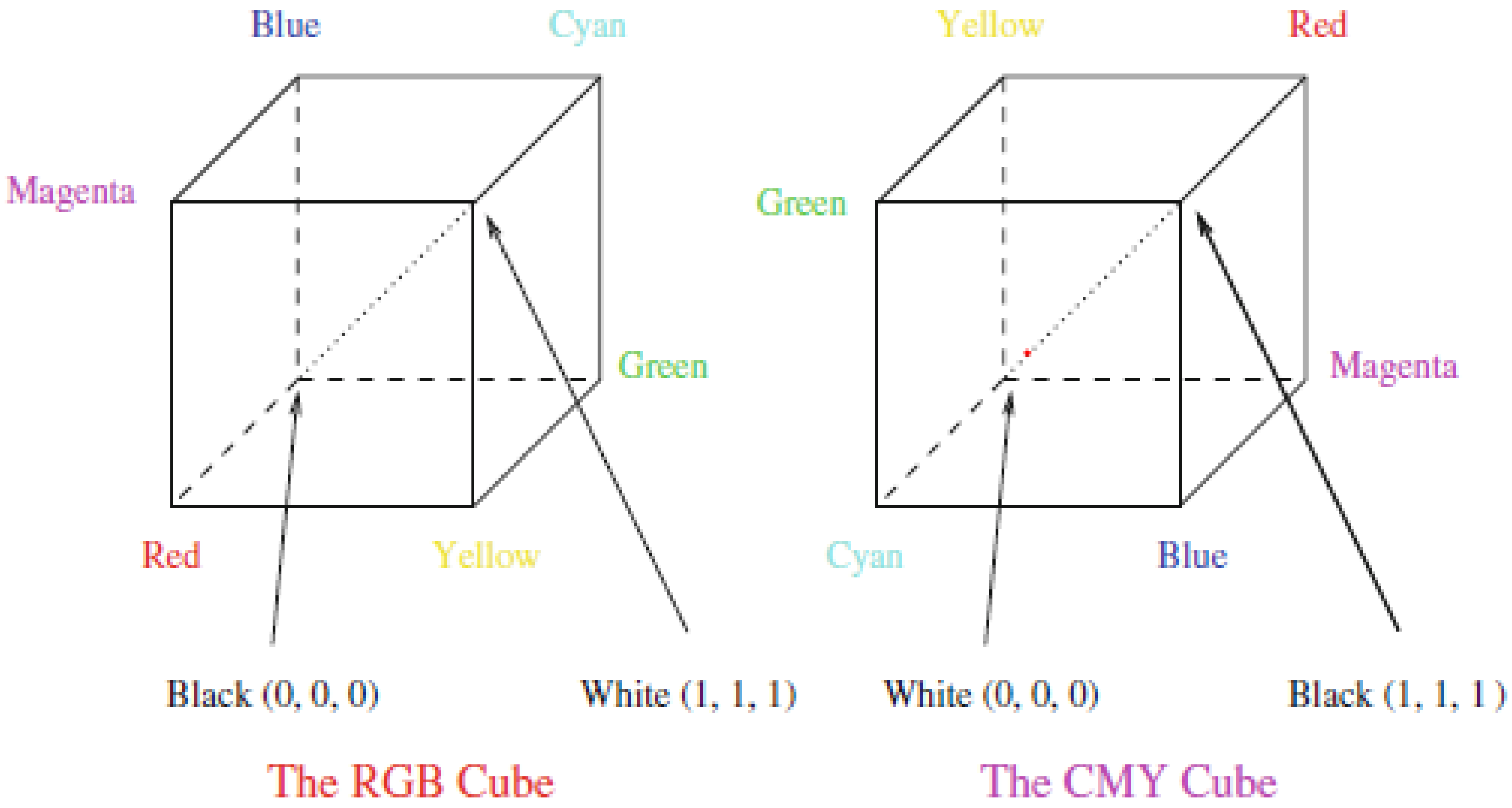
The inverse transform



Additive and subtractive color

RGB is additive color; CMYK is subtractive color

Transformation from RBG to CMY:



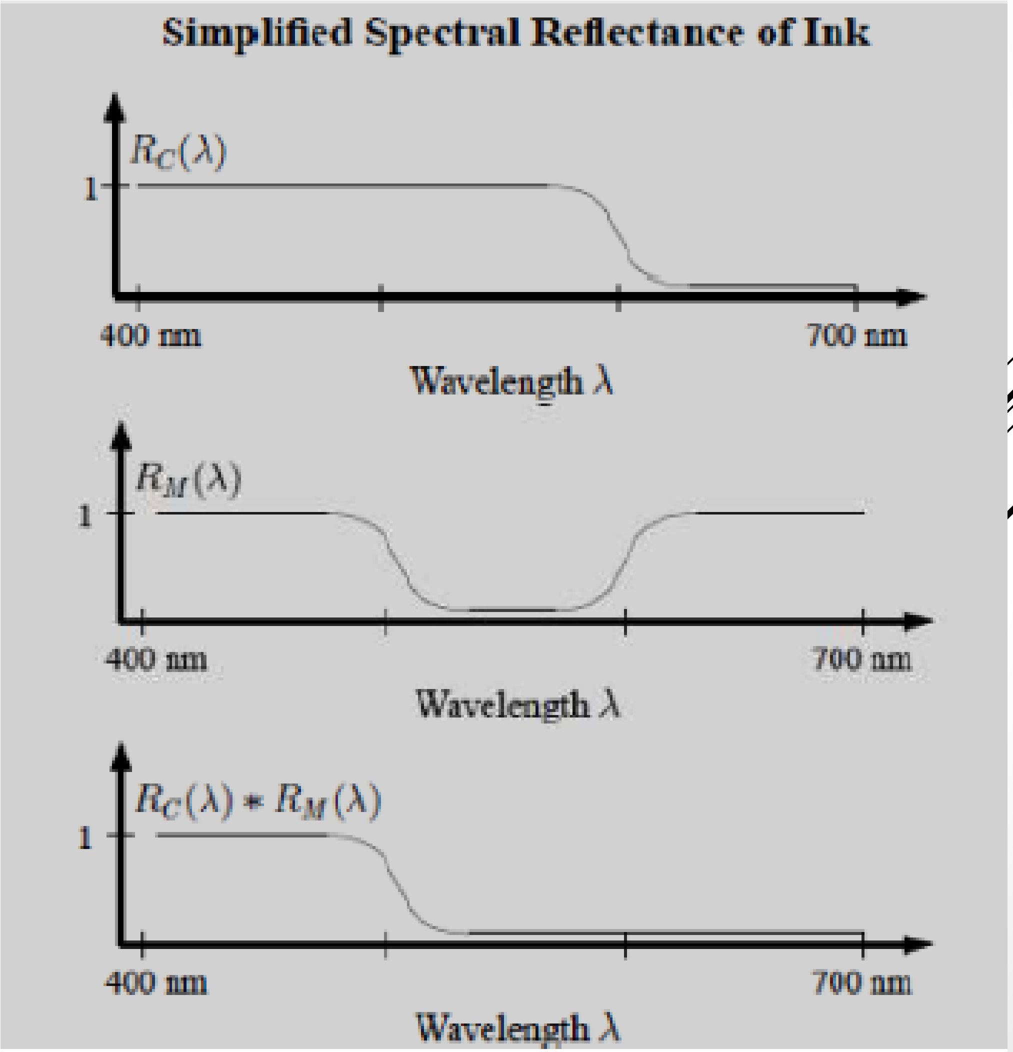
RGB & CMY color cubes

Color Space – CMY(K) model

What color is formed by magenta and cyan ink ??

Reflected light appears blue

Both green & red have been removed



Under color Removal : CMYK

Why CMYK?

1- More often C,M, and Y mix to a muddy brown.

2- Truly black ink is in fact much cheaper than mixing colored inks to make black

Under color removal is used to generate black information

Example:

(C, M, Y) = (0.25, 0.5, 0.75)

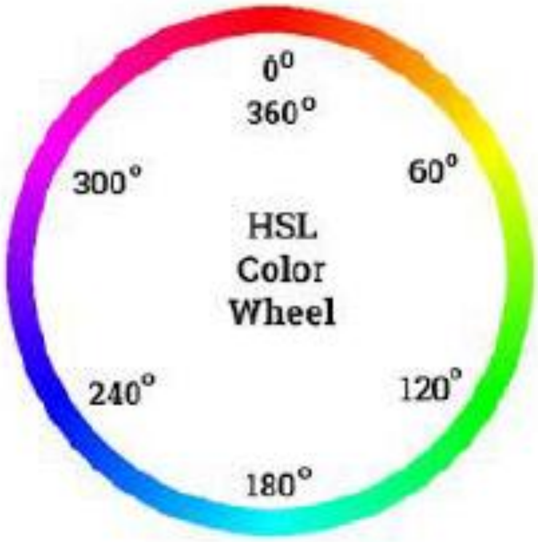
Black (K) = 0.25

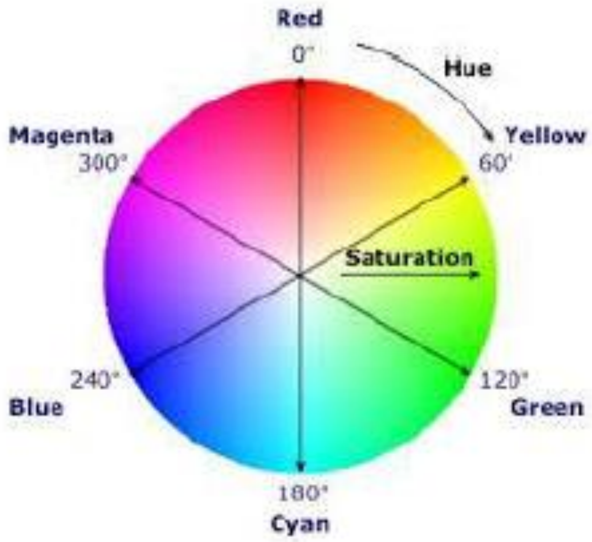
(C, M, Y,K) = (0, 0.25, 0.5,0.25)

$$K \equiv \min\{C, M, Y\}$$

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} C-K \\ M-K \\ Y-K \end{bmatrix}$$

Color Space – HSL model





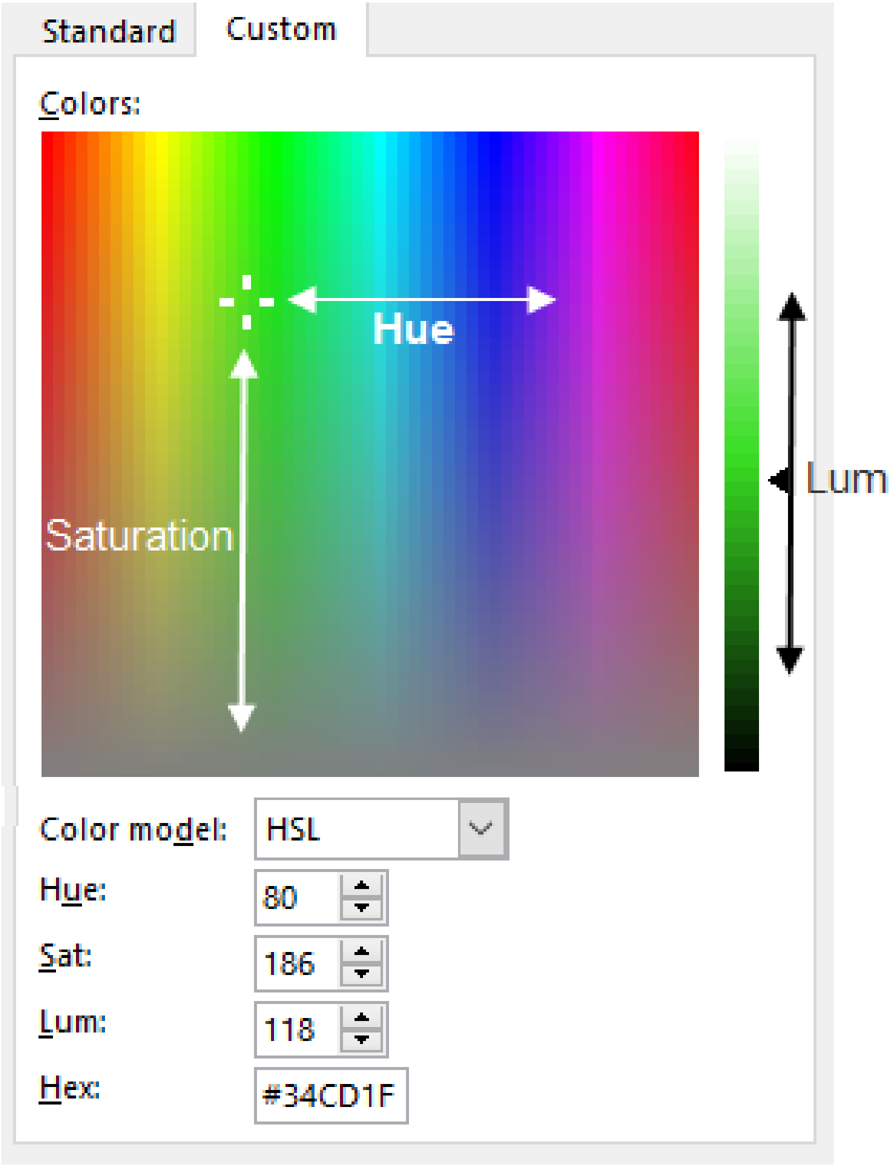
Hue **S**aturation and **L**ightness

Hue is a degree on the color wheel from 0 to 360. 0 is red, 120 is green, 240 is blue.

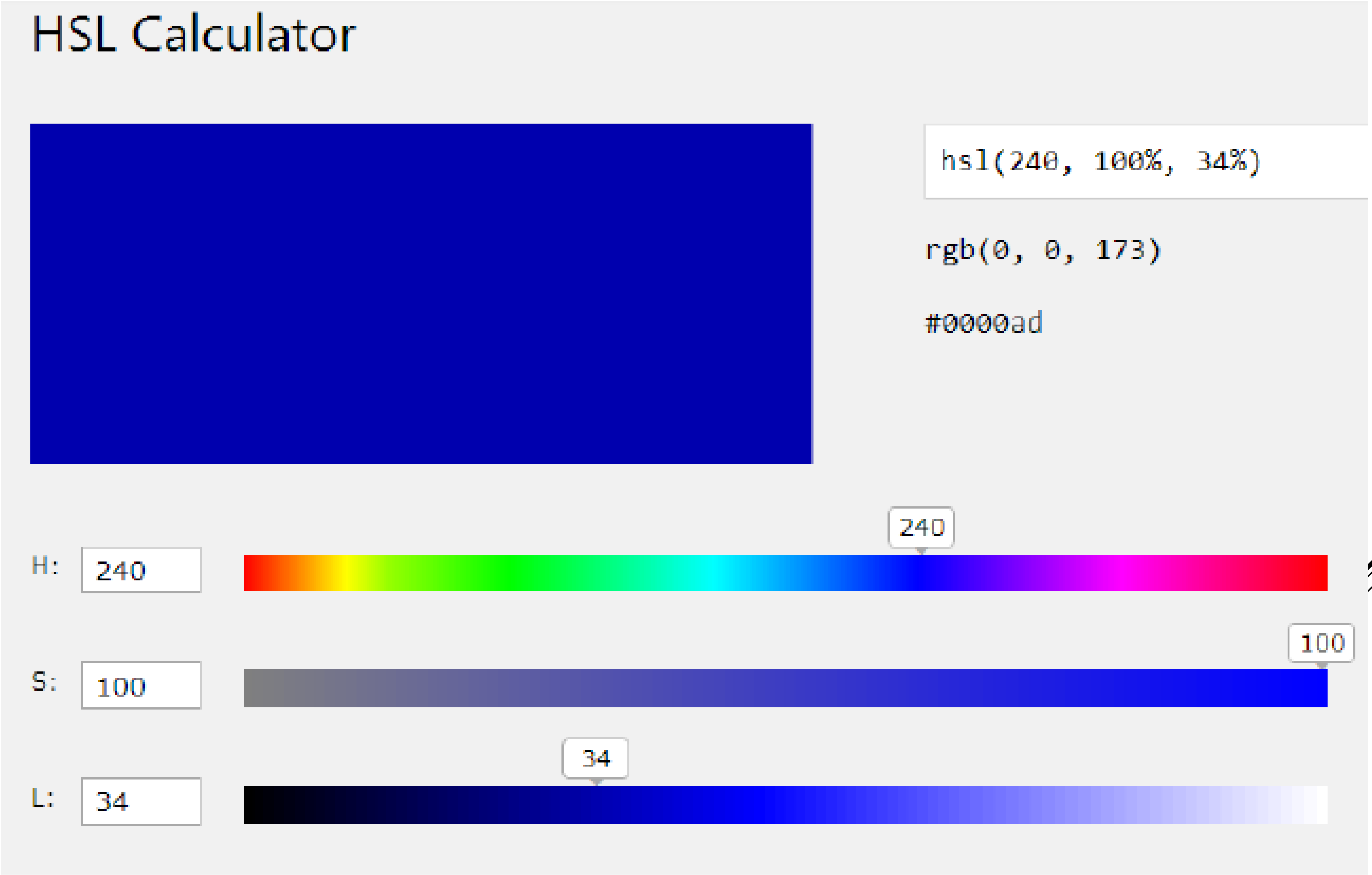
Saturation is a percentage value; 0% means a shade of gray and 100% is the full color.

Lightness is also a percentage; 0% is black, 100% is white.

Color Space – HSL model



Color Space – HSL model



Color Spaces

	RGB	CMY	HSL
Main use	Screens and electronic devices	Printing and publishing	Graphic design and image editing.
Representation	Additive (light addition)	Subtractive (light absorption)	Perceptually uniform color representation
Values	Values range from 0 to 255 for each color.	Values range from 0 to 100% for each color.	Hue ranges from 0° to 360°; Saturation and Lightness range from 0% to 100%.
Description	Refers to colors derived from light.	Based on colors derived from pigments.	Describes colors based on three main components.

Color Models in Video

Why do we need specific video color spaces?

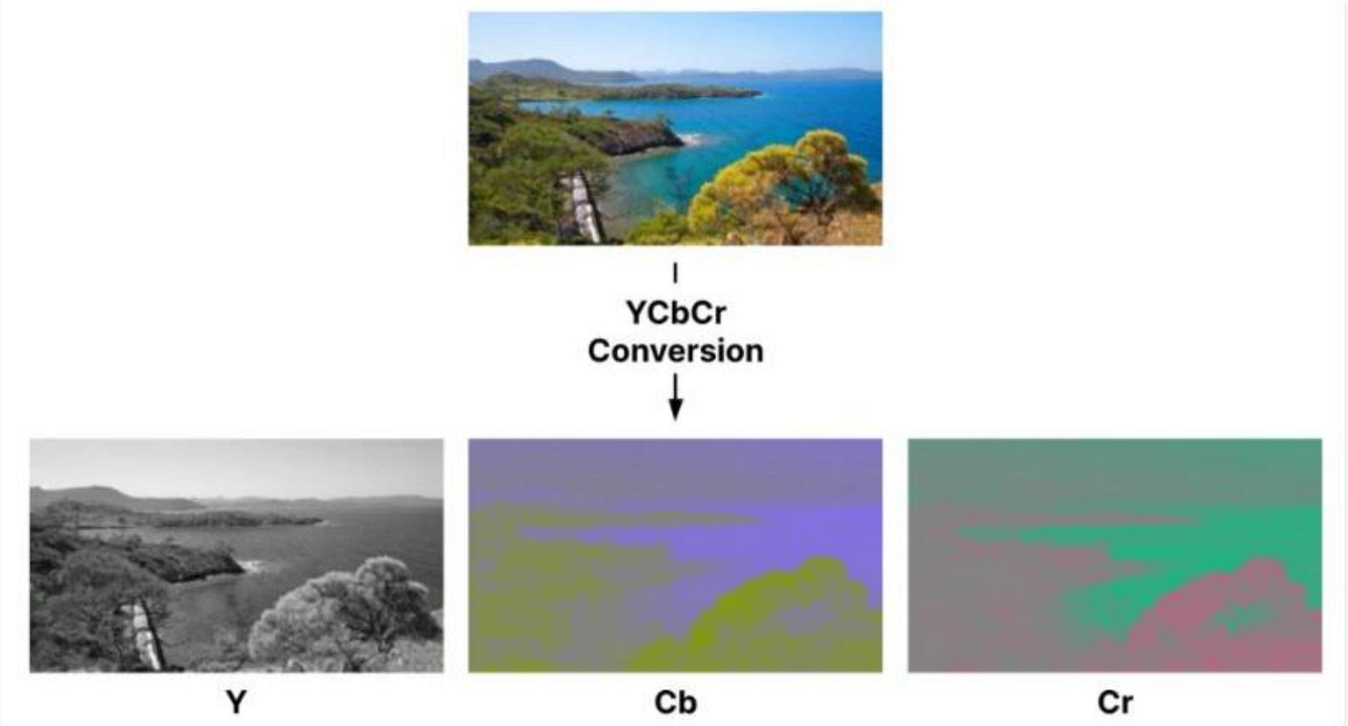
video requires different processing and compression compared to still images. Video consists of numerous frames that need to be displayed smoothly, necessitating efficient *storage* and *transmission*.

Color spaces like YUV and YCbCr are used to reduce data size while maintaining image quality by separating brightness and color information, allowing for better compression.

Color Models in Video

- YUV, YCbCr, .. (Luminance - Chrominance)

These color spaces separate RGB into luminance and chrominance information and are useful in compression applications (both digital and analogue).



Color Models in Video

YUV

- After gamma correction (r′,g′, b′)
- Luminance Y, is derived from R′,G′,B′ signals

$$Y` = 0.299r` + 0.587g` + 0.114b`$$

$$\begin{pmatrix} Y` \\ U \\ V \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.299 & -0.587 & 0.886 \\ 0.701 & -0.587 & -0.114 \end{pmatrix} \begin{pmatrix} r` \\ g` \\ b` \end{pmatrix}$$

- Chrominance U ,V

$$U = b` - Y`$$
$$V = r` - Y`$$

- For a gray pixel (r`=g`=b`)

Y`=(0.299+0.587+0.114)r`=r`=b`

U = V = 0.

- Colour TV can be displayed on a black-and-white television by just using the Y` signal

Color Models in Video

YCbCr

- digital video mostly uses a matrix transform called **YCbCr** that is closely related to YUV
- Cb and Cr is the blue component and red component related to the chroma component

$$\begin{bmatrix} Y' \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.418688 & -0.081312 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} + \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix}$$

End of lecture