

## Color

### Conversion from RGB to CMY

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

#### 1. CMY to and from RGB

- a. Convert  $(0.25, 0.5, 0.75)_{\text{CMY}}$  to the same color in RGB  
It is  $(0.75, 0.5, 0.25)_{\text{RGB}}$
- b. What color is  $(1, 0, 1)_{\text{CMY}}$ ?  
It is  $(0, 1, 0)_{\text{RGB}}$   
So it is Green.
- c. What color is  $(1, 0, 1)_{\text{RGB}}$ ?  
It is  $(0, 1, 0)_{\text{CMY}}$   
So it is Magenta.

#### 2. How Many Colors?

Suppose we use unsigned 8-bit integers to represent the value of each color channel in an RGB value, so the range is between 0 and 255.

- a. How many unique colors can be represented?  
 $2^{24}$  which is approximately 16 million
- b. The human eye can distinguish approximately 10 million different colors. Consider your answer above and what you know about the relationship between RGB space and the CIE XYZ space. What is the relationship between the colors in RGB space and the set of colors perceivable by humans?  
You can represent more colors in RGB than humans can perceive but not all the colors humans can perceive.

### 3. HSV Color Space

#### Conversion from RGB color space to HSV color Space

To find the Hue (H) for color  $(R,G,B)_{\text{RGB}}$ :

$\text{maxRGB} = \max(R,G,B)$   
 $\text{minRGB} = \min(R,G,B)$   
 $D = \text{maxRGB} - \text{minRGB}$

$$S = (\text{maxRGB} - \text{minRGB}) / \text{maxRGB}$$
$$V = \text{maxRGB}$$

If  $\text{maxRGB} = R \rightarrow H = (G - B) / D$   
If  $\text{maxRGB} = G \rightarrow H = 2 + (B - R) / D$   
If  $\text{maxRGB} = B \rightarrow H = 4 + (R - G) / D$   
 $H = (60 * H) \bmod 360$

- a. What is the angle between red  $(1,0,0)_{\text{RGB}}$  and blue  $(0,0,1)_{\text{RGB}}$  on the HSV color wheel?

$(1,0,0)_{\text{RGB}} \rightarrow 0$  degrees and  $(0,0,1)_{\text{RGB}} \rightarrow 240$  degrees...so 240 degrees

- b. What is the angle between yellow and blue on the HSV color wheel?

Yellow is  $(0,0,1)_{\text{CMY}} = (1,1,0)_{\text{RGB}} \rightarrow 60$  degrees  
so the difference is 180 degrees

### 4. CIE XYZ Color Space

- a. Plot the location of the primaries of the XYZ color space on the chromaticity diagram below (e.g. what point corresponds to X).

$X \rightarrow (1,0)$

$Y \rightarrow (0,1)$

$Z \rightarrow (0,0)$

You can derive these by converting from X,Y,Z to x,y using:

$$x = \frac{X}{X + Y + Z}, \quad y = \frac{Y}{X + Y + Z}$$

- b. Draw a geometric figure showing all colors that can be formed by mixing green (at 520 nm) and blue (at 490nm).

It is a line between the 2 points.

