

# Computer Vision 1

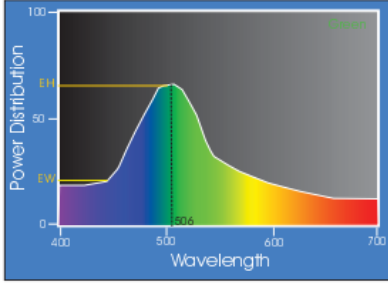
## Cheat Sheet

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## 1 Color Models

Color is part of the electromagnetic spectrum with energy in the range from 380 to 780 nm wavelength. Most of the colors we perceive are a mixture of wavelengths where the amount of energy at each wavelength is given by the spectral energy distribution (SED). When white light shines upon an object, some wavelengths are absorbed and other are reflected (a green object will reflect light with wavelength around 500nm, other wavelengths will be absorbed). The **hue** corresponds with the dominant wavelength of the SED; **saturation** is defined as the proportion of pure light with respect to white light needed to produce the color; **lightness** is the intensity of the reflected light meanwhile **brightness** is the intensity of the light source. Let  $EH$  be the dominant wavelength in the SED and  $EW$  the wavelength contributing to the white light, then the *hue* is equal to  $EH$ , the *saturation* equals to the difference  $EH - EW$  and the *lightness* equals to the area underlined by the SED.



Experiments have been conducted in which a human observer was asked to adjust three knobs which control the intensity of a three primary colors so to match the (perceived) color of the test light. The three primary lights were additively mixed in and the knobs' values were recorded yielding the so called color matching functions  $\bar{r}(\lambda)$ ,  $\bar{g}(\lambda)$  and  $\bar{b}(\lambda)$ . The problem with these was that a negative amount of at least one of the primaries was necessary to produce the full spectra. So the CIE proposed a mathematical transformation, the **XYZ** model, which uses another set of color matching functions:  $\bar{x}(\lambda)$ ,  $\bar{y}(\lambda)$  and  $\bar{z}(\lambda)$ .

The observer perceives color in terms of three color signals based on the trichromacy theory and can be modeled as:

$$C = \int_{\lambda} E(\lambda) S(\lambda) f_C(\lambda) d\lambda \quad (1)$$

where  $C \in \{R, G, B\}$ ,  $E$  is the SPD,  $S$  is the light reflected by objects and  $f_C$  is the color matching function. If we use  $\bar{x}$ ,  $\bar{y}$  and  $\bar{z}$  then we have the XYZ color space. To better represent graphically this color space we can compute the  $xyz$  values as follows:

$$x = \frac{X}{X + Y + Z} \quad y = \frac{Y}{X + Y + Z} \quad z = \frac{Z}{X + Y + Z} \quad (2)$$

where we factor out the intensity. Since the chromaticity values sum to unity, two elements are sufficient to represent a

color. When the  $x$  and  $y$  values are represented on a plane the chromaticity diagram is obtained. We can also infer the hue from the chromaticity diagram: first we need to select a reference white light, the hue is then the wavelength at the spectral curve that intersects the line from reference light through the color point to the spectral curve (this point is  $G_2$ ). If  $\|G_1\|$  is the distance from the color to the white light and  $\|G_2\|$  is the distance from  $G_2$  to the white source, then the saturation is given by  $\frac{\|G_1\|}{\|G_2\|}$ .

RGB values can be obtained using equation 1 and the  $\bar{r}$ ,  $\bar{g}$ , and  $\bar{b}$  color matching functions. The projection of RGB points on the rgb chromaticity triangle is defined by:

$$r = \frac{R}{R + G + B} \quad g = \frac{G}{R + G + B} \quad b = \frac{B}{R + G + B} \quad (3)$$

In the HSI chromaticity diagram, we compute hue and saturation in the following way: by assuming white light we define a reference point of  $r = g = b = 1/3$ , the saturation can then be computed as:

$$S_{rgb}(r, g, b) = \sqrt{(r - 1/3)^2 + (g - 1/3)^2 + (b - 1/3)^2} \quad (4)$$

or

$$S(R, G, B) = 1 - \frac{\min(R, G, B)}{R + G + B} \quad (5)$$

while the hue is given by:

$$H_{rgb}(r, g, b) = \arctan\left(\frac{r - 1/3}{g - 1/3}\right) \quad (6)$$

or

$$H(R, G, B) = \arctan\left(\frac{\sqrt{3}(G - B)}{(R - G) + (R - B)}\right) \quad (7)$$

A color invariant system contains color invariant models that are more or less insensitive to the varying image conditions. For matte surfaces  $RGB$  is sensitive to orientation while  $rgb$  is not (assuming constant white light).

## 2 Surface Reflection

## 3 Image Processing