Colour Models

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Introduction

A colour model is a mathematical model which usually consists of 3 or 4 components to represent each colour. The array of colours described by the model is called the 'Colour Space' [1]. Here are five useful colour models and how to convert between them.

RGB

Figure: RGB Model [1]

RGB is an additive model that works by adding Red, Green and Blue light to create different colours. A combination of all colours of light gives white, while the absence of all colour gives black. This model is used for displaying images on electronic devices such as computer and television screens. These three colours are the primary colours of light and capture a larger range of the human colour space than a similar model would using the primary colours red, blue and yellow. This is because mixing colours of light is not like mixing paint and does not create the wavelength of a new colour although our eyes interpret it that way.

CMYK

Figure: CYMK Model [1]

CYMK is a subtractive model that works by subtracting Red, Green and Blue light from a usually white background. Magenta represents the reduction of green light from white, cyan represents the reduction of red from white and yellow is the reduction of blue from white, and Key the reduction of all light. This model is often used for printing where you start with a light background, and adding ink essentially reduces the light that would naturally be reflected from the paper. Unlike RGB, which has a range of 3x256 values, CMKY has a range of 4x100 values.

Greyscale

A greyscale image is one where each pixel has a value representing its intensity, i.e. the amount of light it carries. Greyscale images are made up of shades of grey, with black having the lowest intensity and white the highest.
Numerical representation is a single fractional value between 0 and 1. In computers, that value is usually stored as a number between 0 and 255.

Python Computations

The conversion of the colour indigo between RGB: [75,0,130] and CMYK: [42,100,0,49] can be computed by the following python code:

Conversion

Greyscale conversion reduces the quantity of information in the image. In the majority of converted images, it is still possible to distinguish between different colours since most of the important information in the image is maintained. In order to transform an RGB image to grey-scale, we use the following conversion:

$$I_{grey-scale}(n,m) = \alpha I_{colour}(n,m,r) + \beta I_{colour}(n,m,g) + \gamma I_{colour}(n,m,b) \text{ [3].}$$

An RGB to greyscale conversion, and any other colour to greyscale conversion, however, is non-invertible.

RGB and CMYK are different colour spaces, and thus it is not possible to map a point in one of them exactly to a point in the other. There are formulas, however, that result in good approximations. These can be seen above in the Python Computations.

HSL/HSV to RGB:
Given a colour with hue $H \in [0^\circ, 360^\circ]$, $saturation_{HSL} \in [0,1]$, and lightness $L \in [0,1]$, we use the following steps:

$$C = (1 - |2L - 1|) \times S_{HSL}$$

$$H' = \frac{H}{60^\circ}$$

$$X = C \times (1 - |H' \mod 2 - 1|)$$

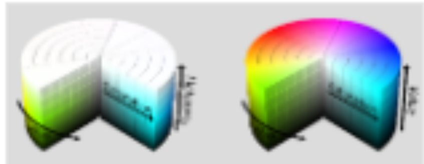
$$(R_1, G_1, B_1) = \begin{cases} (0,0,0) & \text{if H is undefined} \\ (C,X,0) & \text{if } 0 \le H' \le 1 \\ (X,C,0) & \text{if } 1 \le H' \le 2 \\ (0,C,X) & \text{if } 2 \le H' \le 3 \\ (0,X,C) & \text{if } 3 \le H' \le 4 \\ (X,0,C) & \text{if } 4 \le H' \le 5 \\ (C,0,X) & \text{if } 5 \le H' \le 6 \end{cases}$$

Finally, we can find R, G, and B by adding the same amount to each component, to match lightness:
$m = L - C/2$
$(R,G,B) = (R_1 + m, G_1 + m, B_1 + m)$ [6].
A similar approach is used for HSV to RGB by using the formula $C = V \times S_{HSV}$ to yeild the chroma and $m = V - C$ to match value.

HSL

HSL and HSV are alternative representations of the RGB model, and thus do not exist as unique colour spaces. HSL was developed as a representation of our visual perception of colour.

- Hue is the similarity of a visual stimulus to one of the basic perceived colours (red, blue, green, yellow) or to a combination of them. It ranges from 0 to 360 in degrees, where 0 is usually red.
- Saturation is the colourfulness of a stimulus in terms of its own brightness. It ranges from 0 to 1, with 1 as fully saturated and 0 as the equivalent grey.
- Lightness is the brightness of a visual stimulus relative to the brightness of a similarly illuminated white. It ranges from 0(black) to 1(white).



HSV

HSV, unlike HSL, was developed as a representation of the effect of mixing different paint colours together. In this model value and saturation are dependent on each other. Saturation ranges from white to fully saturated colour when value is at its highest. Similarly, value, like lightness, ranges from 0 to 1, where 0 is black and 1 is the chosen hue, which is only 0.5 for lightness.

References

[1] https://en.wikipedia.org/wiki/Color_space
[2] https://en.wikipedia.org/wiki/Color_model
[3] https://www.rapidtables.com/web/color/RGB_Color.html
[4] https://www.easycalculation.com/colorconverter/cmyk-rgb-color-convertor.php
[5] Fundamentals of Image Processing, Chris Solomon and Toby Breckon, Wiley-Blackwell, 2011, Section 4.5
[6] https://en.wikipedia.org/wiki/HSL_and_HSV