Random Experiments on Color Image Processing and Enhancement

Digital Image Processing

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Contents

1 Introduction

1.1 Brief Description

Color images existed long before the rise of computing and digital image processing. While most techniques of monochrome image processing such as blur and edge detection can be directly applied to color images, others require modification. Furthermore, there exists procedures specific only to color images. In this project, we try to implement some of these techniques and note down our findings.

1.2 Authors and Credits

The work has been undertaken by group number 8, whose members are listed in the following table.

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We would like to express our special thanks to Dr. Nghiêm Thị Phương, whose lectures gave us basic understanding on the key principles of digital image processing. The color image processing lecture notes from the UMSL's CS 5420 course [1] also help us gain initial intuition on the matter.

2 Color Spaces

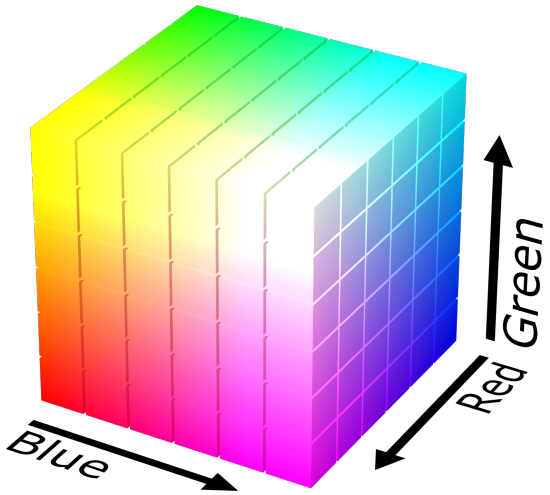
The color spaces in image processing aim to facilitate the specifications of colors in some standard way. Different color spaces suit different usage, namely RGB for computer display, CMYK for printing.

*`https://github.com/McSinyx/recipe`

2.1 RGB Color Model

The RGB color model is an additive color model [2]. The name of the model comes from the initials of the three additive primary colors, red, green, and blue.

The color subspace of interest is the cube shown in the figure below, in which red, green and blue values are at three corners; cyan, magenta and yellow are at three other and black is at the origin and white is at the corner farthest from the origin.



In this model, the gray scale (point of equal RGB values) extends from black to white along the line joining these two point. The different colors in this model are point on or inside the cube and are defined by vectors extending from the origin.

2.2 The CMY Color Model

Cyan, magenta and yellow are the secondary colors of light. For instance, cyan subtracts red light from reflected "white" light composed of equal amounts of red, green and blue light.

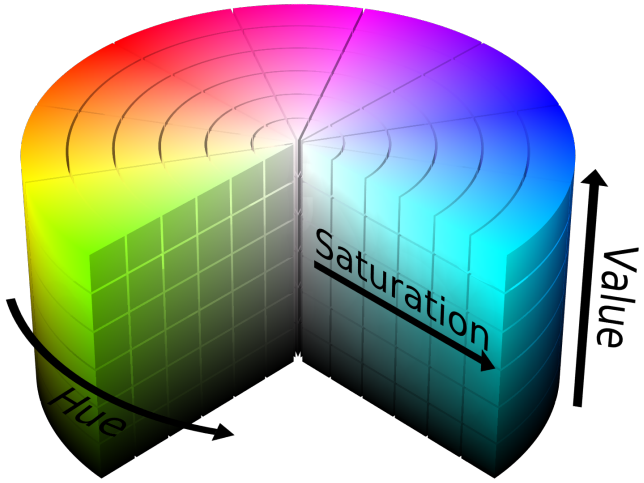
Most devices that deposit colored pigments on paper such as color printers and copies, require CMY data input or perform an RGB to CMY conversion

internally. Such conversion is performed using the following operation

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

2.3 The HSV Color Model

Additive colors models such as RGB or CMY as shown above are not well suited for describing colors in terms that are practical for human interpretation. When humans view a color object we describe it by its hue, saturation and brightness.



While hue is the dominant color as perceived by an observer (red, orange, or yellow), saturation is the relative purity of color—pure spectrum colors are fully saturated [1]. The definition of value is some what less trivial, and thus will be shown as Python code converting from BGR to HSV and vice versa[†]:

```
def bgr_to_hsv(b, g, r):
    """Convert a pixel in BGR to HSV."""
    minc, maxc = min(r, g, b), max(r, g, b)
    if minc == maxc: return 0.0, 0.0, maxc
    diff = maxc - minc
    sat = diff / maxc
```

[†]This is taken from Python standard library `colorsys`, and adapted from RGB to BGR for OpenCV usage.

```
    rc, gc, bc = (maxc-r)/diff, (maxc-g)/diff, (maxc-b)/diff
    if r == maxc: return (bc-gc)/6%1, sat, maxc
    if g == maxc: return (2.0+rc-bc)/6%1, sat, maxc
    if b == maxc: return (4.0+gc-rc)/6%1, sat, maxc

def hsv_to_bgr(h, s, v):
    """Convert a pixel in HSV to BGR."""
    if s == 0.0: return v, v, v
    f = h * 6 % 1
    p = v * (1 - s)
    q = v * (1 - s*f)
    t = v * (1 - s*(1 - f))
    i = int(h*6%6)
    if i == 0: return p, t, v
    if i == 1: return p, v, q
    if i == 2: return t, v, p
    if i == 3: return v, q, p
    if i == 4: return v, p, t
    if i == 5: return q, p, v
```

To use these with images whose pixels stored as 8-bit unsigned integers, we decorate them with

```
def hhu(func):
    return lambda a, b, c: [
        int(i*255) for i in func(a/255, b/255, c/255)]
```

then the conversion of images stored as NumPy arrays of `uint8` will be as trivial as

```
from itertools import starmap
from numpy import reshape, uint8

def convert_color(image, func):
    x, y, z = image.shape
    return reshape(list(starmap(func, reshape(image, (x*y, z)))),
                   (x, y, z)).astype(uint8)
```

As a simple test, conversion back and forth should give the same image: `convert_color(convert_color(image, bgr_to_hsv), hsv_to_bgr)`. We noticed that our implementation in pure Python is significantly slower than OpenCV's `cvtColor` which is from a C extension module.

3 Color Image Enhancements

3.1 Chromatic Aberation Mitigation

Chromatic Aberation is a failure of a lens to focus all colors to the same point. The fringes are more obvious in pictures taken using cheaper lenses. Since this is lens-dependent, mitigation is not as easy as we first thought. That being said, detection of such degration is not difficult

3.2 White Balancing

Assuming we have a good distribution of colors in the image, the average reflected color should be the color of the light. If the light source is assumed to be white, we would know how much white-point should be moved in the color cube.

The grayworld assumption compensation is an approximation of the measurement taken by digital still and video cameras by capturing an evenly lit white sheet of paper or similar.

```
def grayworld_assumption(img):
    result = cvtColor(img, COLOR_BGR2LAB)
    avg_a = average(result[:, :, 1])
    avg_b = average(result[:, :, 2])
    result[:, :, 1] = (result[:, :, 1]
                       - (avg_a-128)*(result[:, :, 0]/255)*1.1)
    result[:, :, 2] = (result[:, :, 2]
                       - (avg_b-128)*(result[:, :, 0]/255)*1.1)
    result = cvtColor(result, COLOR_LAB2BGR)
```

```
return result
```

The CIE LAB color space is used because much greater shifts could be made, color shifts do not affect contrast and contrast shifts in turn don't affect color. It expresses color as three values:

- L* for the lightness from black (0) to white (100)
- a* from green to red
- b* from blue to yellow.

First, the average values are calculated for a* and b* channels. The OpenCV library LAB color space is not interpreted as CV internal conventions for LAB definition 8-bit color depth. So, the conversions are done as:

- L* : $\frac{L * 255}{100}$
- a* : a + 128
- b* : b + 128

The colors in a and b channels are then shifted relative to their lightness level. The 1.1 overshoot is because we cannot be sure to have gotten the data in the first place.

$$a_{\text{shift}} = a * \frac{L}{100} * 1.1$$

The resulting image is quite enhanced compared to the original.

4 Pseudo Color Rendering

By mapping each intensity level to a color, one may derive a pseudo color image from a greyscale images. Typical usage of such technique is in thermal imaging, elevation and medical imaging to help the human visual system pick out detail, estimate quantitative values, and notice patterns in data in a more intuitive fashion [3].

In OpenCV, this is available under `applyColorMap`. It is also trival to reimplement this function only using NumPy:

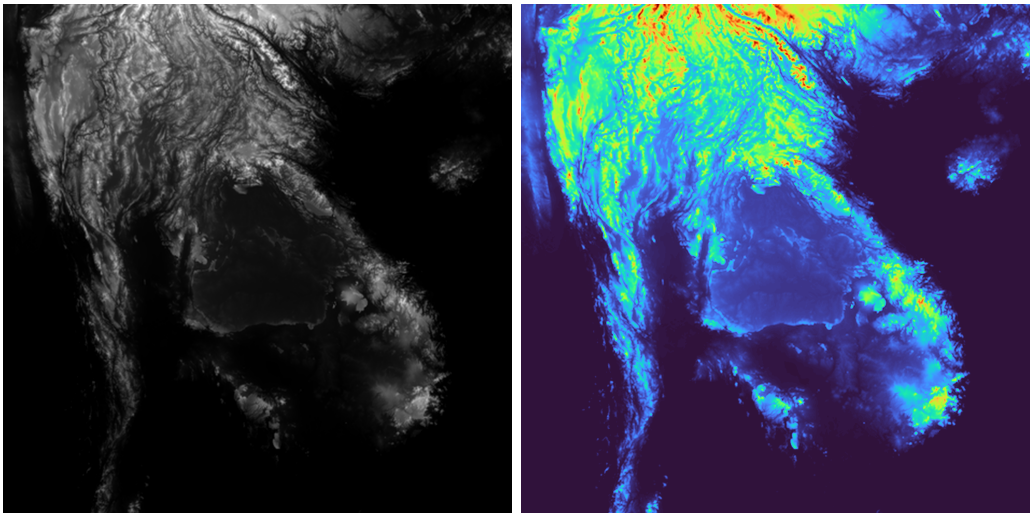
```
import numpy as np

def map_color(grey, mapping):
    r = np.vectorize(lambda i: mapping[i][0])
    g = np.vectorize(lambda i: mapping[i][1])
    b = np.vectorize(lambda i: mapping[i][2])
    # OpenCV uses BGR by default for whatever reason.
    return np.stack((b(grey), g(grey), r(grey)), axis=-1)
```

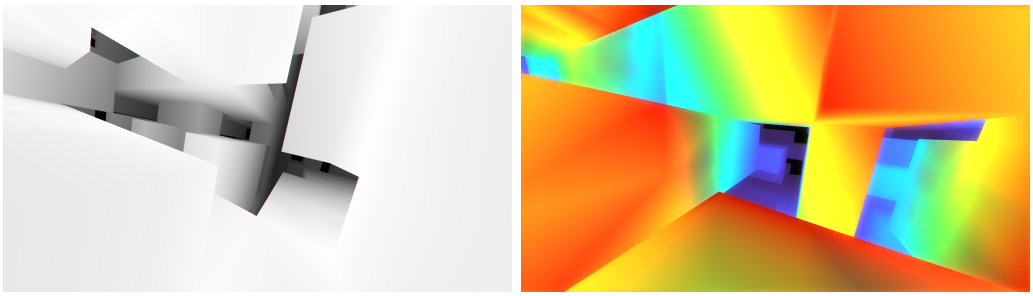
For demonstration, we are going to use the Turbo colormap [3]. We initially considered solely changing the hue based on intensity, which is also known as the rainbow map, however it is not a visually intuitive mapping [4].

Firstly, we tried to apply the mapping on the heightmap of mainland Vietnam and its neighboring regions[‡]. As seen in the side-by-side comparison, the colormapped image allows the human eyes to notice more details, especially the high mountains in the north and the Khorat Plateau (center of the image).

[‡]The original images are taken from heightmapper: `https://tangrams.github.io/heightmapper/`



In addition, we experimented with pseudo lighting, that is, use colormaps in place of normal greyscale lighting. The experiment was carried out on Phong's game Axuy, where colormapping proved to be an enhancement on helping players detecting shooting range (Axuy is a first person shooter game). The video where the game is in action is available on YouTube[§].



5 Conclusion

Through working on these experiments, we have gained certain understandings on color image processing, as well as improving our skills in Python and NumPy and OpenCV. It was also concluded that very often, in practice it is not a wise idea to write lower-level image processing code in Python—C/C++ or even Cython would be much better performance-wise.

[§] `https://www.youtube.com/watch?v=QVGAaoordpk`

6 References

[1] Sanjiv K. Bhatia. "Color Image Processing". *CS 5420: Digital Image Processing*. University Of Missouri—St. Louis, Fall 2018.

[2] Robert Hirsch. *Exploring Colour Photography: A Complete Guide*. Laurence King Publishing, 2004. ISBN 1-85669-420-8.

[3] Anton Mikhailov. *Turbo, An Improved Rainbow Colormap for Visualization*. Google AI Blog, August 20, 2019.

[4] Noeska Smit. *Rainbow Colormaps—What are they good for? Absolutely nothing!* medvis.org, August 21, 2012.