Processing Color Images

Color perception: hue, saturation, lightness
- Hue: distinguishes among colors
- Saturation: how much whites mixed, how pure the color is
- Lightness: perceived intensity of reflecting/self-luminous object

Tri-stimulus theory: 3 types of color sensors, combination of cone cell stimulations gives perception of color

CIE XYZ Primaries — (X, Y, Z) three standard primaries
Color-matching functions:

$$X = k\int P(\lambda)\bar{x}_\lambda d\lambda, \quad Y = k\int P(\lambda)\bar{y}_\lambda d\lambda, \quad Z = k\int P(\lambda)\bar{z}_\lambda d\lambda$$

Chromaticity values
Projection to 2D — X+Y+Z = 1

$$x = \frac{X}{X+Y+Z}, \quad y = \frac{Y}{X+Y+Z}, \quad z = \frac{Z}{X+Y+Z} = 1 - x - y$$

- x = y = z = 1/3 —> standard white light
- Edge is saturated (spectral colors)

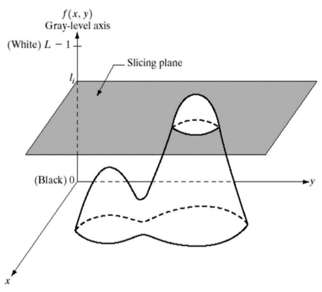
Color representation

- RGB
- HSV

24-bit each color —> three two hex digit value
FF0000 —> pure red
000000 —> black
FFFFFF —> white

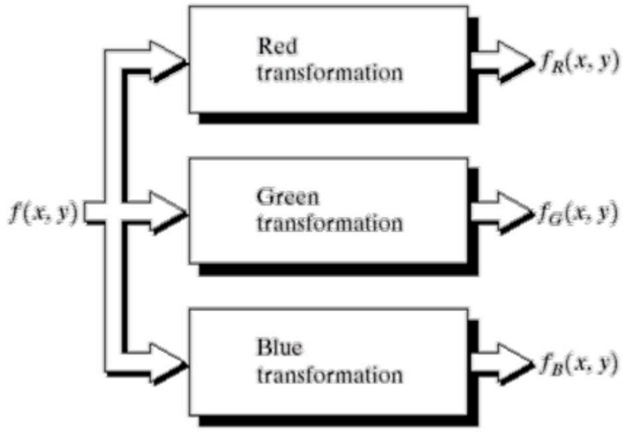
Pseudo-color image processing (Intensity slicing, Intensity to color)
Pseudo-color image processing: assign colors to grey values
Method: Intensity slicing

1. Intensity slicing:



过程: grey levels are from 0 to L-1, set p planes for different intensities (I1, ... Ip). These planes partition the grey level into p+1 intervals. For each interval, set a different color.

2. Intensity to color
Three separate transformations of the pixel value to give r, g, b values for the colored pixel



Full-color image processing
- Process each color component individually (Per-color-component processing)
- Work with color pixels directly (Vector-based processing)

Color Transformation
Processing the components of a color image within the context of a single color model

RGB, YUV, CMY(K), YIQ
- RGB: additive primaries, used in monitors
- CMY: subtractive primaries, used in printers
- CMYK: rich in black, black costs lower
- HSV: intuitive understanding
- YIQ: I and Q generate colors, Y is intensity, used in color TV broadcasting

RGB <—> CMY

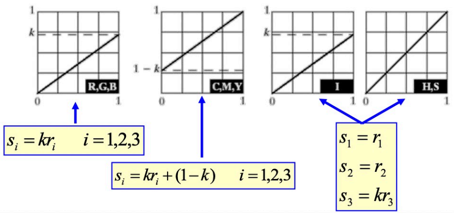
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}, \quad \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

RGB <—> CMYK

$$K := \min(C, M, Y)$$
$$C := C - K$$
$$M := M - K$$
$$Y := Y - K$$

Color image intensity
e.g. Reduce the intensity be 30%, values are multiplied by 0.7

$$g(x,y) = kf(x,y)$$



Color complements
Color complements: opposite colors on color wheel
Color complement value: 255 - current value

Color slicing
Color slicing: highlight a specific range of colors
原理： color of interest —> standout, replace all colors outside the selected range by a neutral color (mid-grey)

1. Colors of interest are enclosed by ***cube*** (or ***hypercube*** for n>3)

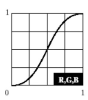
$$s_i = \begin{cases} 0.5 & if \left[|r_j - a_j| > \frac{W}{2} \right]_{any 1 \le j \le n} \\ r_i & otherwise \end{cases}, \quad i = 1,2,\ldots,n$$

2. Colors of interest are enclosed by ***Sphere***

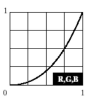
$$s_i = \begin{cases} 0.5 & if \sum_{j=1}^{n} (r_j - a_j)^2 > R_0^2 \\ r_i & otherwise \end{cases}, \quad i = 1,2,\ldots,n$$

Tone and color correction
Tonal range: key-type —> general distribution of color intensities
- High-key images: most of information is concentrated at high intensities
- Low-key images: most of information is concentrate at low intensities
- Middle-key: most of information concentrate in between

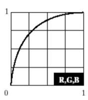
Tone correction
Middle-key



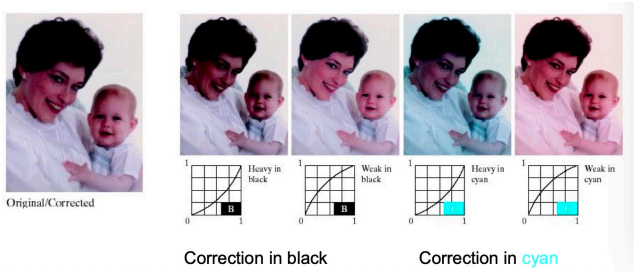
High-key



Low-key



Color balancing (correction)
基本思想:
The proportion of any color can be increased by
1. Decrease the amount of the complementary color in the image
2. Increase the adjacent colors (immediate two)
3. Decrease the adjacent complement (immediate two)



Histogram equalization on intensity (HSV)
Histogram equalizing the intensity (not change H, S)
Histogram equalization on HSV: (reason)
This maintains the color balance while allowing the intensities to be adjusted

Smoothing
基本原理：average the pixel values

In HSV: only apply the smoothing filter to the intensity component
In RGB: apply the smoothing filter respectively to R, G, B color channel, using a mask that gives each pixel a new value that is the average of surrounding pixels.
The advantage for HSV over RGB:
1. Smoothing in RGB color space averages color pixel values —> color of each pixel being the average of the color of the neighbors
2. HSV: the color and saturation of each pixel remains unchanged

Sharpening
In RGB: apply laplacian to each color plane in RGB
In HSV: apply laplacian to the intensity component in HSV

Segmentation
Segmentation usually performed in HSV color space as this separates color as a separate component

Summary

CIE XYZ Primaries
Chromaticity values: X+Y+Z = 1
CIE chromaticity diagram
Color representation: three two hex digit
e.g. FF0000 —> purest red

Pseudo-color image processing — assign color to grey values
- Intensity slicing
- Intensity to color

Full-color image processing
- Per-color-component processing
- Vector-based processing

Color Transformation
Processing components of color image within the context of single color model

Color transformations
RGB, CMY(K), HSV, YIQ
RGB: used in monitor, additive
CMY: used in printers, subtractive
CMYK: used in printers, rich in black, black cost lower
HSV: intuitive understanding
YIQ: color TV broadcasting (I,Q — color, Y — intensity)

Change image intensity
Color complements
Color slicing (cube, sphere)
Tone correction —> tone-range/key-type (high, medium, low-key)
Color balancing (3 ways)
Histogram equalization on intensity (HSV): —> median change, saturation correction
- Why use HSV: maintains the color balancing while allowing the intensities to be adjusted (equalized)

Smoothing
    In RGB: 1. Respectively 2. Mask —> average of the surrounding pixels
    In HSV: only on intensity component
    HSV over RGB (advantage): 1. RGB —> color average of … 2. HSV, hue, saturation remains unchanged

Sharpening: In RGB, In HSV
Segmentation: usually in HSV —> separate color component

Practice

b) This question is about **Colour processing**.

[8 marks]

i) When using histogram correction of colour images, what colour space would you use? Give the reason for using this colour space.

(2 marks)

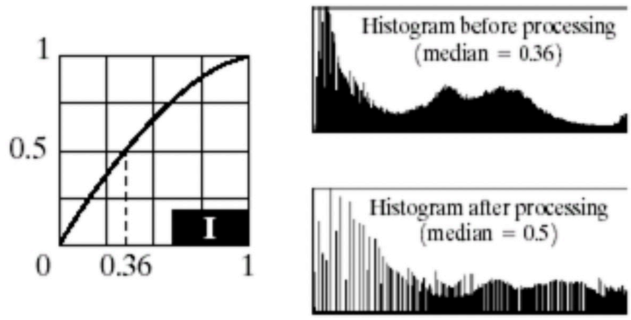
ii) Explain, including relevant diagrams, how the technique would be used for correcting intensity.

(4 marks)

iii) What problem would this produce in the resulting image and how could this be corrected?

(2 marks)

(1) I will use HSV color space. The reason is that we only apply the histogram correction to the intensity component of HSV and it maintains the color balancing while allows the intensity to be adjusted
(2) Take the medium of the intensity value before processing and draw a curve that makes the median to 0.5 after goes through (0,0) and (1,1). Use this lookup table to adjust intensity component
(3) There will be less perception of color. The saturation value can be increased to compensate



b) This question is about **Colour processing**.

[5 marks]

i) Explain, including a diagram, how intensity slicing is used to give pseudo colours to improve understanding of images such as temperature maps.

(3 marks)

ii) Give **FOUR** examples of operations that perform colour processing.

(2 marks)

(1) The intensity slicing basically slice the grey level (0, L-1) with p intensities and create p+1 intervals. In this case, each interval can be assigned to a different color. According to the temperature maps, as to keep pace with the human conventional thinkings, blue are regarded as cold (low temperature), red are regarded as hot (high temperature), we can leveling the temperature into several internals and assign a proper color for different intervals.

(2) Change the image intensities, color complements, histogram equalization on intensities, tone correction, color balancing, color image smoothing, color image sharpening