Chapter 6
Color Image Processing

Isaac Newton, 1666

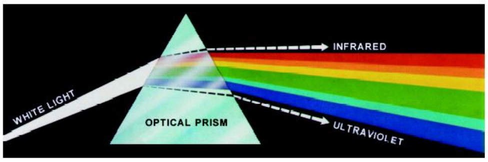

FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

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Color Image Processing

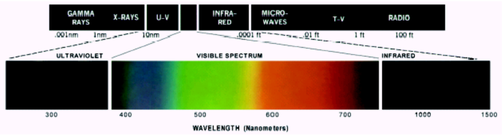


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

Chapter 6
Color Image Processing: Color Image Representation

Color images can be represented by an intensity function $C(x,y,\lambda)$ which depends on the wavelength λ of the reflected light. (so, for fixed λ, $C(x,y,\lambda)$ represents a monochrome image).

As in the monochrome case, $0 < C(x,y,\lambda) < C_{max}$

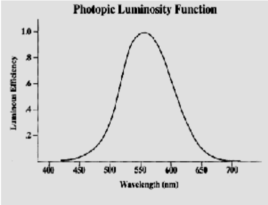
The brightness response of a human observer to an image will therefore be

$$f(x,y) = \int_0^\infty C(x,y,\lambda)\, V(\lambda)\, d\lambda$$

where $V(\lambda)$ is the response factor of the human eye at frequency λ.

$V(\lambda)$ is called the relative luminous efficiency function of the visual system. For the human eye, $V(\lambda)$ is a bell-shaped function, see plot next slide.

Relative Luminous Efficiency Function



Ref.: http://www.reefnet.on.ca/gearbag/wwwlux.html

Chapter 6
Color Image Processing: Color Image Representation

Recall that the 6-7 million cones (sensors) in the human eye are responsible for color vision, see Chapter 2.

Experimental evidence shows that theses can be divided into three principal sensing categories corresponding to roughly red, green and blue: (65% of cones are sensitive to RED, 33% to GREEN and 2% to blue)

We, therefore, have three brightness response functions:

$$f_R(x,y) = \int_0^{\infty} C(x,y,\lambda)\, V_R(\lambda)\, d\lambda$$

$$f_G(x,y) = \int_0^{\infty} C(x,y,\lambda)\, V_G(\lambda)\, d\lambda$$

$$f_B(x,y) = \int_0^{\infty} C(x,y,\lambda)\, V_B(\lambda)\, d\lambda$$

The three relative luminous efficiency functions are plotted in the next slide.

Chapter 6
Color Image Processing

1965 Experimental curves:

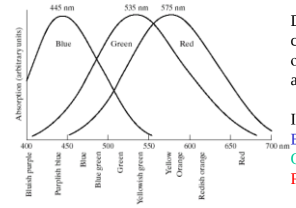


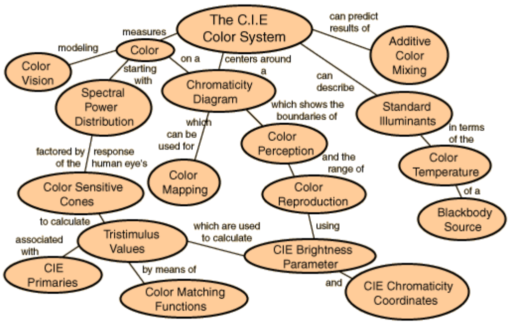
FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

Due to these absorption characteristics, colors are seen as variable combinations of so called “primary” colors red, green and blue.

In **1931**, CIE designated the following:
Blue = 435.8nm;
Green = 546.1nm; and
Red = 700nm

- Remember that there is no single color called red, green or blue in the color spectrum!
- Also, these fixed RGB components cannot generate ALL spectrum colors!

C.I.E Color Standardisation (1931)


The C.I.E Color System
measures
Color
modeling
Color Vision
starting with
Spectral Power Distribution
factored by the human eye's response
Color Sensitive Cones
to calculate
Tristimulus Values
associated with
CIE Primaries
by means of
Color Matching Functions
which are used to calculate
CIE Brightness Parameter
and
CIE Chromaticity Coordinates
on a
centers around a
Chromaticity Diagram
which can be used for
Color Mapping
which shows the boundaries of
Color Perception
and the range of
Color Reproduction
using
can predict results of
Additive Color Mixing
can describe
Standard Illuminants
in terms of the
Color Temperature
of a
Blackbody Source

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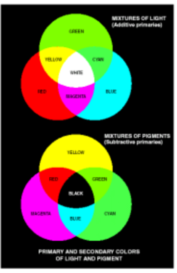
Color Image Processing

Primary colors can be added in pairs to procude secondary colors of light: e.g. magenta, cyan and yellow.
Mixing the three primaries produces white color.

A primary color of pigments or colorants is defined as one that Subtracts or absorbs a primary color of light and reflects the other two.



primary colors of pigments are magenta, cyan and yellow and their secondary colors are red, green and blue

a
b

FIGURE 6.4 Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp Business Division.)

Chapter 6
Color Image Processing: Color Image Representation

Tristimulus Values (X,Y,Z)

Are the amounts of red, green and blue needed to form any particular color.

A color is specified by its trichromatic coefficients defined as:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

Note that $x+y+z = 1$! (i,e. only two of the trichromatic coefficients are independent.)

Experimental curves and tables are used to find the tristimulus values needed to generate a given color.

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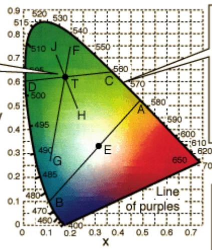
The combination of light wavelengths to produce a given perceived color is not unique. The pairs CD, FG and JH can each produce the color T if combined in the right proportions.



The solid line outline encompasses all the hues that are perceivable to the normal human eye. The horseshoe shaped curve contains the spectral colors. The straight line at the bottom is the line of purples.

Any point within the curve represents a unique perceivable hue. But there are many combinations that will produce that hue.

E is the achromatic point. AB or any pair for which the connecting line passes through E can form a complementary color pair.

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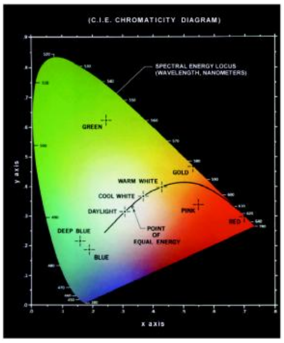
Color Image Processing

Alternatively, one can use the chromaticity diagram to specify colors, e.g. the CIE chromaticity diagram shown here. (this is a 2-D red-green plot, but remember the last equation in the previous slide!

Ex: the point shown as GREEN is made of 62% green, 25% red and 13% blue.

FIGURE 6.5 Chromaticity diagram. (Courtesy of the General Electric Co., Lamp Business Division.)



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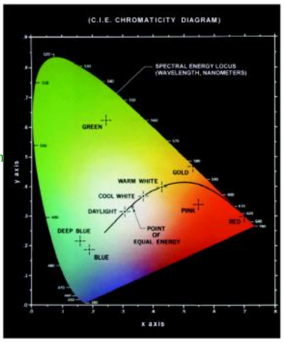
Color Image Processing

FIGURE 6.5 Chromaticity diagram. (Courtesy of the General Electric Co., Lamp Business Division.)

- Pure colors are mapped on the boundary of the chromaticity diagram, fully saturated colors
- Colors inside the diagram as combinations of these colors
- Reference white is the point of equal energy, with zero saturation value

The diagram is useful for color mixing, e.g.

- a straight line joining any two points defines all colors generated by adding those colors,
- in particular, if one of these points is reference white and the other is some color on the boundary, then the colors on the line in-between represent all the shades of that particular spectrum color



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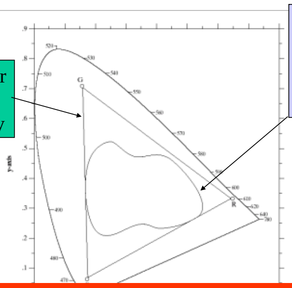
Color Image Processing



Typical color gamut of an RGB display

color gamut of a high quality color printer, irregular shape is due to additive and subtractive color combinations

Remember that due to the shape of the chromaticity diagram, no fixed three colors can reproduce all colors inside the diagram!

(irregular region).

Chapter 6
Color Image Processing: Color Models

Color models or color spaces refer to a color coordinate system in which each point represents one color.

Different models are defined (standardized) for different purposes, e.g.

Hardware oriented models:

- RGB for color monitors (CRT and LCD) and video cameras,
- CMYK (cyan, magenta, yellow and black) for color printers

Color manipulation models:

- HSI (hue, saturation and brightness) is closest to the human visual system
- Lab is most uniform color space
- YCbCr (or YUV) is often used in video where chroma is down-sampled (recall that the human visual system is much more sensitive to luminance than to color)
- XYZ is known as the raw format
- others

Two important aspects to retain about color models:

1. conversion between color models can be either linear or nonlinear,
2. some models can be more useful as they can decouple color and gray-scale components of a color image, e.g. HSI, YUV.

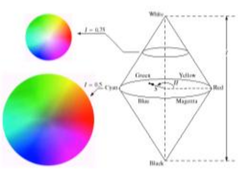
Chapter 6
Color Image Processing: Color Image Representation

Three Perceptual Measures

1. **Brightness**: varies along the vertical axis and measures the extent to which an area appears to exhibit light. It is proportional to the electromagnetic energy radiated by the source.

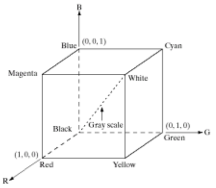
2. ***Hue****:* denoted by H and varies along the circumference. It measure the extent to which an area matches colors red, orange, yellow, blue or purple (or a mixture of any two). In other words, hue is a parameter which distinguishes the color of the source, i.e., is the color red, yellow, blue, etc.

3. **Saturation**: the quantity which distinguishes a pure spectral light from a pastel shade of the same hue. It is simply a measure of white light added to the pure spectral color. In other words, saturation is the colorfulness of an area judged in proportion to the brightness of the object itself. Saturation varies along the radial axis.



Chapter 6
Color Image Processing: RGB Color Model

FIGURE 6.7 Schematic of the RGB color cube. Points along the main diagonal have gray values, from black at the origin to white at point (1, 1, 1).



The eight vertices of the cube are occupied by
red, green and blue;
magenta, cyan and yellow;
and finally black and white.
(RGB values have been normalised in the range [0,1])

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Color Image Processing

FIGURE 6.8 RGB 24-bit color cube.

Pixel depth refers to the number of bits used to represent each pixel in the RGB space

If each pixel component (red, green and blue) is represented by 8 bits, the pixel is said to have a depth of 24 bits.

A **full-color** image refers to a 24-bit RGB color image. The number of possible colors in a full-color image is:

$$(2^8)^3 = 16{,}777{,}216 \text{ colors (or 16 million colors)}$$

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Color Image Processing

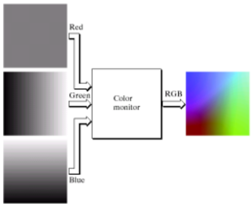

FIGURE 6.9 (a) Generating the RGB image of the cross-sectional color plane (127, G, B). (b) The three hidden surface planes in the color cube of Fig. 6.8.

An example showing how to generate the RGB image for the cross-sectional color plane (127,G,B)
Note that each plane is represented as a gray-scale image.

Note: color image acquisition is the reverse process, i.e. three filters are used, each is sensitive to each of the three primary colors

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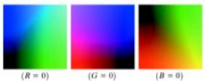
Color Image Processing

FIGURE 6.8 RGB 24-bit color cube.

RGB color cube



The hidden surfaces of the cube

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Color Image Processing

A subset of these colors is called *all-systems-safe* colors. In Internet applications they're called *safe Web colors* or *safe browser colors.*
These are colors which are reproduced faithfully independent of the display capability.
These are 216 colors made with combinations of component values 0,51,102,153,204 and 255

Number System	Color Equivalents					
Hex	00	33	66	99	CC	FF
Decimal	0	51	102	153	204	255

TABLE 6.1 Valid values of each RGB component in a safe color.

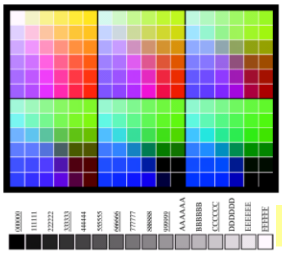

FIGURE 6.10 (a) The 216 safe RGB colors. (b) All the grays in the 256-color RGB system (grays that are part of the safe color group are shown underlined).

all the grays in the 256-color system

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Color Image Processing

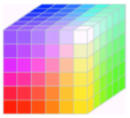

FIGURE 6.11 The RGB safe-color cube.

Unlike the color cube which is solid, the safe-color cube above has valid colors only on the surface planes (36 colors per plane for a total of 216 colors).

Chapter 6
Color Image Processing: Color Models

CMY and CMYK Color Models

Most devices that deposit color pigments on paper, e.g. printers and copiers, use CMY inputs or perform RGB to CMY conversion internally:

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

Recall that all color values have been normalised in the range [0,1].

Remarks:

1. Note that, e.g. a surface coated with cyan does not contain red, that is C = 1 – R.
2. Since equal amounts of the pigment primaries should produce black, in printing this appears as muddy-looking black; therefore, a fourth color, black is added, leading to CMYK color model (four-color printing).

Chapter 6
Color Image Processing: Color Models

HSI Color Model

Although RGB and CMY color models are very well suited for hardware and RGB reflects well the sensitivity of the human eye to these primary colors, both are not suited for describing color in a way that is easily interpreted by human.

When human see a color object, they tend to describe it by its hue, saturation and brightness, i.e. HSI model is used

In addition, HSI decouples brightness from the chroma components.

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Color Image Processing

Perceptual relationship between RGB and HSI color models

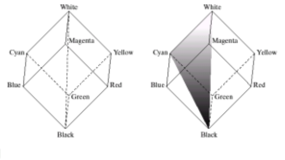

FIGURE 6.12 Conceptual relationships between the RGB and HSI color models.

- Note that the intensity increases from black to white
- All points along the intensity axis are gray and thus have 0 saturation value.
- Saturation increases as a function of the distance from the intensity axis
- The shaded region has a single color, cyan, with different shades, rotating it wrt to intensity axis results in a new hue value (new color)

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Color Image Processing

In fact, HSI is represented by a vertical intensity axis and the locus of color points lying on planes ⊥ to this axis. The boundary of these planes defined by the intersection with the faces of the cube is either hexagonal or triangular, see below.

Note also that primaries are separated by 120

For visualization purposes, can also display the boundary as a circle!

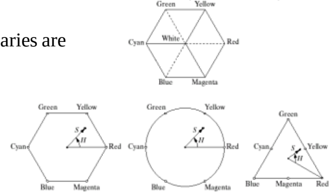

FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.

Chapter 6
Color Image Processing: Color Models

HSI-RGB Color Model Conversions
From RGB to HSI:

the hue is: $$H = \begin{cases} \theta & if \quad B \le G \\ 360 - \theta & if \quad B > G \end{cases}$$

with $$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}} \right\}$$

the saturation: $$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)]$$

and the intensity is: $$I = \tfrac{1}{3}(R+G+B)$$

It’s assumed that RGB values are normalised and Θ is measured wrt red axis see Fig. 6.13.

Conversion from HSI to RGB depends on which sector H is located, see details in Eqs. 6.2-5 – 6.2-15.

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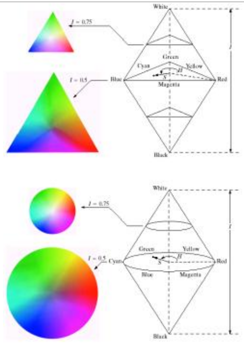
Color Image Processing

a
b

FIGURE 6.14 The HSI color model based on (a) triangular and (b) circular color planes. The triangles and circles are perpendicular to the vertical intensity axis.

HSI color model with different intensity levels and different cross section shapes.



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Color Image Processing

The HSI components of the RGB 24-bit color cube image are shown below.

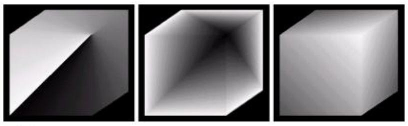
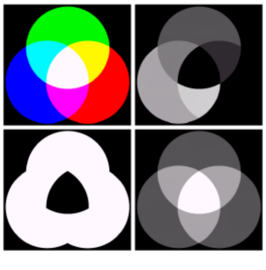


FIGURE 6.15 HSI components of the image in Fig. 6.8. (a) Hue, (b) saturation, and (c) intensity images.

Chapter 6
Color Image Processing: Manipulating HSI Component Images



RGB image composed of primary and secondary colors

Hue component

Notice how red is mapped to black since its hue is 0

Saturation component

Intensity component

Idea: can change any of these color components independently by Changing the gray levels of that component.

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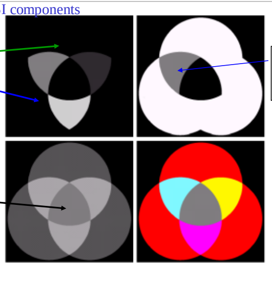
Color Image Processing

Example of modifying HSI components



Modified hue where blue and green are set to 0

Modified saturation where saturation of the cyan region is halved

Modified intensity where intensity of the central white region is halved

Finally, this is the modified HIS image converted back to RGB.

Note how the outer circles became red, cyan saturation is reduced and white central region became gray.

HSI color model allows independent control over the hue, Saturation and intensity values.

Stop/Resume

Chapter 6
Pseudo-color Image Processing

- Pseudocolor or false color image processing consists of assigning (false) colors to gray level values based on some specific criterion.
- Goal and Motivation
  - improve human visualization
    - human can distinguish at most 20-30 gray shades but thousands of colors!
  - attract attention
- Major techniques
  - intensity slicing
  - gray level to color transformation

Chapter 6
Color Image Processing: **Intensity slicing**

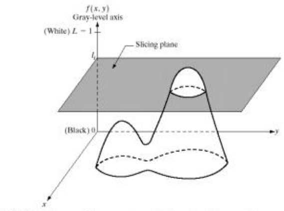


FIGURE 6.18 Geometric interpretation of the intensity-slicing technique.

assign different colors to levels above and below the slicing plane

usually, several levels are used.

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Color Image Processing

can think of intensity slicing as another form of quantisation in which the construction levels are different colors, see below.

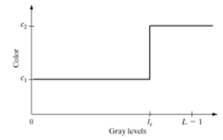

FIGURE 6.19 An alternative representation of the intensity-slicing technique.

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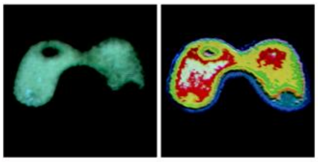
Color Image Processing

a simple example is shown below, a b&w image of the Picker Thyroid Phantom (a radiation test pattern). It´s difficult to see the details of gray level variations in some areas. Intensity slicing improves visualization.



a b

FIGURE 6.20 (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)

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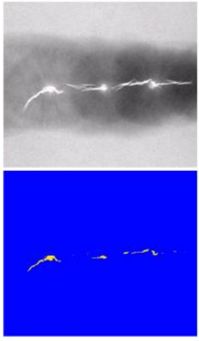
Color Image Processing

a
b

FIGURE 6.21 (a) Monochrome X-ray image of a weld. (b) Result of color coding. (Original image courtesy of X-TEK Systems, Ltd.)



another example: a weld cracks are much better seen in the pseudocolored image below by human inspector.

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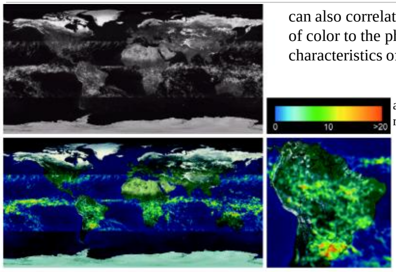
Color Image Processing

can also correlate the choice of color to the physical characteristics of the image



average monthly rainfall

a b
c d

FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South America region. (Courtesy of NASA.)

Chapter 6
Color Image Processing: Gray level to color transformation

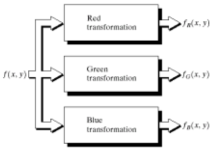


FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_R, f_G, and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

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Color Image Processing

(b) good color separation for background, garmet bag and explosives; however, backgrd and explosives are assigned the same color due to the trans-formation used.

(a) original X-ray

(c) explosives and garmet bag have been nearly the same color, an observer can see through the hidden explosives!

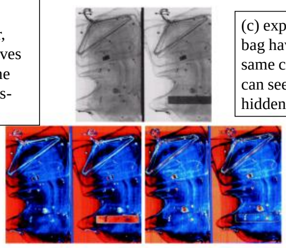
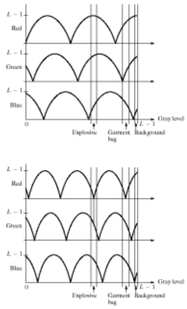


FIGURE 6.24 Pseudocolor enhancement by using the gray-level to color transformations in Fig. 6.25. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)

Chapter 6
Color Image Processing: transformations used

produced image (b) in the previous example.

produced image (c) in the previous example.



note the phase and frequency changes in the transformations produces different colors

FIGURE 6.25 Transformation functions used to obtain the images in Fig. 6.24.

Chapter 6
Color Image Processing: **multi-spectral images**

Many images are multispectral, i.e. they have been acquired by different sensors at different wavelengths. Combining them to obtain a color image can be achieved as follows:

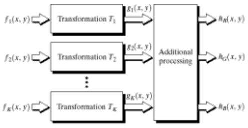


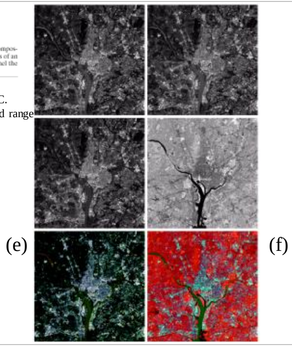
FIGURE 6.26 A pseudocolor coding approach used when several monochrome images are available.

additional processing may include color balancing, combining images and selecting three of them for display, etc.

Chapter 6
Color Image Processing: **example**

FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (c) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral images courtesy of NASA.)

(a)-(d) 4 spectral satellite images of Washington, D.C.
(a)-(c) are in visible range while (d) is in the infra-red range



(e) is obtained by combining (a)-(c) into an RGB image;

while (f) by combining
(a), (b) and the near infra-red (d).

Chapter 6
Color Image Processing: Galileo pictures of the moon Io

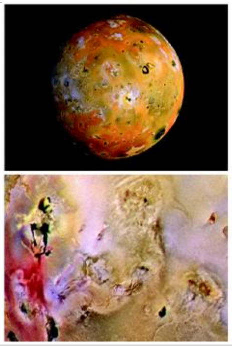
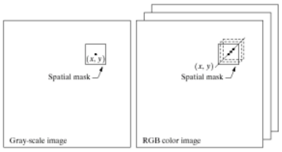


FIGURE 6.28 (a) Pseudocolor rendition of Jupiter Moon Io. (b) A close-up. (Courtesy of NASA.)

a beautiful close-up!

Chapter 6
Color Image Processing:
Basic Full Color Image Processing

FIGURE 6.29 Spatial masks for gray-scale and RGB color images.



a color image is multi-valued, i.e. in RGB, each pixel has 3 values

consider the following color transformation:

$$g(x,y) = T[f(x,y)]$$

let r_i and s_i denote the color components of f and g, respectively,

$$s_i = T_i(r_1, r_2, \ldots, r_n) \quad where\, n = 3\, or\, 4$$

Chapter 6
Color Image Processing

FIGURE 6.30 A full-color image and its various color-space components. (Original image courtesy of Med-Data Interactive.)

result of scanning full color image above (in CMYK)

conversion to RGB

conversion to HSI

notice that all components are normalized to 0 (black) and 1 (white).

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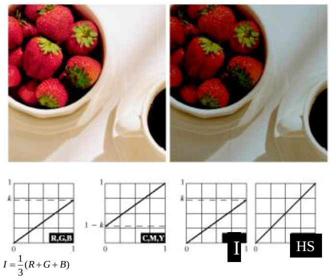
Color Image Processing

Example: decrease intensity component by 30%. In RGB and CMY, must apply transformation to all components, on the other hand, in HSI, only I component is transformed.



a b
c d e

FIGURE 6.31 Adjusting the intensity of an image using color transformations. (a) Original image. (b) Result of decreasing its intensity by 30% (i.e., letting $k = 0.7$). (c)–(e) The required RGB, CMY, and HSI transformation functions. (Original image courtesy of MedData Interactive.)

recall $I = \frac{1}{3}(R + G + B)$

Chapter 6
Color Image Processing: **color complements**

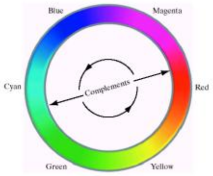
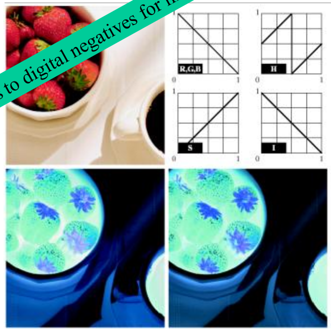


FIGURE 6.32 Complements on the color circle.

Chapter 6
Color Imag cessing

analogous to digital negatives for monochrome images



a b
c d

FIGURE 6.33 Color complement transformations. (a) Original image. (b) Complement transformation functions. (c) Complement of (a) based on the RGB mapping functions. (d) An approximation of the RGB complement using HSI transformations.

Chapter 6
Color Image Processing: **color slicing**

Idea: highlight a range of colors in an image in order to

- separate them from background, or
- use the region defined by color mask for further processing, e.g. segmentation

This is a complex extension of gray level slicing due to the multi-valued nature of color images

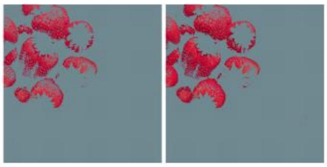
How can this be done? Can map the colors outside some range of interest to some neutral color and leave the rest as they are. Let $w=(a_1,a_2,a_3)$ be the average of the color region of interest and W the width of this region, then

$$s_i = \begin{cases} 0,5 & if \left[|r_j - a_j| > \frac{W}{2} \right]_{\forall 1 \le j \le 3} \\ r_i & \end{cases} \qquad \text{for } i=1,2,3$$

If a sphere is used to specify the region of interest, then

$$s_i = \begin{cases} 0,5 & if \sum_{j=1}^{3} (r_j - a_j)^2 \succ R_0^2 \\ r_i & \end{cases}$$

Chapter 6
Color Image Processing: **color slicing example**



a b

FIGURE 6.34 Color slicing transformations that detect (a) reds within an RGB cube of width $W = 0.2549$ centered at (0.6863, 0.1608, 0.1922), and (b) reds within an RGB sphere of radius 0.1765 centered at the same point. Pixels outside the cube and sphere were replaced by color (0.5, 0.5, 0.5).

Chapter 6
Color Image Processing: Tone and color corrections

Goal: correct color image through pixel transformations to get a better visualization and / or print out.

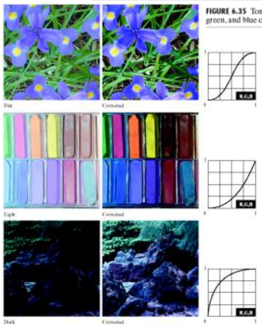
L*a*b* color space is perceptually uniform, i.e. color differences are perceived uniformly.

Like HSI, L*a*b* decouples intensity from color

Example: tonal correction for three common tonal imbalances: flat, light and dark images, see images next.

Chapter 6
Color Image Processing: Tonal transformations

FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not alter the image hues.



S-shaped transformation for boosting contrast

power-law-like transformation to correct light and dark details, as in B&W images.

Chapter 6
Color Image Processing: color balancing

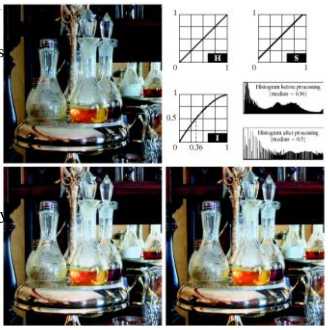
FIGURE 6.36 Color balancing corrections for CMYK color images.

Chapter 6
Color Image Processing: Histogram equalization

Q: would it be wise to equalize color components independently?

A: not so clever, this way colors change!

Solution: equalize intensity component only, e.g. in HSI color space.



a b
c d

FIGURE 6.37 Histogram equalization (followed by saturation adjustment) in the HSI color space.

Chapter 6
Color Image Processing: color image smoothing

Local Average

$$\bar{c}(x,y) = \frac{1}{K} \sum_{(x,y)\in S_{xy}} c(x,y)$$

$$= \begin{bmatrix} \frac{1}{K} \sum_{(x,y)\in S_{xy}} R(x,y) \\ \frac{1}{K} \sum_{(x,y)\in S_{xy}} G(x,y) \\ \frac{1}{K} \sum_{(x,y)\in S_{xy}} B(x,y) \end{bmatrix}$$

a b
c d

FIGURE 6.38 (a) RGB image. (b) Red component image. (c) Green component. (d) Blue component.

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Color Image Processing

a b c

FIGURE 6.39 HSI components of the RGB color image in Fig. 6.38(a). (a) Hue. (b) Saturation. (c) Intensity.

Chapter 6
Color Image Processing

smoothing all color components versus smoothing only intensity component:

a b c

FIGURE 6.40 Image smoothing with a 5 × 5 averaging mask. (a) Result of processing each RGB component image. (b) Result of processing the intensity component of the HSI image and converting to RGB. (c) Difference between the two results.

note that (a) is smoother and lost some of its original colors, in contrast to (b) which preserved its hue and saturation.

Chapter 6
Color Image Processing: color image sharpening

only intensity component was processed

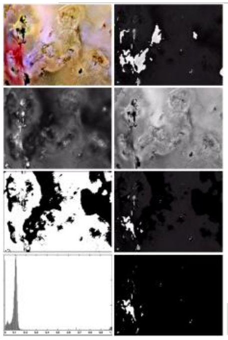
a b c

FIGURE 6.41 Image sharpening with the Laplacian. (a) Result of processing each RGB channel. (b) Result of processing the intensity component and converting to RGB. (c) Difference between the two results.

Laplacian of a color image can be computed component-wise:

$$\nabla^2[c(x,y)] = \begin{bmatrix} \nabla^2 R(x,y) \\ \nabla^2 G(x,y) \\ \nabla^2 B(x,y) \end{bmatrix}$$

Chapter 6
Color Image Processing: **segmentation**



(a) original (b) Hue

(c) saturation (d) intensity

(e) thresholding saturation (@10%)
(f) product of hue and saturation

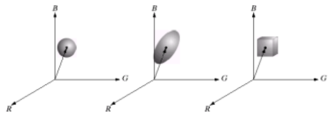
(g) histogram of (f)
(h) segmentation of red component in (a)

a b c d e f g h

FIGURE 6.42 Image segmentation in HSI space. (a) Original. (b) Hue. (c) Saturation. (d) Intensity. (e) Binary saturation mask (black = 0). (f) Product of (b) and (e). (g) Histogram of (f). (h) Segmentation of red components in (a).

Chapter 6
Color Image Processing: **Segmentation**

Suppose that regions of specific color range are to be segmented. The specific color is specified by an average color **a** and a neighborhood around it, defined by a suitable distance measure: we say that z is similar to a if D(a,z) is smaller than a threshold D_0.



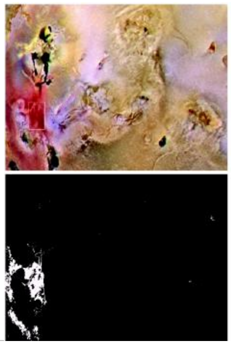
a b c

FIGURE 6.43 Three approaches for enclosing data regions for RGB vector segmentation.

(a) Euclidean distance (most general)
(b) Malahanobis distance (take into account properties of the data)
(c) Bounding box (reduce computational complexity)

Chapter 6
Color Image Processing

Want to segment reddish colors in the image, as in the rectangular region.
1. compute the mean vector a
2. use a bounding box of size 2.5 x std deviation in each color
3. color as black any pixel whose colors fall outside the box and as white the other pixels.



a b

FIGURE 6.44 Segmentation in RGB space. (a) Original image with colors of interest shown enclosed by a rectangle. (b) Result of segmentation in RGB vector space. Compare with Fig. 6.42(h).

This segmentation is more accurate compared to the one performed in HSI, see Fig. 6.42 (h)

Chapter 6
Color Image Processing

a b c d
e f g h

FIGURE 6.45 (a)–(c) *R*, *G*, and *B* component images and (d) resulting RGB color image. (f)–(g) *R*, *G*, and *B* component images and (h) resulting RGB color image.

Chapter 6
Color Image Processing

a b
c d

FIGURE 6.46 (a) RGB image. (b) Gradient computed in RGB color vector space. (c) Gradients computed on a per-image basis and then added. (d) Difference between (b) and (c).

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Color Image Processing

a b c

FIGURE 6.47 Component gradient images of the color image in Fig. 6.46. (a) Red component, (b) green component, and (c) blue component. These three images were added and scaled to produce the image in Fig. 6.46(c).

Chapter 6
Color Image Processing: Noise in color images

a b
c d

FIGURE 6.48 (a)–(c) Red, green, and blue component images corrupted by additive Gaussian noise of mean 0 and variance 800. (d) Resulting RGB image. [Compare (d) with Fig. 6.46(a).]

Consider the RGB components, each was corrupted with Gaussian noise (0,800).

None of the components look very objectionable including the color image!

Chapter 6
Color Image Processing

Now, convert the same image to HSI and look at the components!

a b c

FIGURE 6.49 HSI components of the noisy color image in Fig. 6.48(d). (a) Hue. (b) Saturation. (c) Intensity.

this is due to the nonlinearities in the conversion between RGB and HSI. The intensity component I does not look bad, why?

Chapter 6
Color Image Processing

Suppose that only one of the RGB channel is corrupted with noise, say the green channel, converting this to HSI yields a high degradation in the hue and saturation components.

a b
c d

FIGURE 6.50
(a) RGB image with green plane corrupted by salt-and-pepper noise.
(b) Hue component of HSI image.
(c) Saturation component.
(d) Intensity component.

Chapter 6
Color Image Processing: **Image compression**

Compression is the process of reducing or eliminating redundant and or irrelevant data.

Example:

(a) a full 24-bit color image,
(b) JPEG 2000 compressed image (230:1) (i.e. 230 bits in the original are represented by 1 bit in the compressed image)

a b
c d

FIGURE 6.51 Color image compression. (a) Original RGB image. (b) Result of compressing and decompressing the image in (a).