Color Image Processing

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About Presentations

- Give time. Do not think that you can present a new topic by just spending about a few hours on it only.
  - Not by studying only within the last two days
  - Not by giving only a few hours
- Remember, you know the what you are presenting the best.
  - Do not assume the audience know a lot about the subject.
  - Give more introductory background
- Make sure you follow the instructions
  - if you are advised certain steps, you should pay attention to them.
- If there is a certain subject that you do not know, look it up.
- Use your voice and tone carefully.
  - Do not just read the content in your slides.
- Do not use a lot of text and content in one slide.

About Final Projects

- Your final project submission will include:
  - A **presentation** (PPT format).
  - A **paper** (written in CVPR format).
    - Tex is available: http://cvpr2020.thecvf.com/sites/default/files/2019-09/cvpr2020AuthorKit.tar
  - The **data** that you used! If you cannot submit the data, you cannot use it in your final project.
    - Provide a link for your data. It is students' responsibility to make sure that the data is available.
  - The **code** that generates the results (the metrics) that you used in your submitted paper (on Github).

About Final Projects

1. In your final paper do not forget to:
2. Describe what you are planning to do and why it is hard in the introduction section.
3. Perform literature survey
    1. Understand what other techniques have been available in the literature and provide an up-to-date summary.
4. Provide your proposed solution in details:
    1. Include a full flow-diagram of the solution including the input and output formats
    2. Provide a figure that shows the full network with details.
    3. Explain what is new in your solution in details.
5. Describe the used datasets and metrics in your Experiments & provide your experimental results.

Color

- Used heavily in human vision.
- Visible spectrum for humans is 400 nm (blue) to 700 nm (red).
- Machines can "see" (sense) much more; e.g., X-rays, infrared, radio waves.

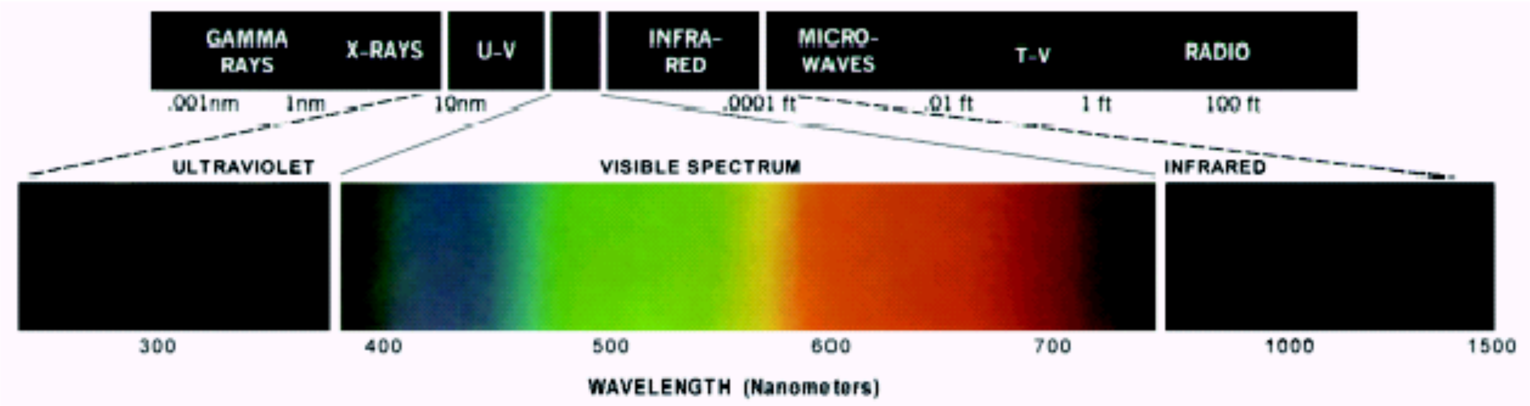
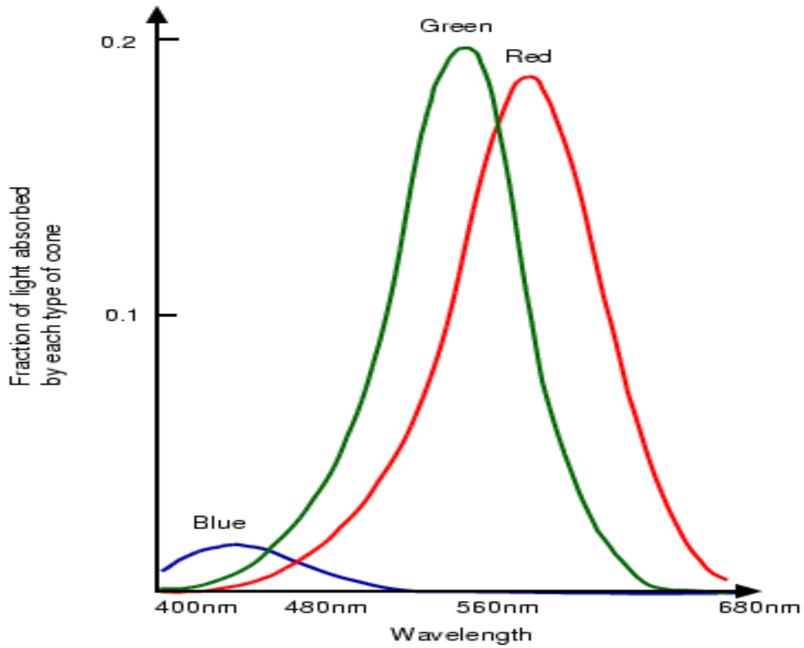


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

Adapted from Gonzales and Woods

Human visual system

- There are two types of photosensitive cells:
  - Cones
    - Sensitive to colored light, but not very sensitive to dim light.
  - Rods
    - Sensitive to achromatic light.
- We perceive color using three different types of cones.
  - Each one is sensitive in a different region of the spectrum.
    - 440 nm (BLUE)
    - 545 nm (GREEN)
    - 580 nm (RED)
  - They have different sensitivities (we are more sensitive to green than red).



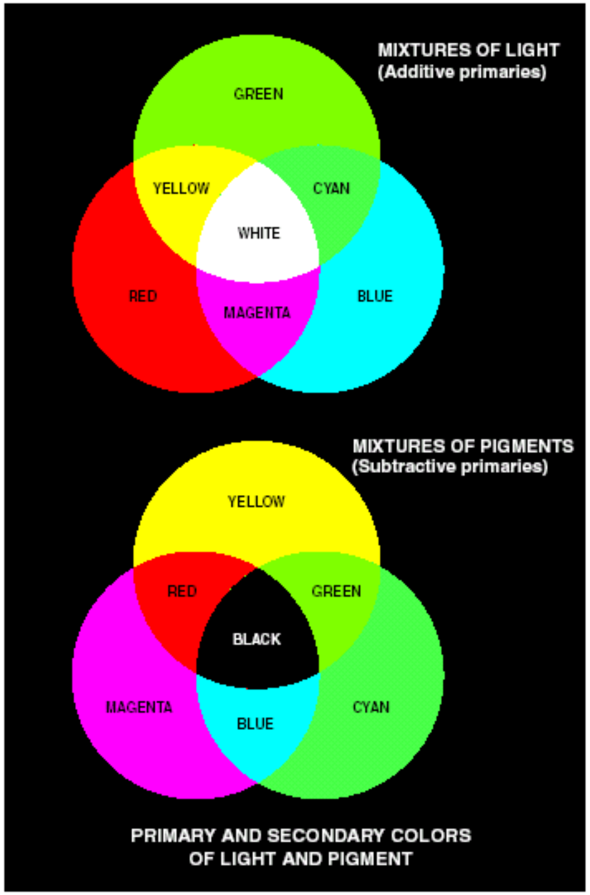
Adapted from Octavia Camps, Penn State

Color models

- They provide a standard way of specifying a particular color using a 3D coordinate system.
- Hardware oriented
  - RGB: additive system (add colors to black) used for displays.
  - CMY: subtractive system used for printing.
  - YIQ: used for TV and is good for compression.
- Image processing oriented
  - HSV: good for perceptual space for art, psychology and recognition.

Adapted from Octavia Camps, Penn State

Additive and subtractive colors



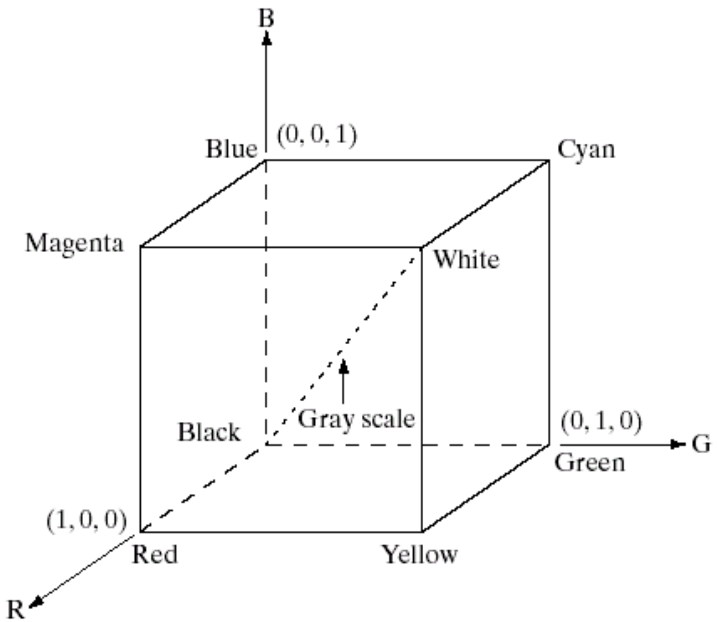
a
b

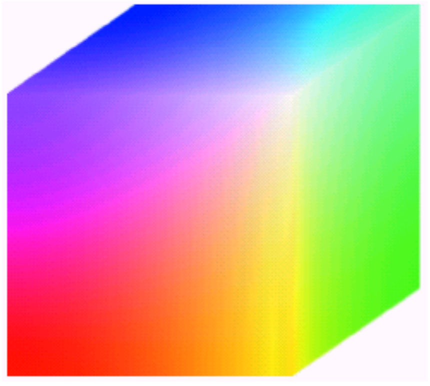
FIGURE 6.4 Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp Business Division.)

Adapted from Gonzales and Woods

RGB model

- Additive model.
- An image consists of 3 bands, one for each primary color.
- Appropriate for image displays.





Adapted from Gonzales and Woods

CMY model

- **Cyan-Magenta-Yellow** is a subtractive model which is good to model absorption of colors.
- Appropriate for paper printing.

Cyan (C)
Magenda (M)
Yellow (Y)

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

Adapted from Octavia Camps, Penn State

CIE chromaticity model

- The **Commission Internationale de l'Eclairage** defined 3 standard primaries: X, Y, Z that can be added to form all visible colors.
- Y was chosen so that its color matching function matches the sum of the 3 human cone responses.

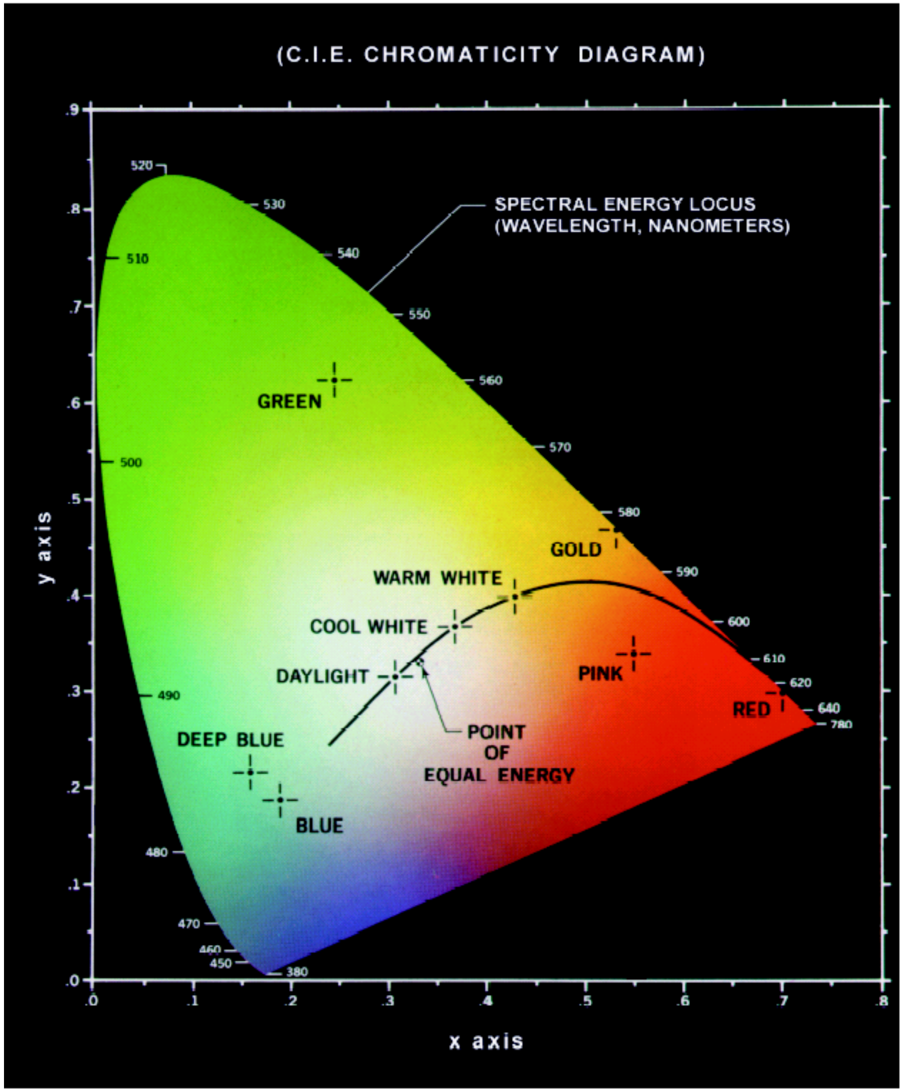
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.6067 & 0.1736 & 0.2001 \\ 0.2988 & 0.5868 & 0.1143 \\ 0.0000 & 0.0661 & 1.1149 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.9107 & -0.5326 & -0.2883 \\ -0.9843 & 1.9984 & -0.0283 \\ 0.0583 & -0.1185 & 0.8986 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Adapted from Octavia Camps, Penn State

CIE chromaticity model

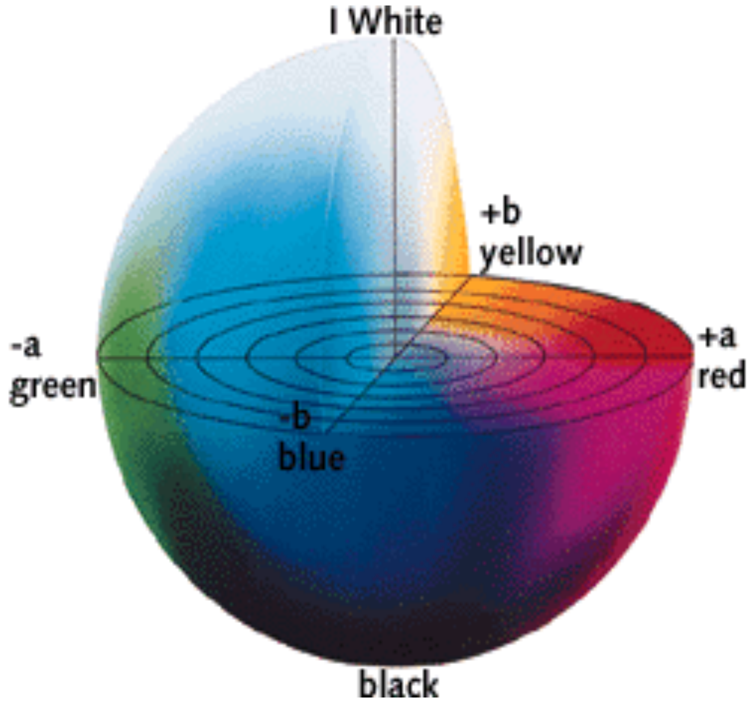
- x, y, z normalize X, Y, Z such that
  $$x + y + z = 1.$$
- Actually only x and y are needed because
  $$z = 1 - x - y.$$
- Pure colors are at the curved boundary.
- White is (1/3, 1/3, 1/3).



Adapted from Octavia Camps, Penn State

CIE Lab (L*a*b) model

- One luminance channel (L) and two color channels (a and b).
- In this model, the color differences which you perceive correspond to Euclidian distances in CIE Lab.
- The a axis extends from green (-a) to red (+a) and the b axis from blue (-b) to yellow (+b). The brightness (L) increases from the bottom to the top of the 3D model.



http://en.wikipedia.org/wiki/Lab_color_space

Adapted from Linda Shapiro, U of Washington

YIQ model

- Have better compression properties.
- Luminance Y is encoded using more bits than chrominance values I and Q (humans are more sensitive to Y than I and Q).
- Luminance is often used for color to gray-tone conversion.
- All 3 values used by color TVs.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.532 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Adapted from Octavia Camps, Penn State

HSV model

- HSV: Hue, saturation, value are non-linear functions of RGB.
- Hue relations are naturally expressed in a circle.

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

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

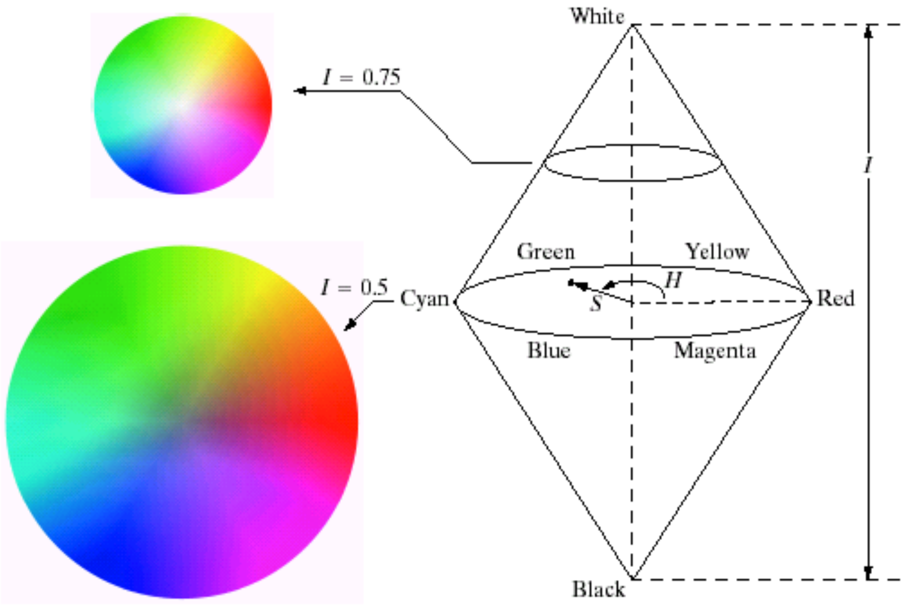
$$H = \cos^{-1}\left\{\frac{1/2[(R-G)+(R-B)]}{\sqrt{\left[(R-G)^2+(R-B)(G-B)\right]}}\right\} \text{if} \quad B<G$$

$$H = 360 - \cos^{-1}\left\{\frac{1/2[(R-G)+(R-B)]}{\sqrt{\left[(R-G)^2+(R-B)(G-B)\right]}}\right\} \text{if} \quad B>G$$

Adapted from Octavia Camps, Penn State

HSV model

- Uniform: equal (small) steps give the same perceived color changes.
- Hue is encoded as an angle (0 to 2π).
- Saturation is the distance to the vertical axis (0 to 1).
- Intensity is the height along the vertical axis (0 to 1).



Adapted from Gonzales and Woods

HSV model

(Left) Image of food originating from a digital camera.
(Center) Saturation value of each pixel decreased 20%.
(Right) Saturation value of each pixel increased 40%.

Adapted from Linda Shapiro, U of Washington

Color models

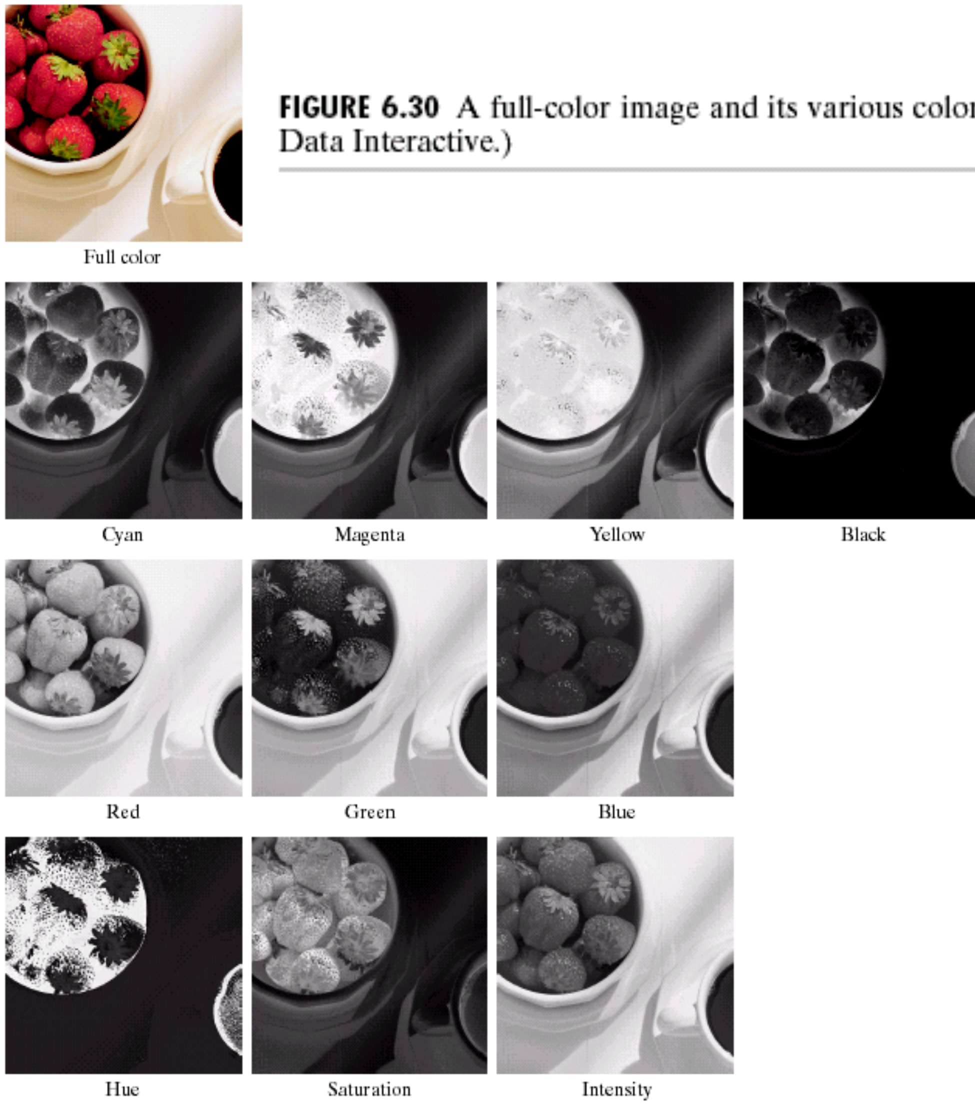


FIGURE 6.30 A full-color image and its various color-space components. (Original image courtesy of Med-Data Interactive.)

CMYK

RGB

HSV

Adapted from Gonzales and Woods

Examples: pseudocolor

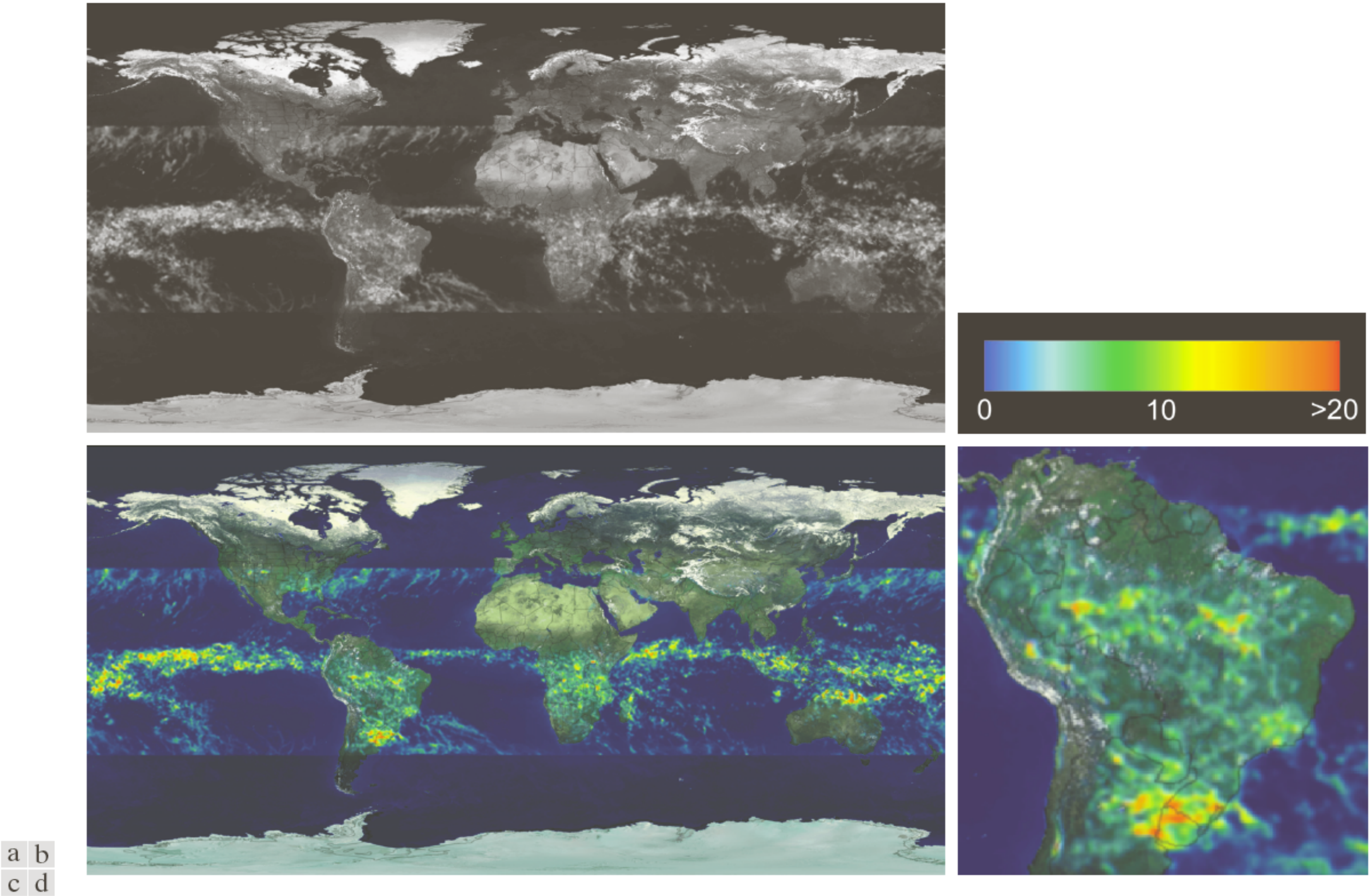


FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South American region. (Courtesy of NASA.)

Examples: pseudocolor

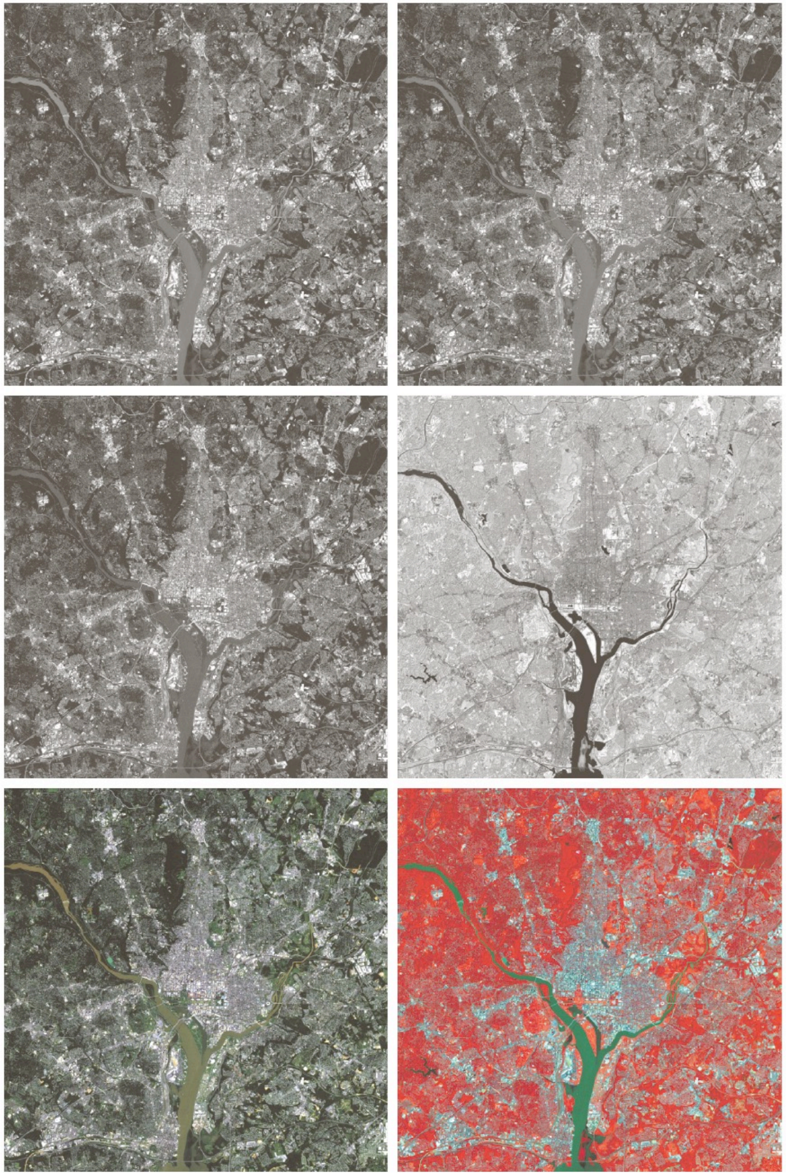


FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral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

a	b
c	d
e	f

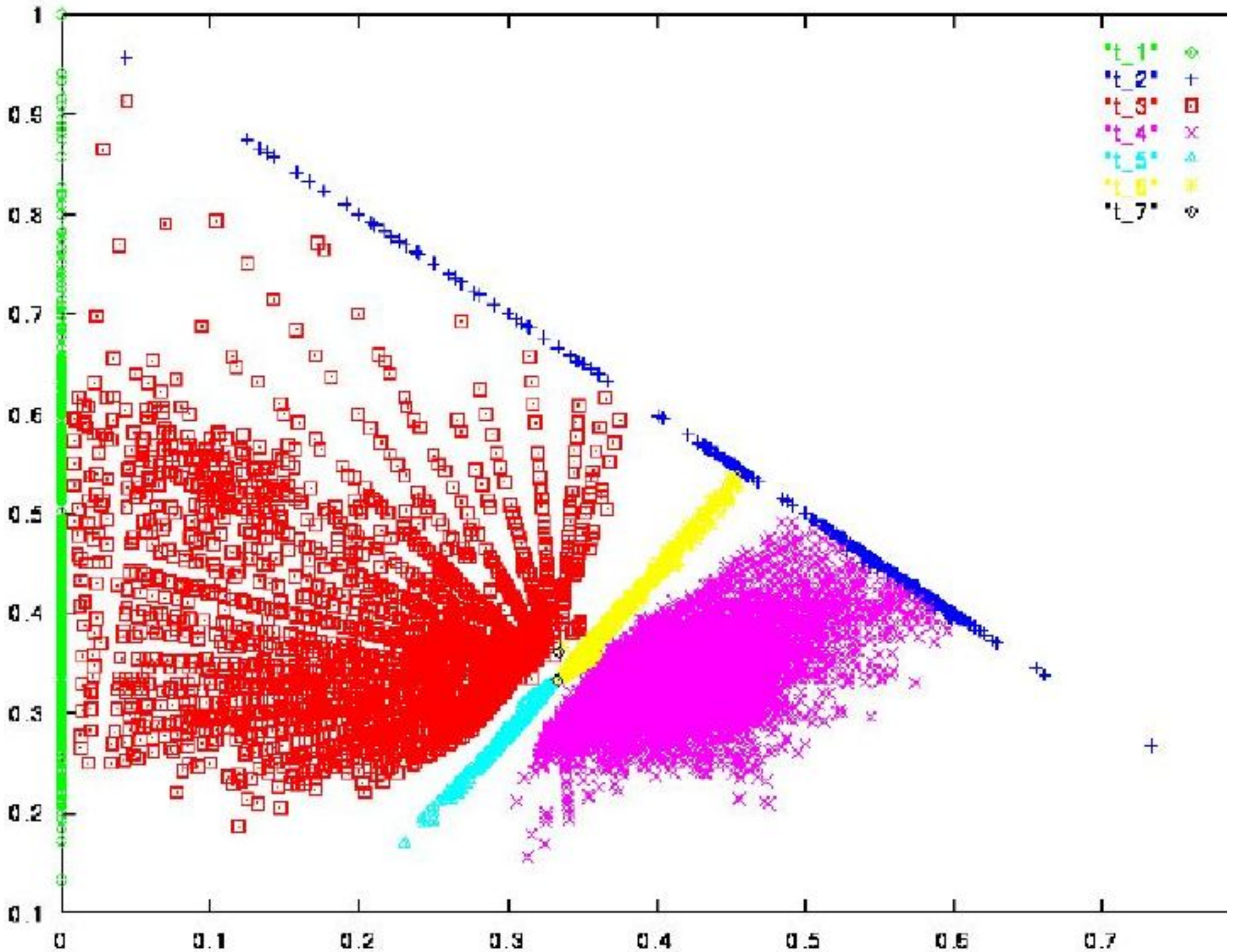
Examples: segmentation

- Can cluster on color values and pixel locations.
- Can use connected components and an approximate color criteria to find regions.
- Can train an algorithm to look for certain colored regions – for example, skin color.

Original RGB image

Color clusters by k-means

Examples: segmentation

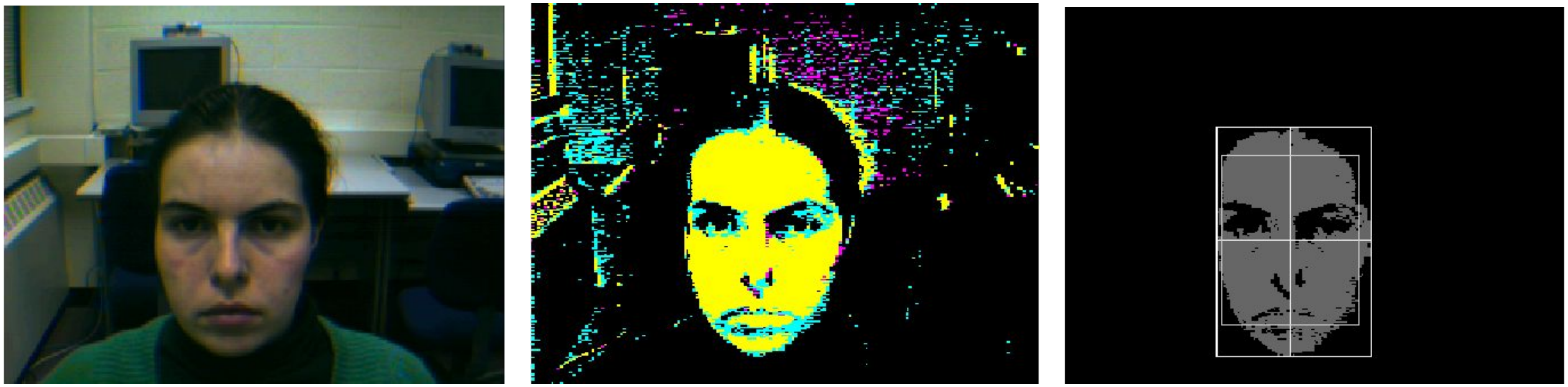


Skin color in RGB space:

Purple region shows skin color samples from several people. Blue and yellow regions show skin in shadow or behind a beard.

Adapted from Linda Shapiro, U of Washington

Examples: segmentation



(Left) Input video frame.

(Center) Pixels classified according to RGB space.

(Right) Largest connected component with aspect similar to a face.

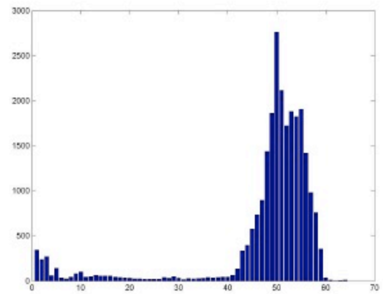
Adapted from Linda Shapiro, U of Washington

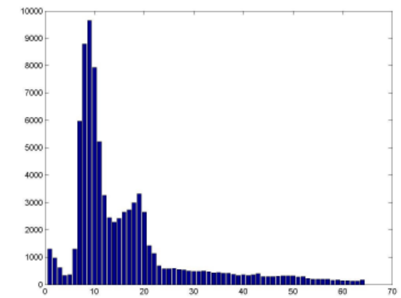
Examples: histogram

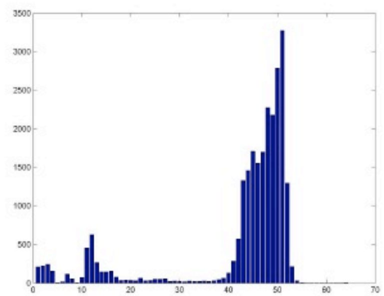
- Histogram is fast and easy to compute.
- Size can easily be normalized so that different image histograms can be compared.
- Can match color histograms for database query or classification.

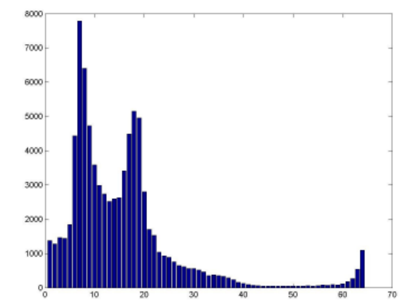
Adapted from Linda Shapiro, U of Washington

Examples: histogram

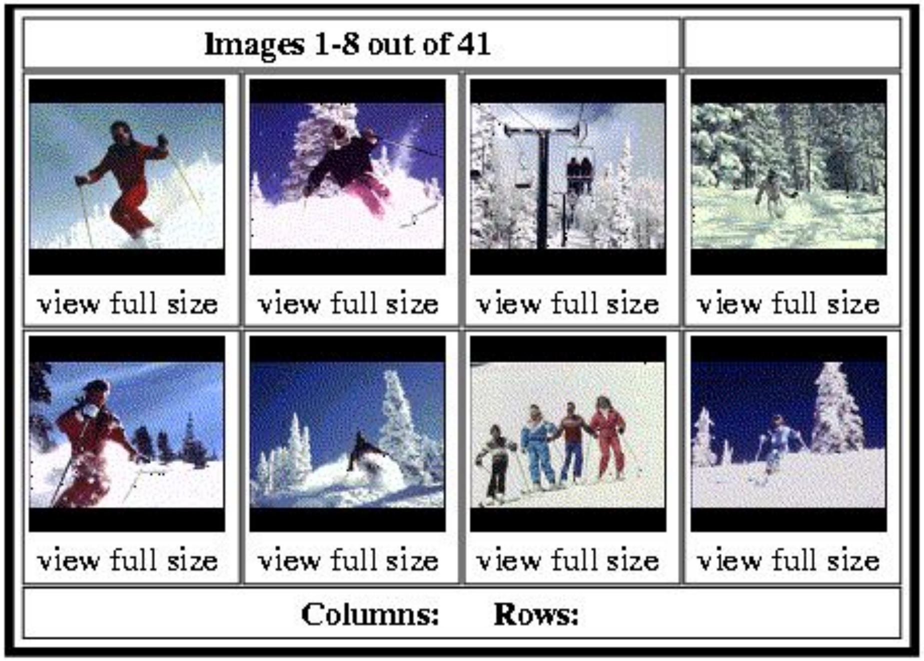




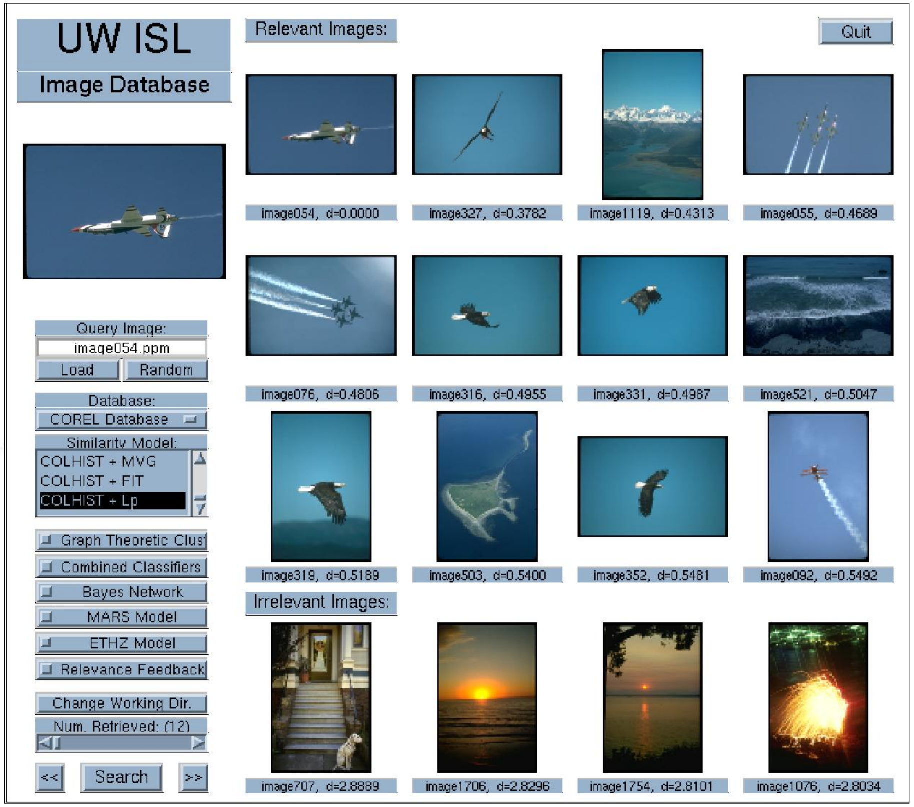




Examples: image retrieval



Adapted from Linda Shapiro, U of Washington



Summary

- To print (RGB → CMY or grayscale)
- To compress images (RGB → YUV)
  - Color information (U,V) can be compressed 4 times without significant degradation in perceptual quality.
- To compare images (RGB → CIE Lab)
  - CIE Lab space is more perceptually uniform.
  - Euclidean distance in Lab space hence meaningful.
- https://en.wikipedia.org/wiki/Color_model