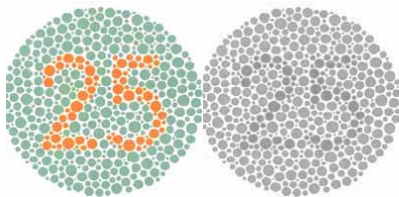.

Color image processing

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**Methods for Image Processing**

academic year 2015–2016

Color images

- Color is a feature that can greatly improve the description of the scene.
- The shades of colors the can be discriminated by the human visual system are much more than the gray ones (thousands vs. dozens).
- The color can be studied as:

  - a physical phenomenon;
  - a perceptive phenomenon.

Physical nature of the color

- ► Structure of the visible light
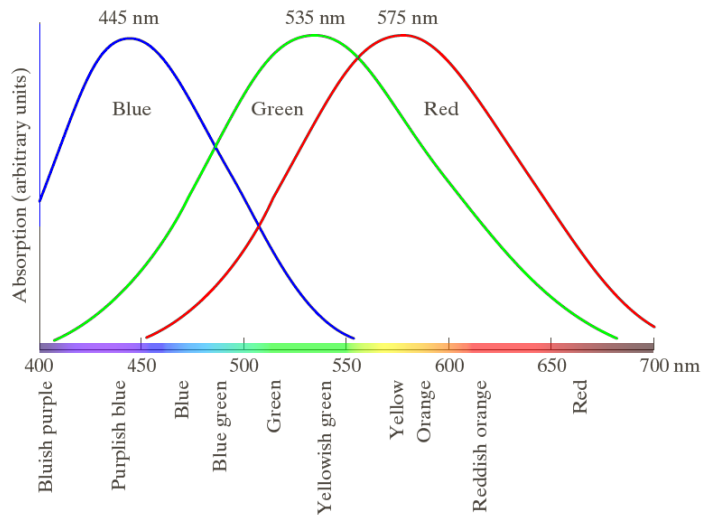 - ► white light decomposition (Isaac Newton, 1666)
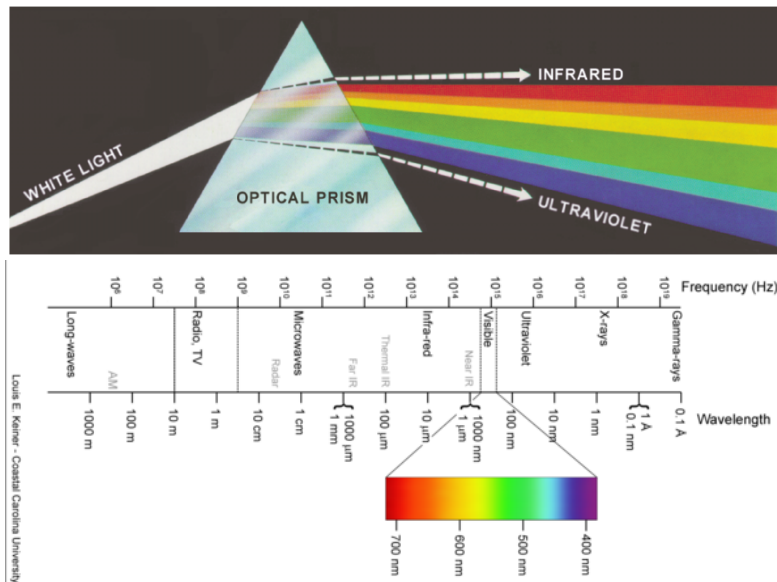
Physical nature of the color (2)

- ► Features of a light source:
  - ► radiance: emitted energy [Watt, W]
    - ► measured with respect to a particular angle and surface.
  - ► luminance: perceived energy [lumen, lm]
  - ► brightness: subjective description (e.g., glare)

Color perception

▶ Photopic vision, due to the cones (1965):

▶ each perceived color results from the activation of the cones belonging to the different types.

Color perception (2)

▶ CIE primary colors (1931):
  ▶ blue: 435.8 nm
  ▶ green: 546.1 nm
  ▶ red: 700 nm
▶ arbitrarily established before the experimental evidence of the previous figure;
▶ primary and secondary colors
  ▶ mixing the primary colors, *most* of the visible colors can be obtained;
  ▶ in particular, the secondary colors.
▶ emitted light (source) and reflected light (pigment)
  ▶ additive and subtractive composition

Color perception (3)

▶ primary (and secondary) colors additive and subtractive:
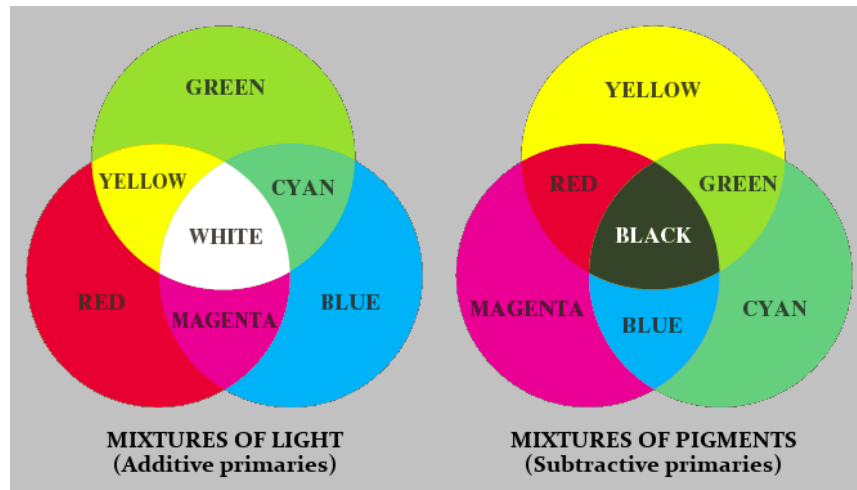
Color spaces

▶ Features of the light:

  ▶ luminosity

    ▶ generalization of the intensity

  ▶ hue

    ▶ dominant color

  ▶ saturation

    ▶ color purity, quantity of white (pink is half saturated red)

hue + saturation = chromaticity

▶ A color space provide a reference system for measuring the color.
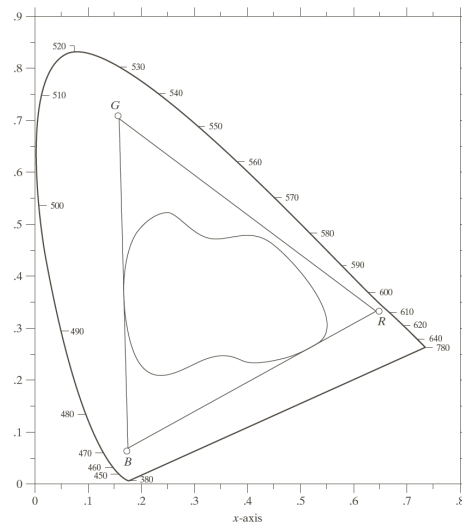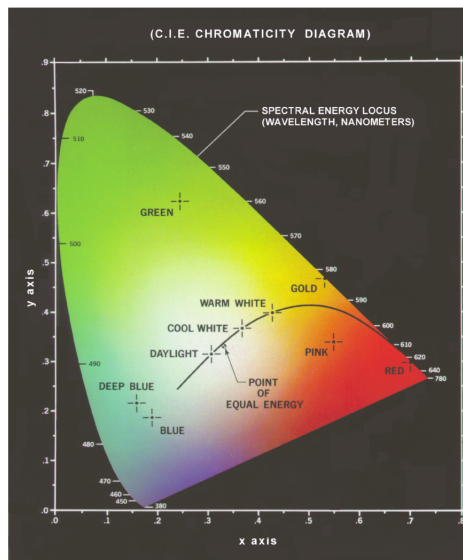
Color spaces (2)

▶ Tristimulus: color coordinates for intensity value equal to 1.
  ▶ X, Y, Z are color (not visible corresponding to R, G and B stimulii)
  ▶ normalizing:

$$x = \frac{X}{X + Y + Z} \qquad y = \frac{Y}{X + Y + Z} \qquad z = \frac{Z}{X + Y + Z}$$
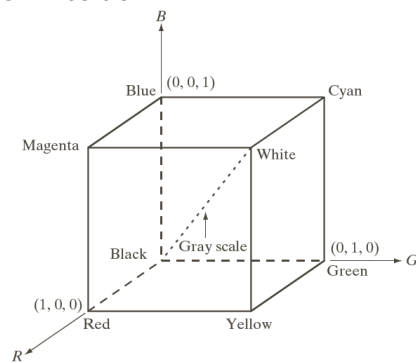
$$x + y + z = 1$$

▶ A graph can be traced on the x-y plane and z can be derived as $z = 1 - x - y$.
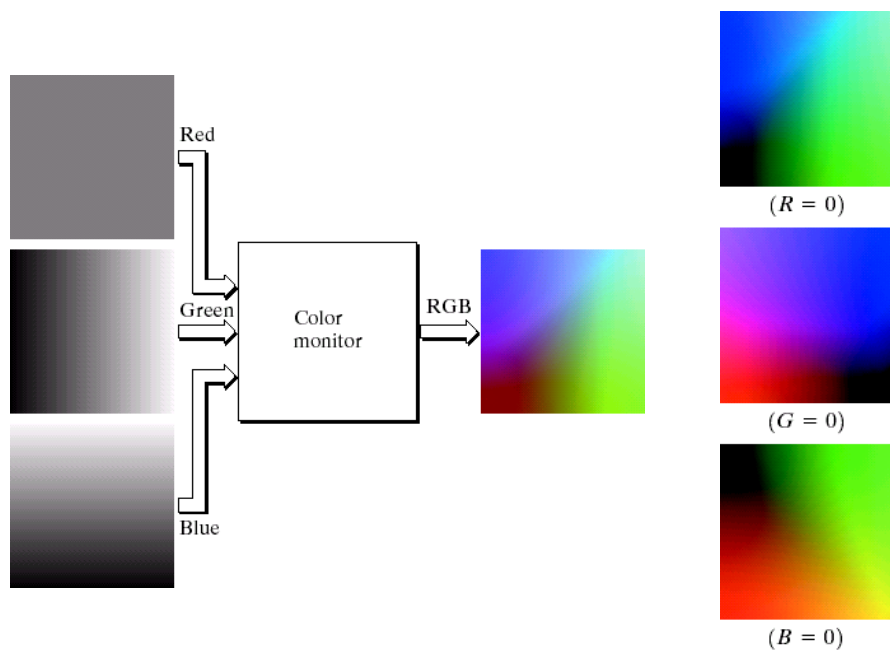
Color spaces (3)
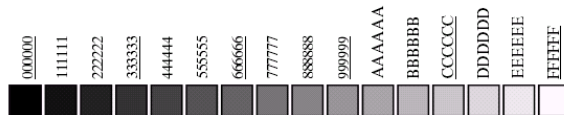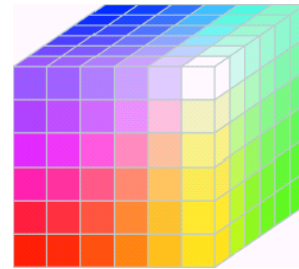
.

RGB color model

    ▶ RGB: cube

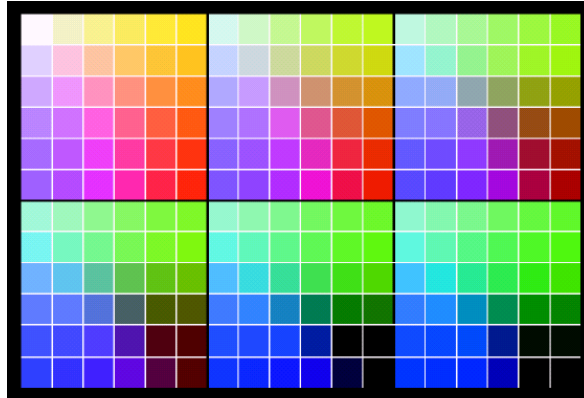# RGB color model (2)

    ▶ RGB color formation

RGB color model (3)

▶ "safe" colors: quantization 6×6×6 = 216

Other color models

▶ CMY (CMYK)

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

▶ CIE L*a*b*

$$L^* = 116\, h\left(\frac{Y}{Y_W}\right) - 16$$

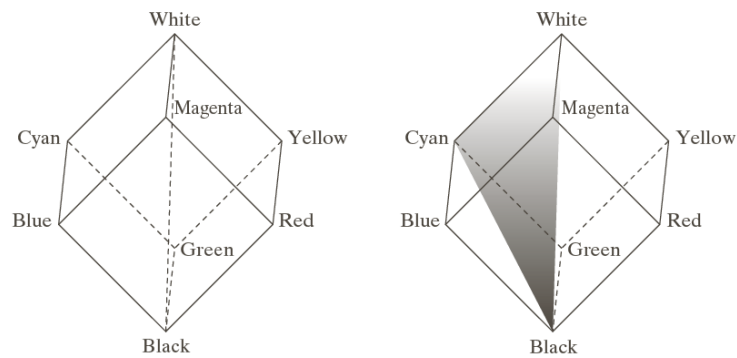$$a^* = 500\left[h\left(\frac{X}{X_W}\right) - h\left(\frac{Y}{Y_W}\right)\right]$$

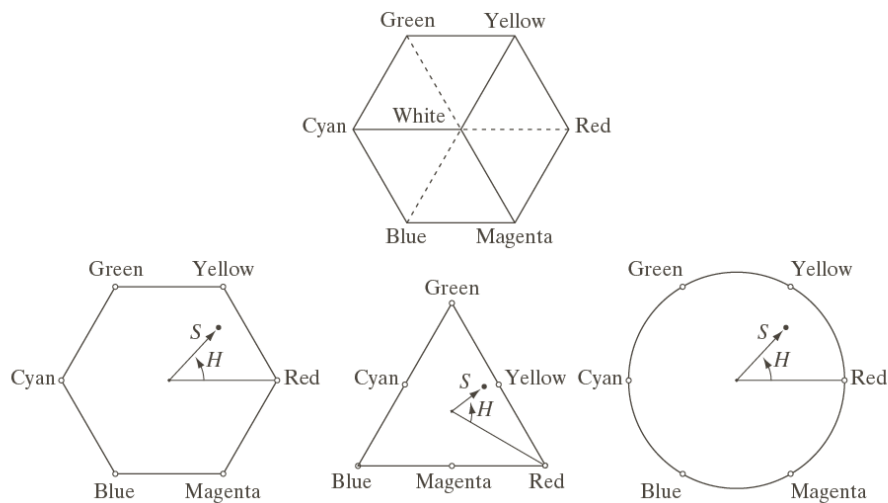$$b^* = 200\left[h\left(\frac{Y}{Y_W}\right) - h\left(\frac{Z}{Z_W}\right)\right]$$

where

$$h(q) = \begin{cases} \sqrt[3]{q} & q > 0.008856 \\ 7.787\, q & q \leq 0.008856 \end{cases}$$
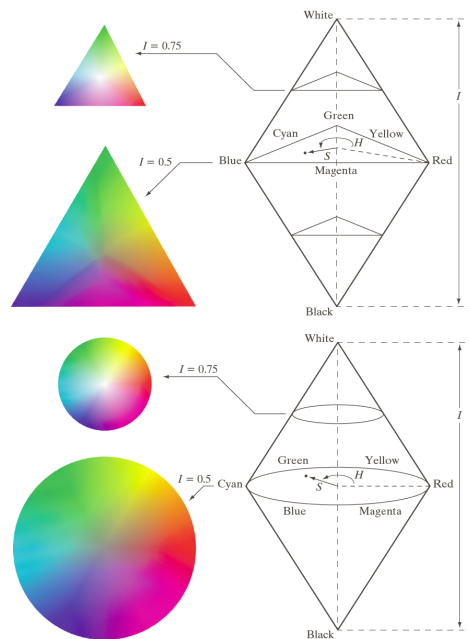
HSI color model

- ▶ RGB is useful for colors representation, not for description.
- ▶ HSI: (Hue, Saturation, Intensity)
  - ▶ HSV: (Hue, Saturation, Value)
- ▶ Hue: dominant color
- ▶ Saturation: distance from white
- ▶ Intensity: distance from black
- ▶ HSI fits better to the human perception of the color sensation.


HSI color model (2)

HSI color model (3)

RGB to/from HSI conversion

- ▶ RGB from/to HSI conversion formulas can be derived from the geometric relations between the two spaces.
- ▶ However, it should be noticed that:
  - ▶ hue is an angle with respect to the red position;
    - ▶ it can be normalized by dividing its value for the round angle;
    - ▶ red has hue value of both 0 and 1.
  - ▶ white and black are identified only by the intensity value.
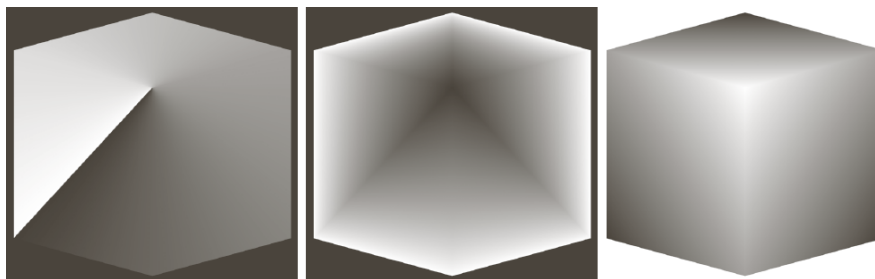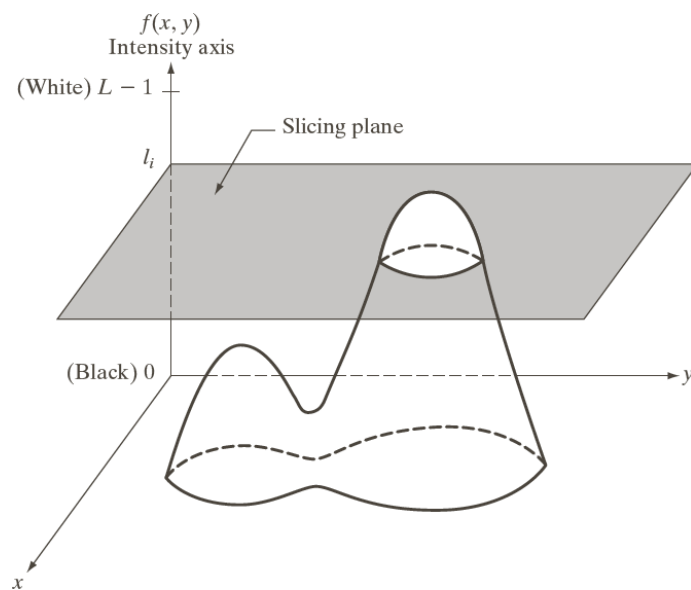

RGB cube represented in the HSI space.

HSI processing example

▶ Processing can be more easy in HSI space, since its effects are more predictable in terms of color modification.
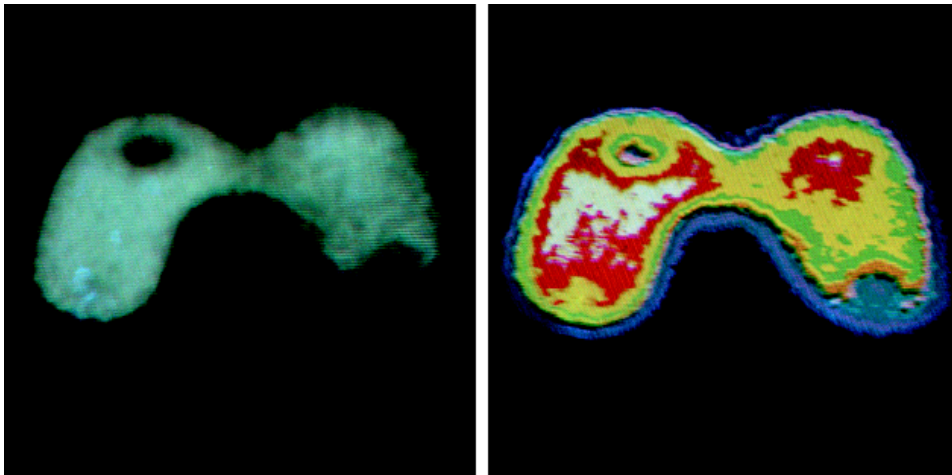

H   S   I
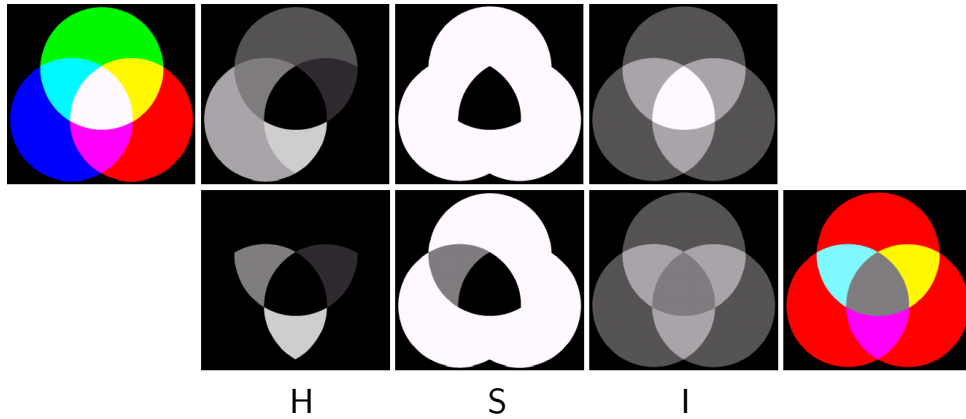
Intensity slicing

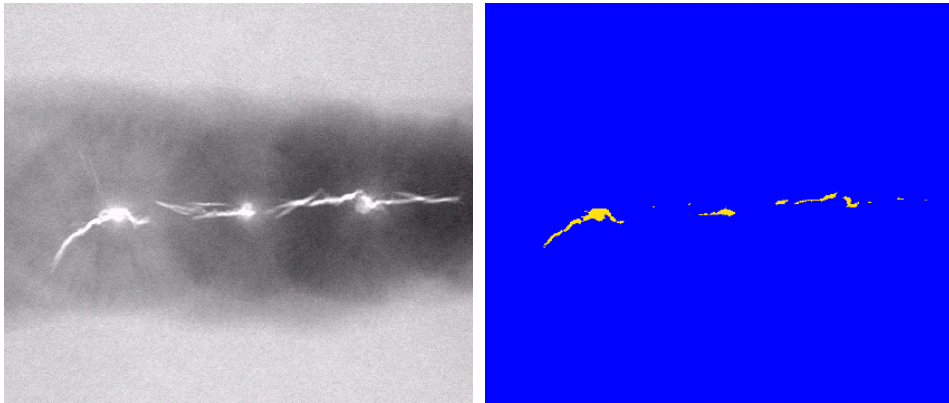▶ Pseudocolor processing consists in assigning different color to different intensity ranges.

Intensity slicing (2)
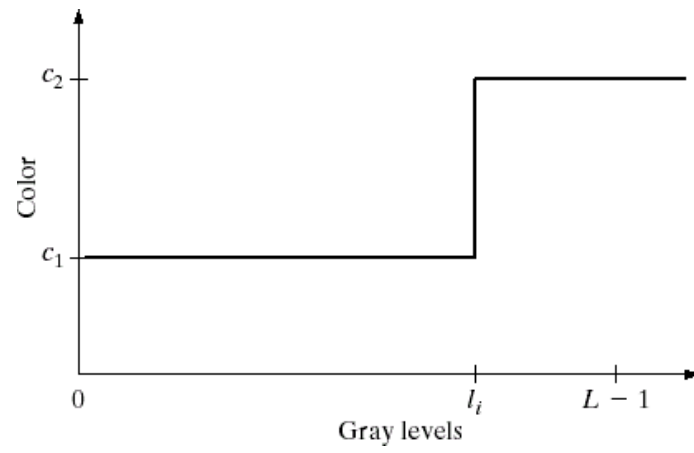
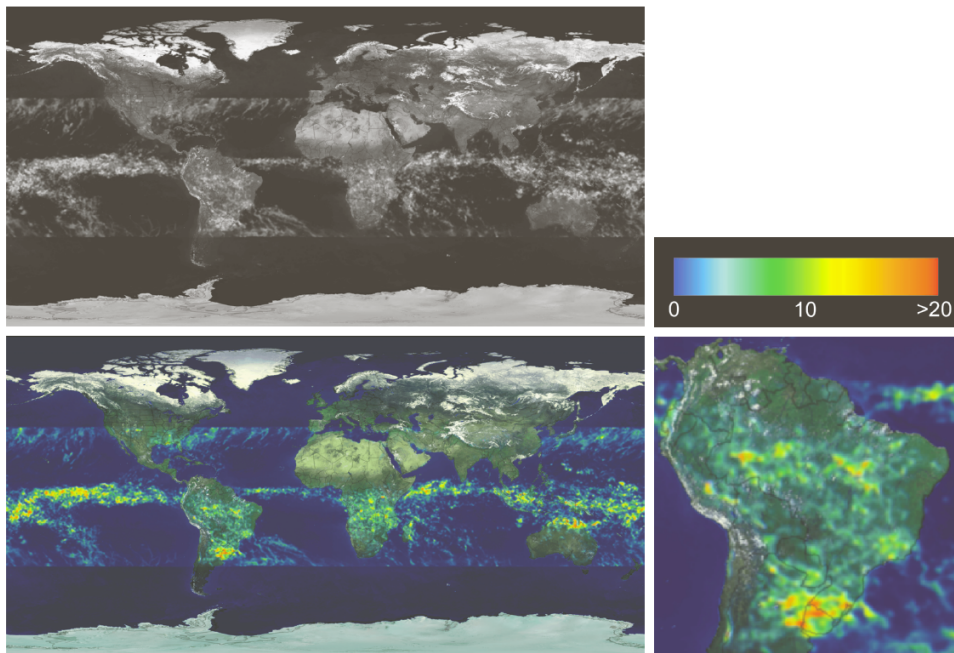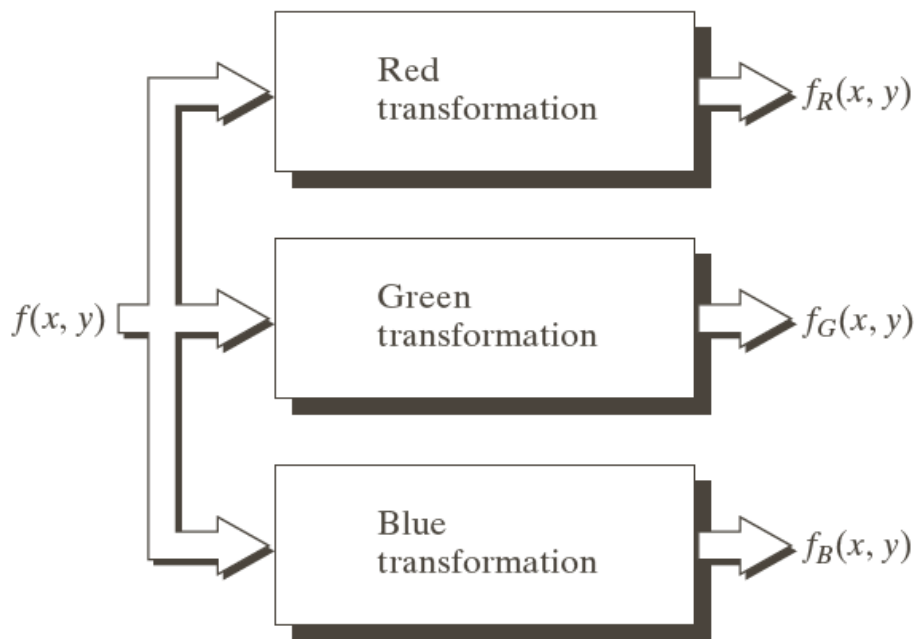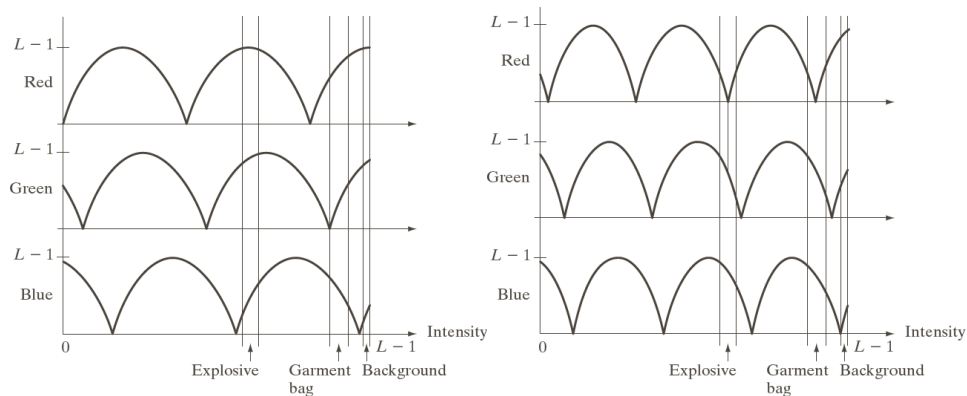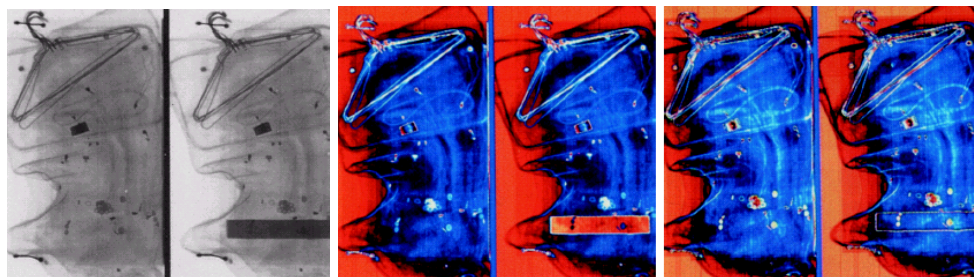## Intensity slicing (3)
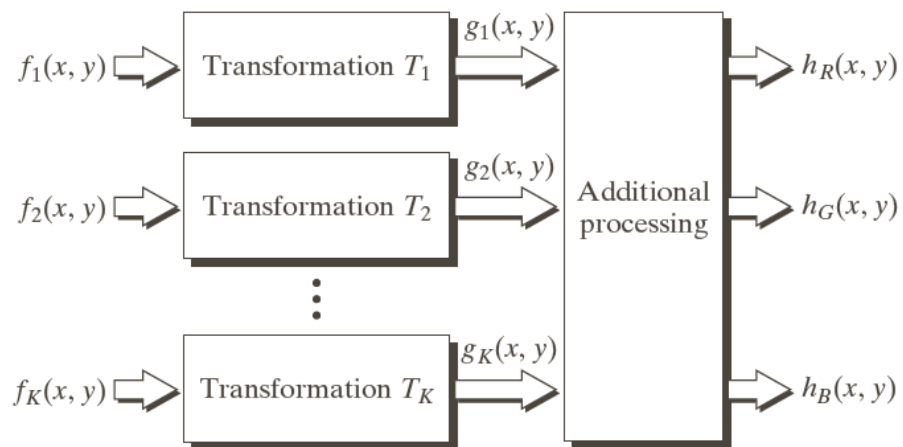
Intensity slicing (4)

Intensity slicing (5)
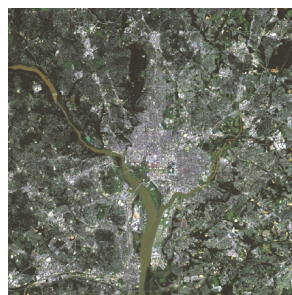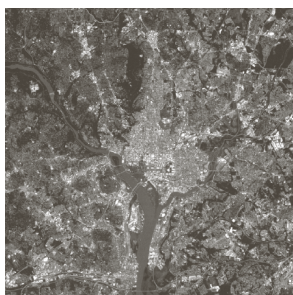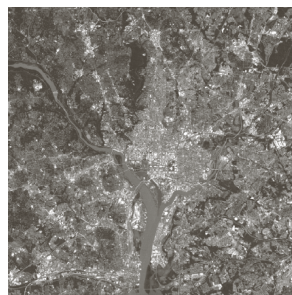
Intensity to color transformations

Intensity to color transformation (2)
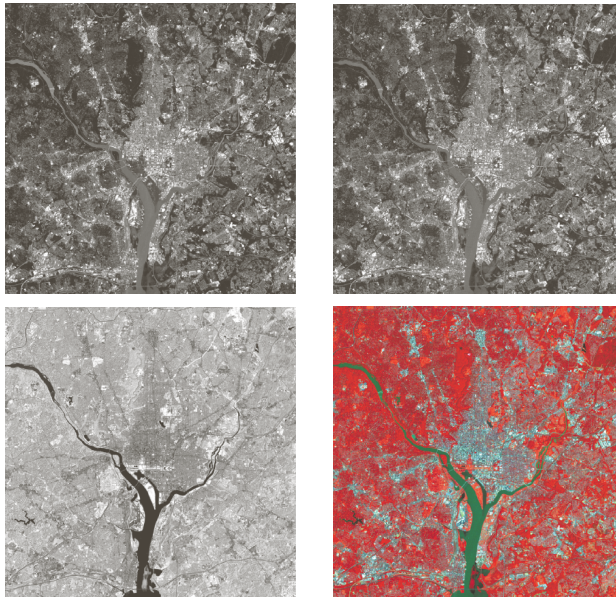
Intensity to color transformation (3)

Intensity to color transformation (4)

a	b
c	d

(a) visible blue;

(b) visible green;

(c) visible red;
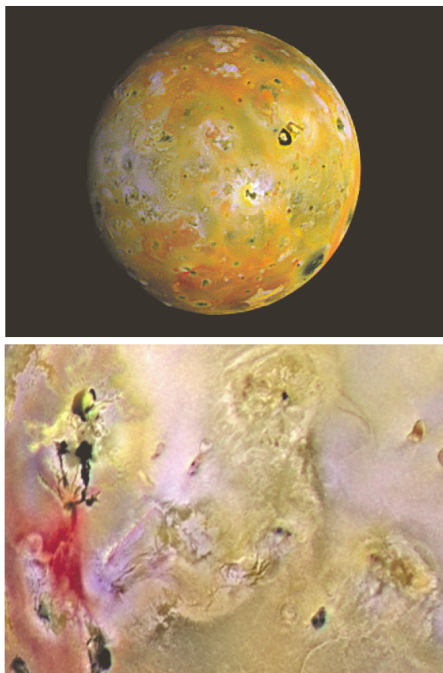
(d) composite of (a)-(c) as RGB.

Intensity to color transformation (5)

a	b
c	d

(a) visible blue;

(b) visible green;

(c) near infrared;

(d) composite of (a)-(c) as RGB.

Intensity to color transformation (6)

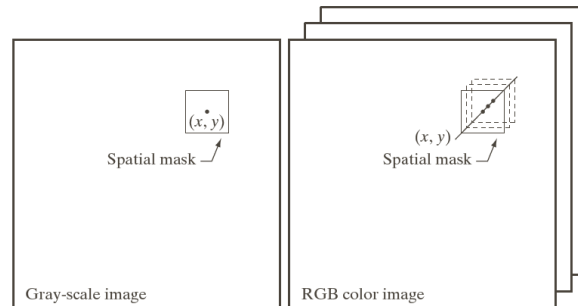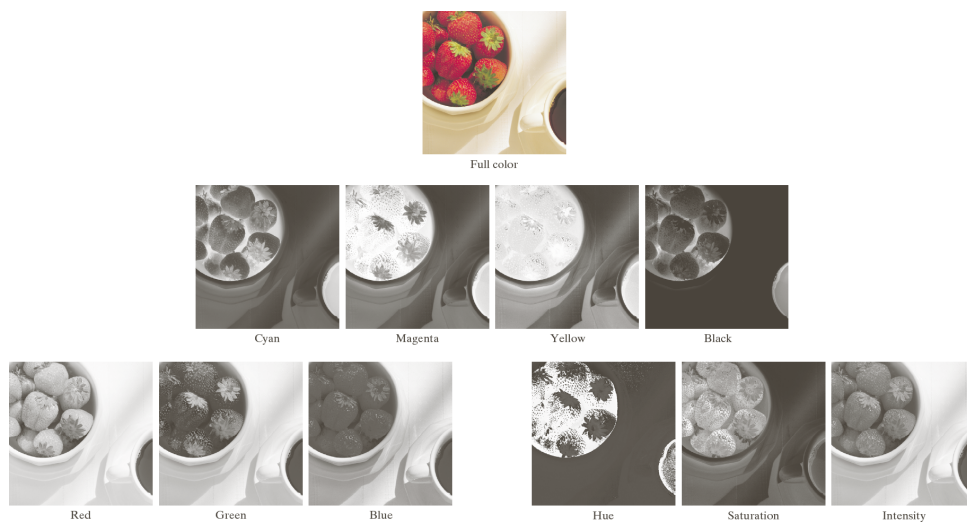| a |
|---|
| b |

Chemical composition remapped onto color space.

(a) Io, a Jupiter moon;

(b) material newly ejected from a volcano is depicted in red, while older material is yellowish.
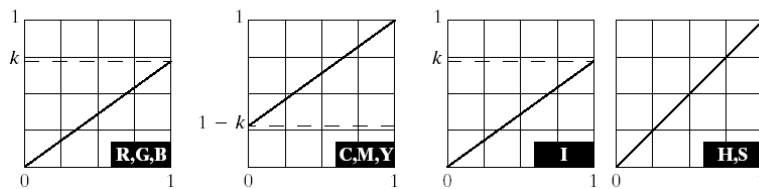
Color image processing

► The concept of spatial mask can be generalized for color images.

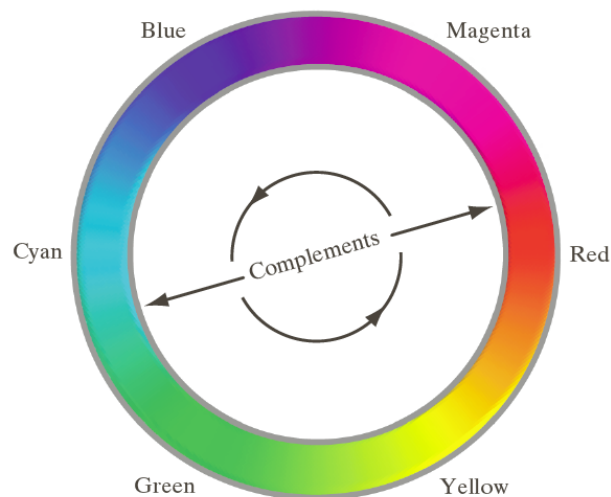# Representation in different color spaces
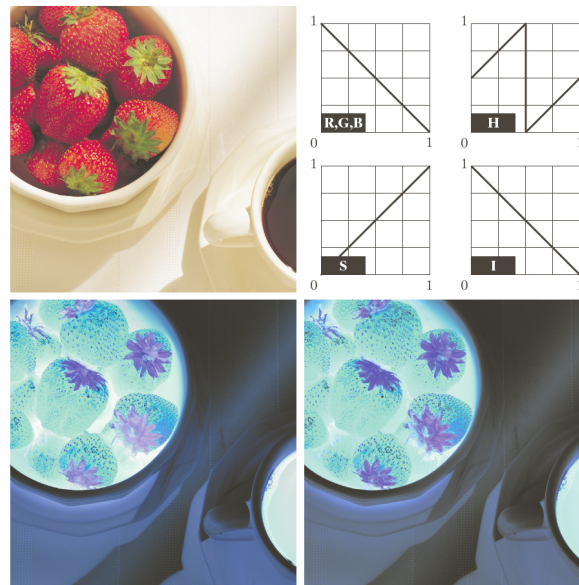
Intensity adjustment

- ▶ The same processing can be operated in different color spaces.

Complement

- ▶ Complement is the generalization of the negative intensity transformation.
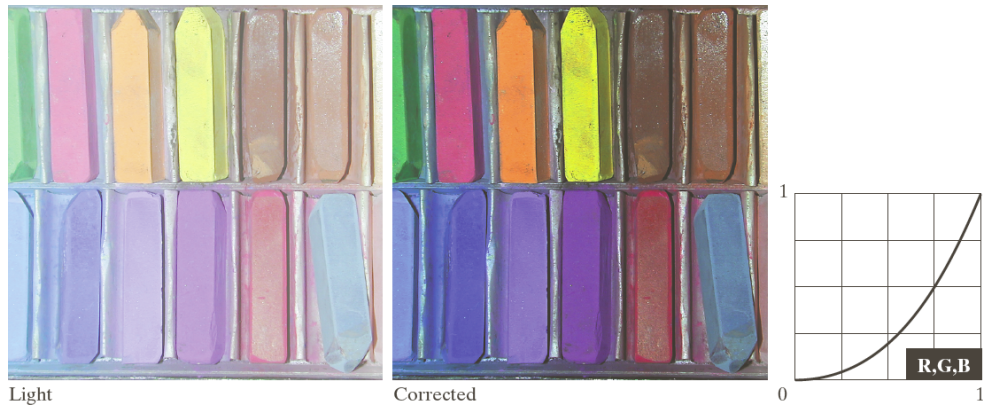
Complement (2)

- ▶ Complement can be obtained both in RGB and HSI space.
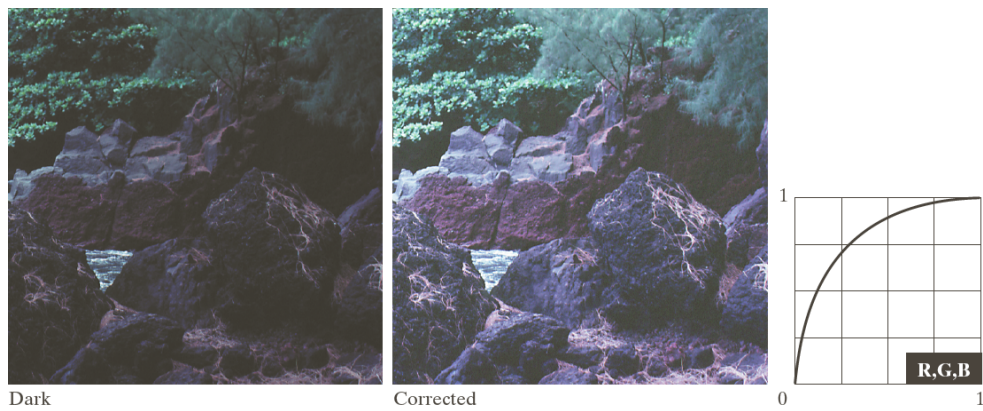 - ▶ Although in RGB it is more simply expressed.
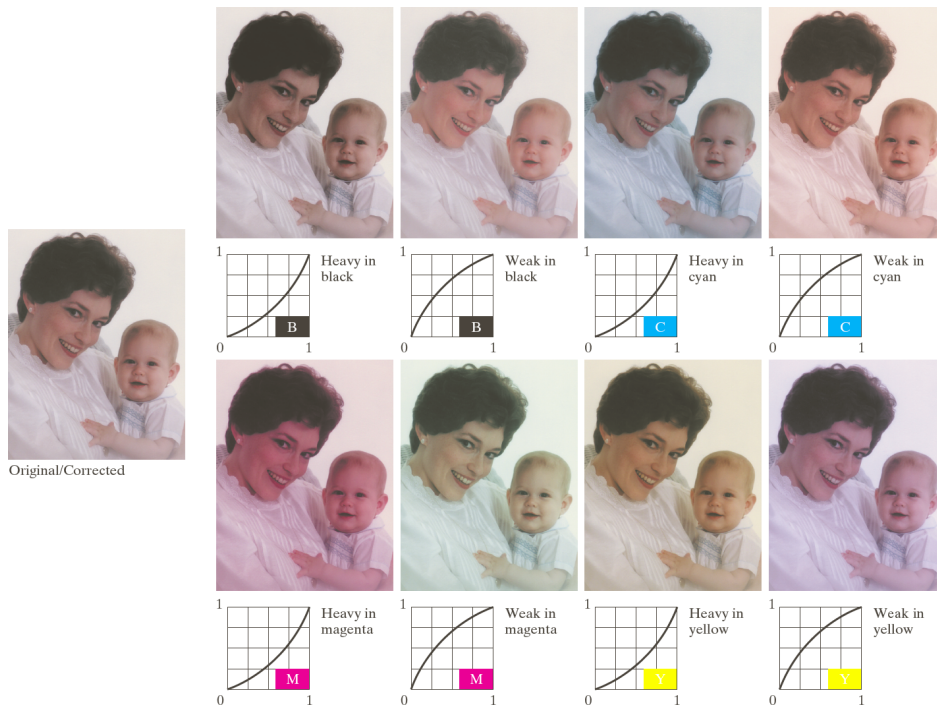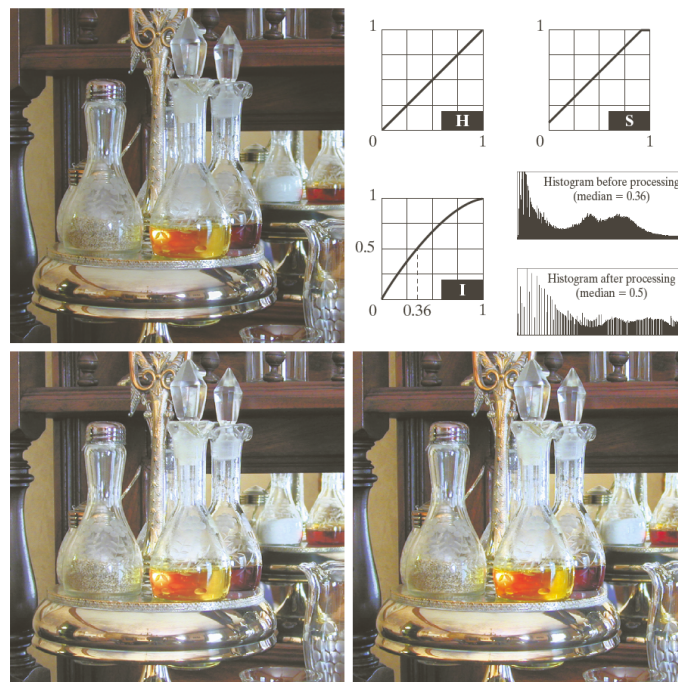
Tonal correction

Flat   Corrected

Tonal correction (2)

Light   Corrected

Tonal correction (3)

Dark   Corrected

Color balancing correction

Original/Corrected

Histogram equalization

Lena
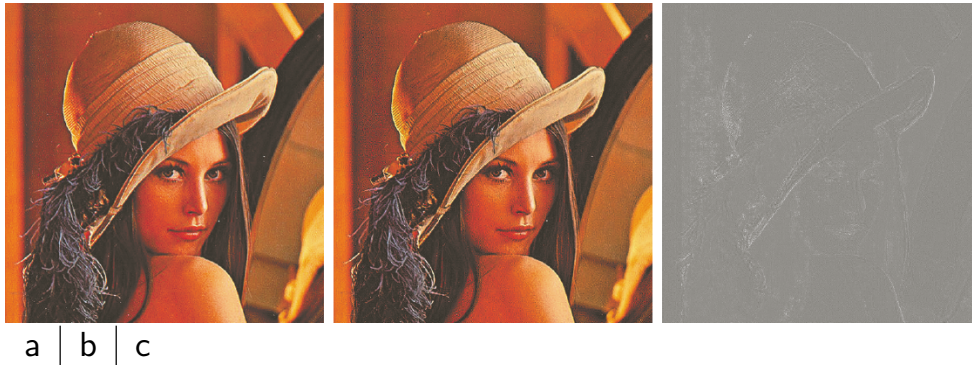

R   G   B

H   S   I

Smoothing

a | b | c
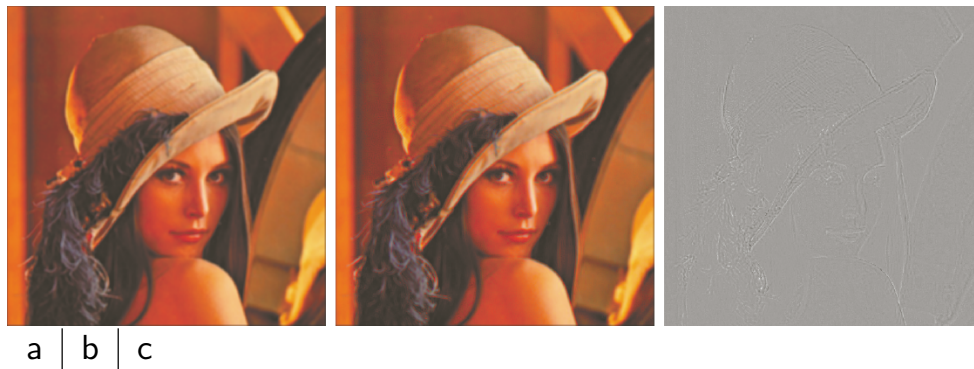
(a) 5×5 smoothing applied to all the RGB channels.

(b) 5×5 smoothing applied to the intensity channel.

(c) Difference.

Laplacian

a | b | c

(a) Laplacian sharpening applied to all the RGB channels.

(b) Laplacian sharpening applied to the intensity channel.

(c) Difference.

Homeworks and suggested readings

DIP, Sections 6.1–6.6

- ▶ pp. 394–443

GIMP

- ▶ Colors
  - ▶ Hue-Saturation
  - ▶ Brightness-Contrast
  - ▶ Threshold
  - ▶ Levels
  - ▶ Curves
  - ▶ Invert
  - ▶ Auto

Lena story

- ▶ http://en.wikipedia.org/wiki/Lenna
- ▶ http://www.ee.cityu.edu.hk/~lmpo/lenna/Lenna97.html