

Color image processing

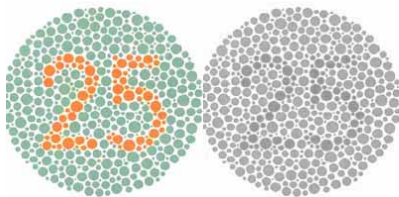
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Methods for Image Processing

academic year 2017–2018

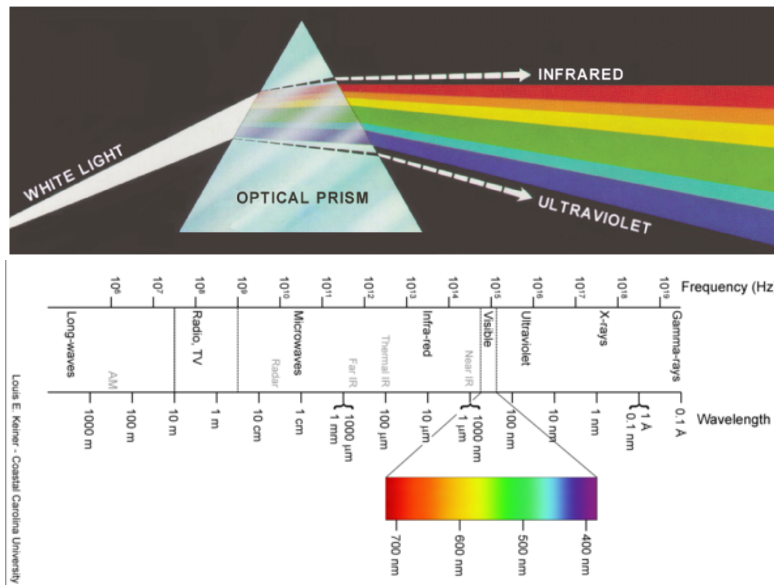
Color images



- ▶ Color is a feature that can greatly improve the description of the scene.
- ▶ The shades of colors that 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)

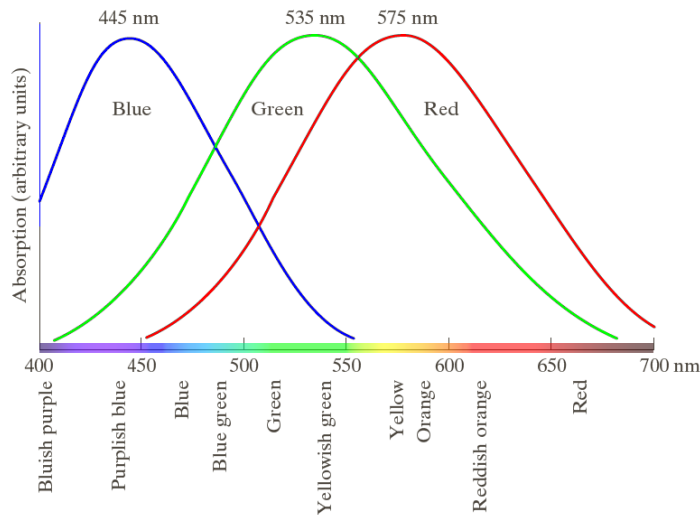


Physical nature of the color (2)

- ▶ 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):



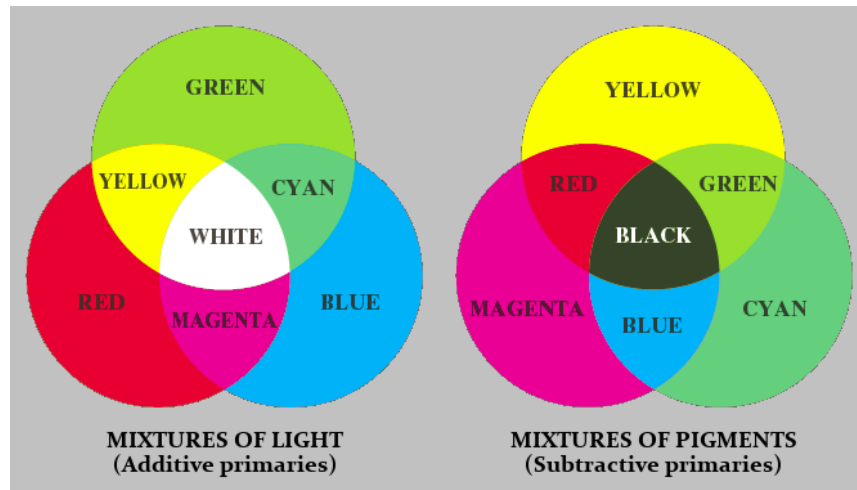
- ▶ each perceived color results from the activation of the cones belonging to the different types.

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)

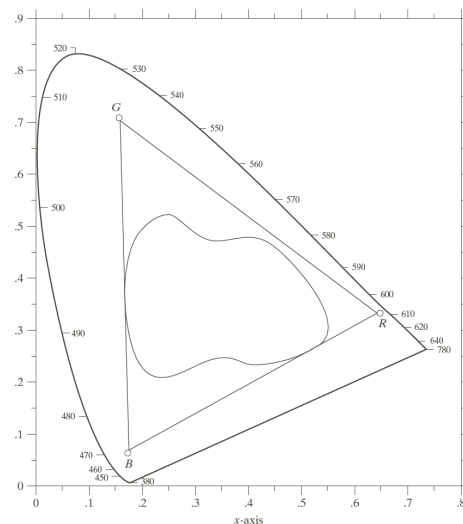
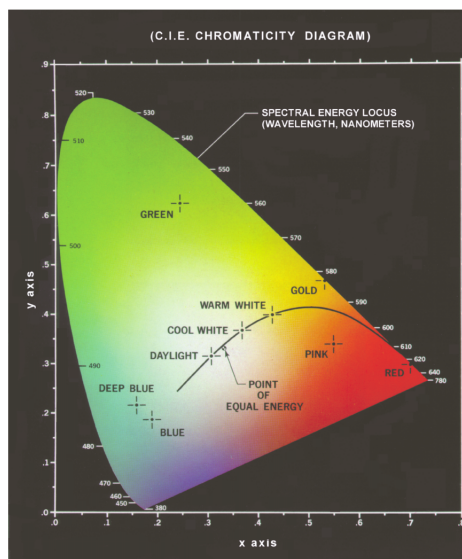
- ▶ Tristimulus: color coordinates for intensity value equal to 1.
 - ▶ X, Y, Z are color (not visible corresponding to R, G and B stimuli)
 - ▶ normalizing:

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

$$x + y + z = 1$$

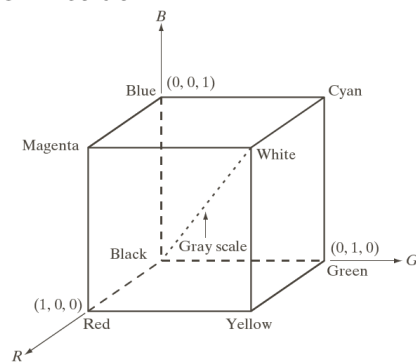
- ▶ A graph can be traced on the x - y plane and z can be derived as $z = 1 - x - y$.

Color spaces (3)



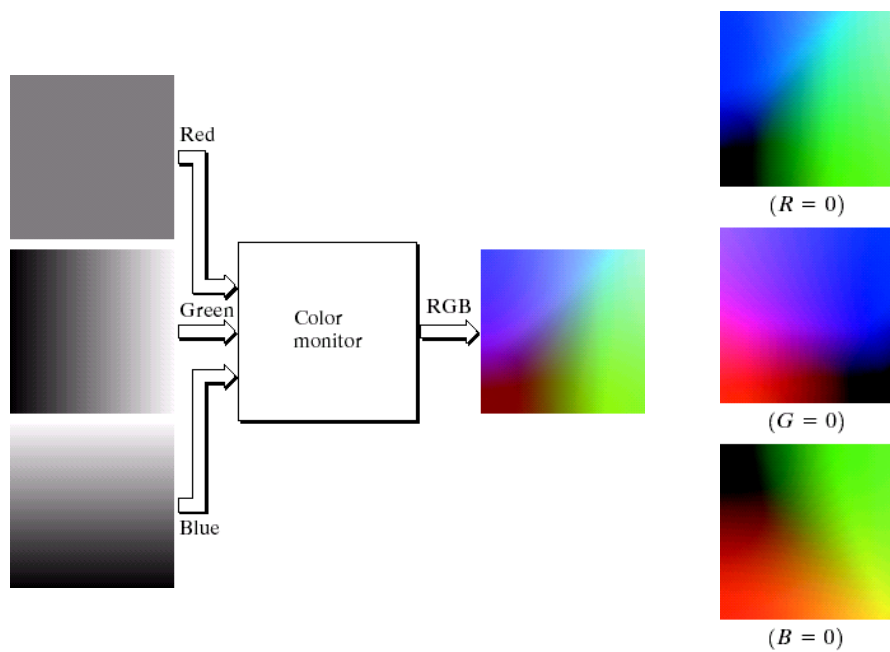
RGB color model

► RGB: cube



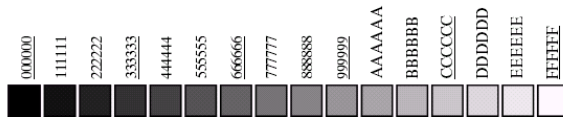
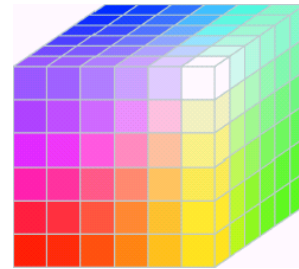
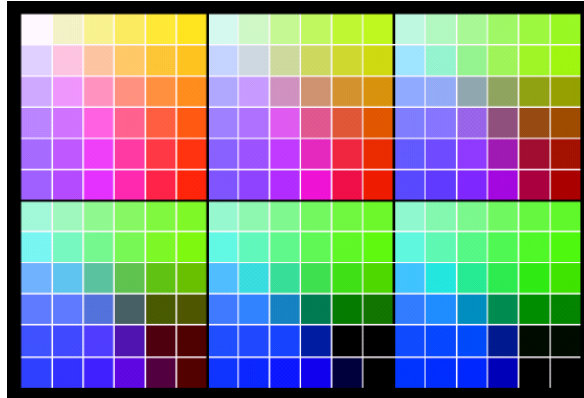
RGB color model (2)

► RGB color formation



RGB color model (3)

- ▶ “safe” colors: quantization $6 \times 6 \times 6 = 216$



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 $L^*a^*b^*$

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

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

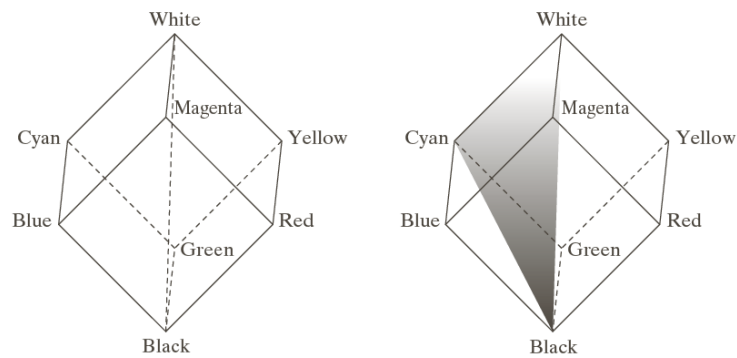
$$b^* = 200 \left[h \left(\frac{Y}{Y_W} \right) - h \left(\frac{Z}{Z_W} \right) \right]$$

where

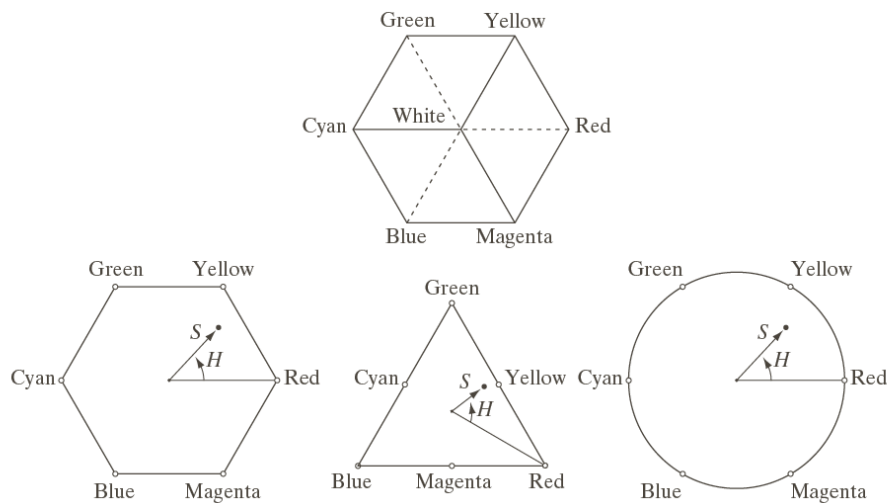
$$h(q) = \begin{cases} \sqrt[3]{q} & q > 0.008856 \\ 7.787 q & q \leq 0.008856 \end{cases}$$

HSI color model

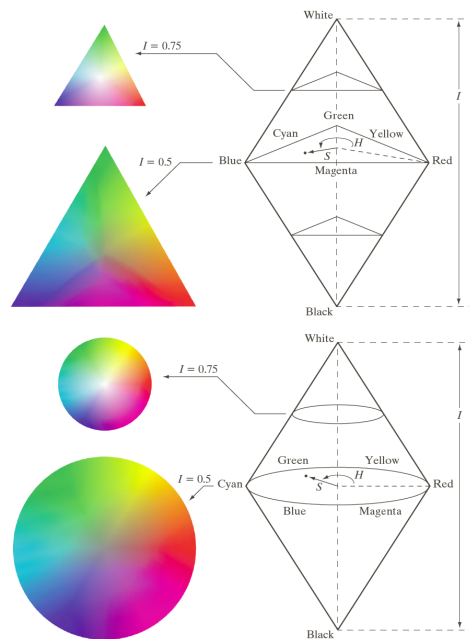
- ▶ RGB is useful for colors representation, not for description.
- ▶ HSI: (Hue, Saturation, Intensity)
 - ▶ HSV: (Hue, Saturation, Value)
- ▶ Hue: dominant color
- ▶ Saturation: distance from white
- ▶ Intensity: distance from black
- ▶ HSI fits better to the human perception of the color sensation.



HSI color model (2)

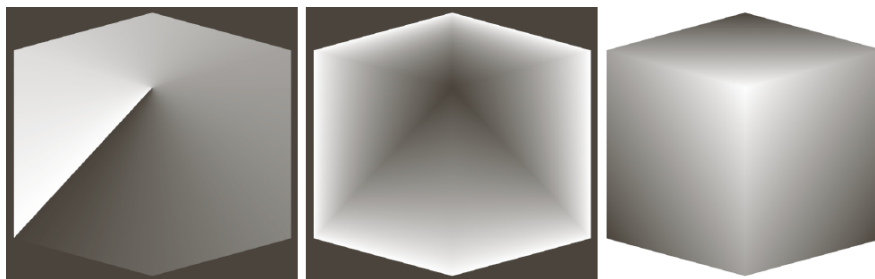


HSI color model (3)



RGB to/from HSI conversion

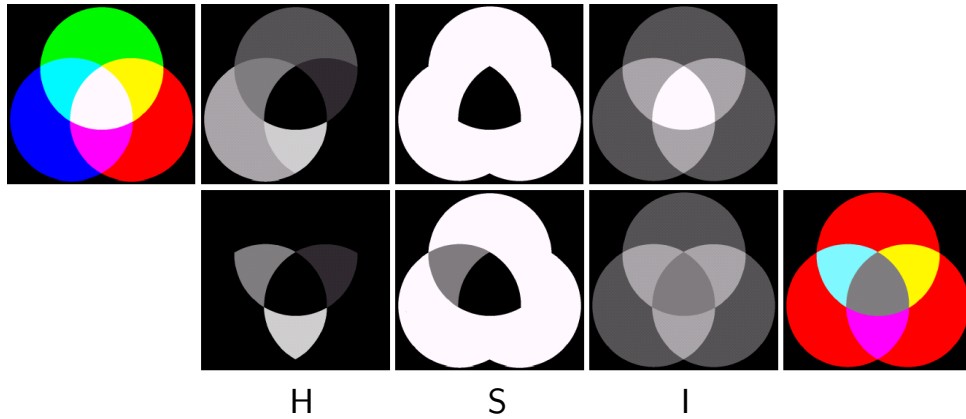
- ▶ RGB from/to HSI conversion formulas can be derived from the geometric relations between the two spaces.
- ▶ However, it should be noticed that:
 - ▶ hue is an angle with respect to the red position;
 - ▶ it can be normalized by dividing its value for the round angle;
 - ▶ red has hue value of both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



RGB cube represented in the HSI space.

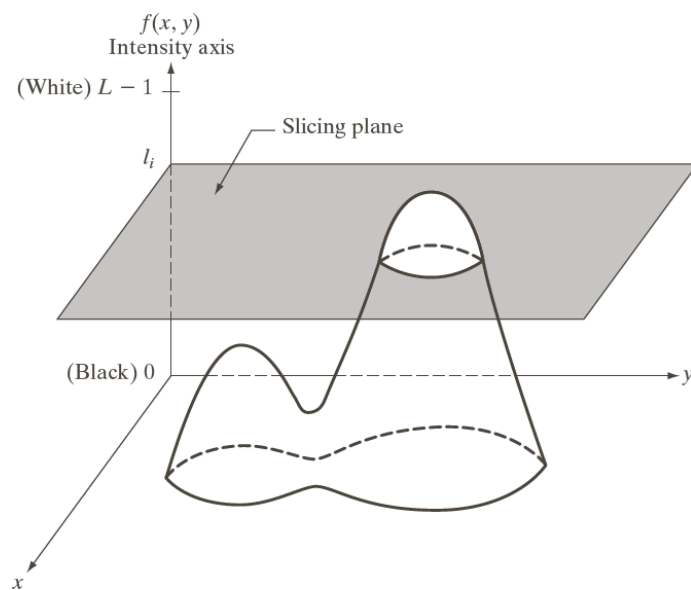
HSI processing example

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

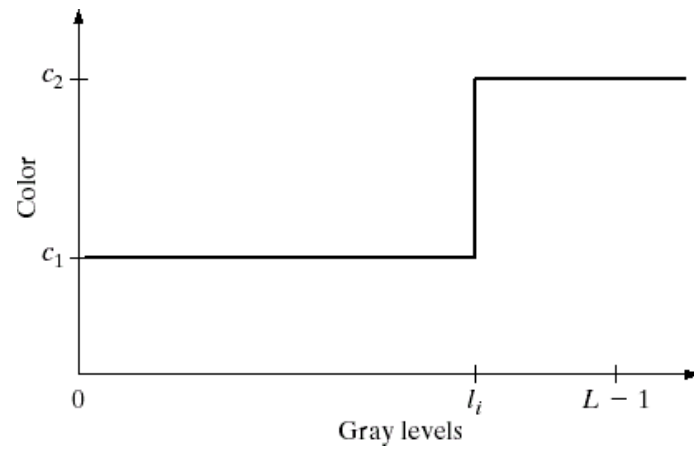


Intensity slicing

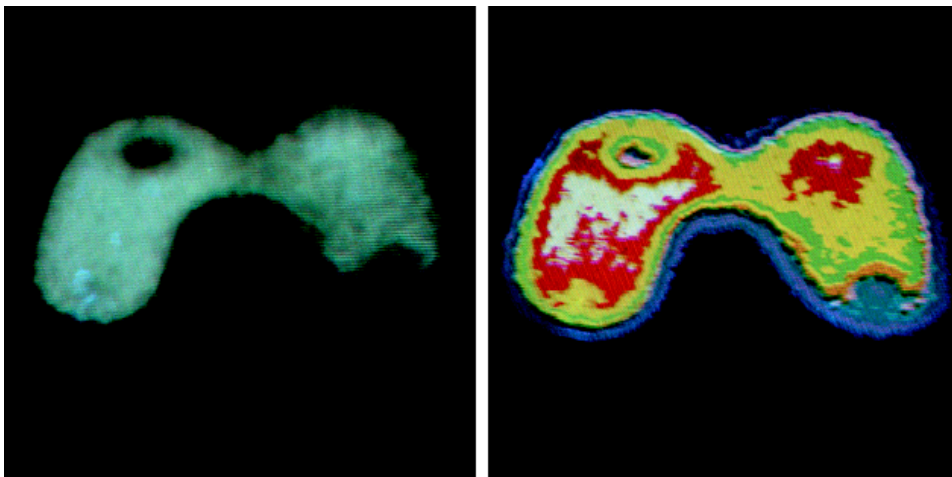
- ▶ Pseudocolor processing consists in assigning different color to different intensity ranges.



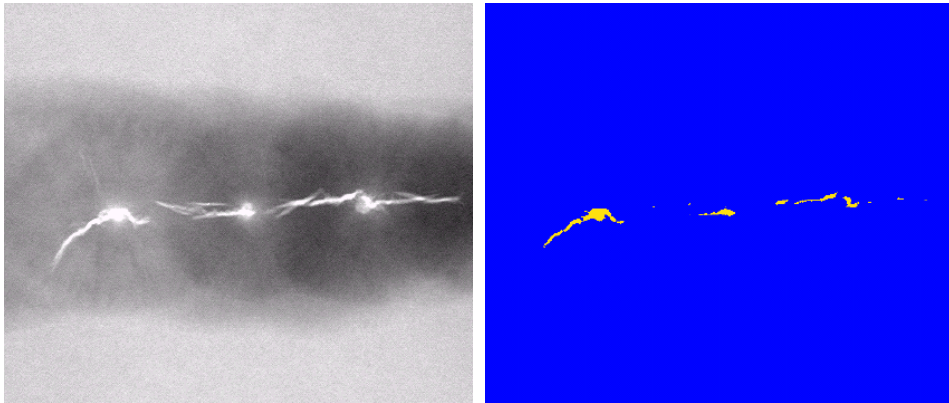
Intensity slicing (2)



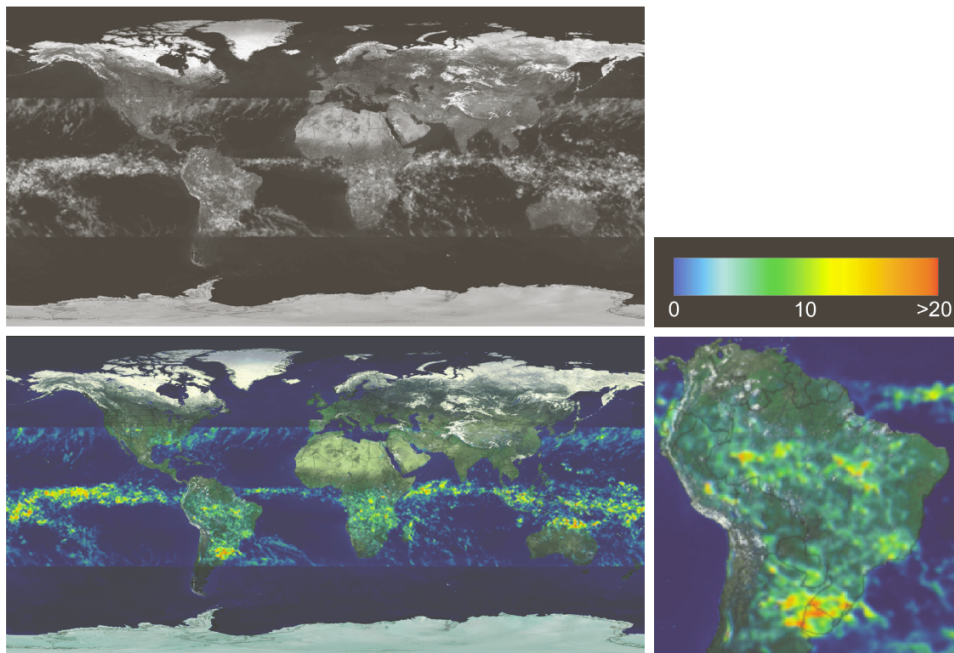
Intensity slicing (3)



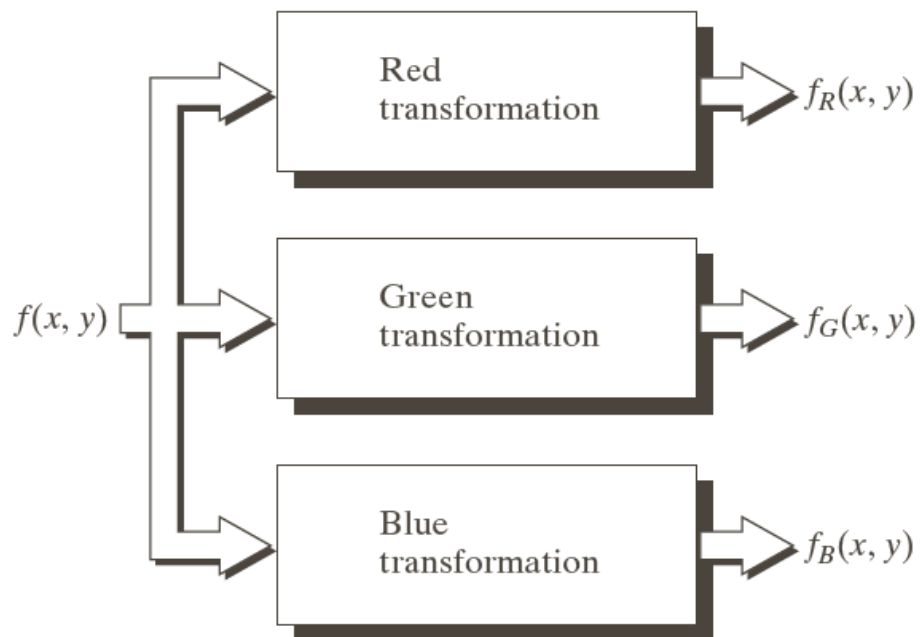
Intensity slicing (4)



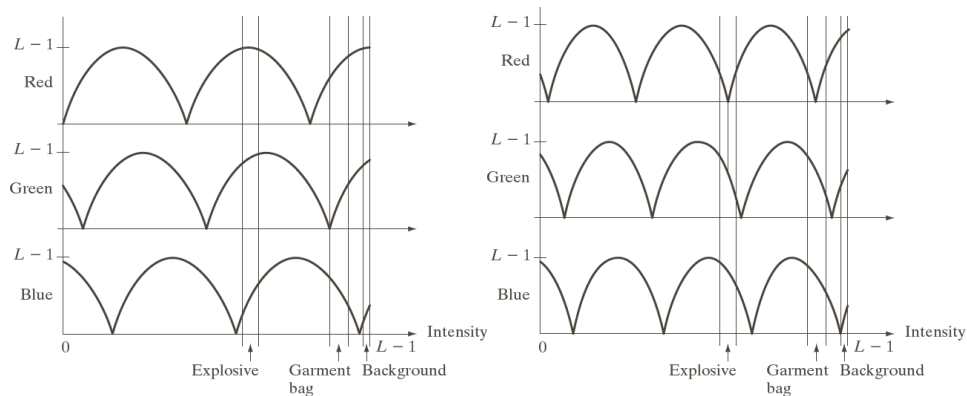
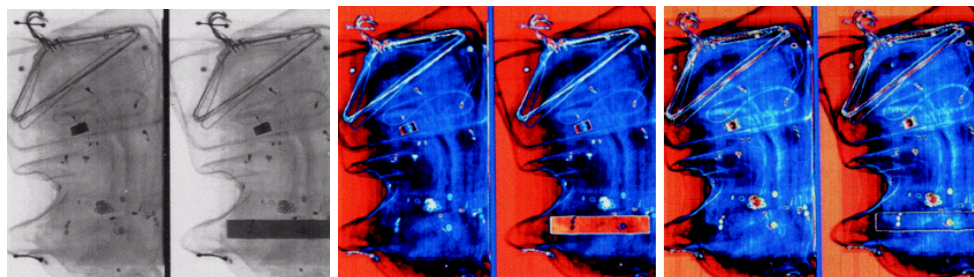
Intensity slicing (5)



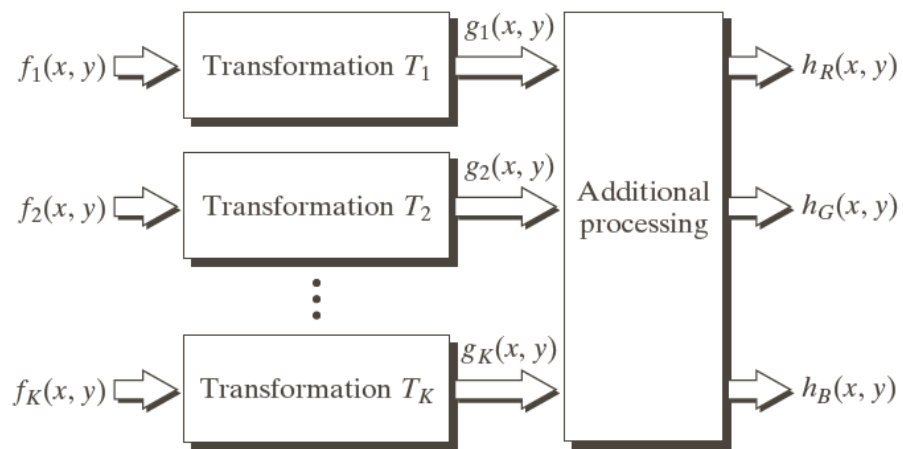
Intensity to color transformations



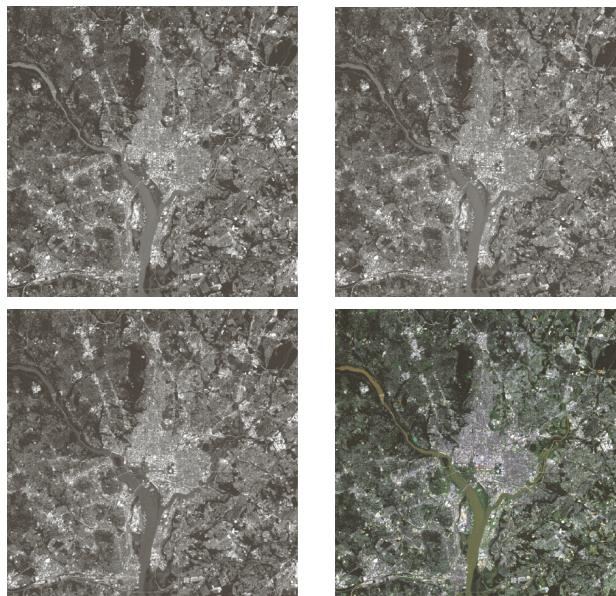
Intensity to color transformation (2)



Intensity to color transformation (3)



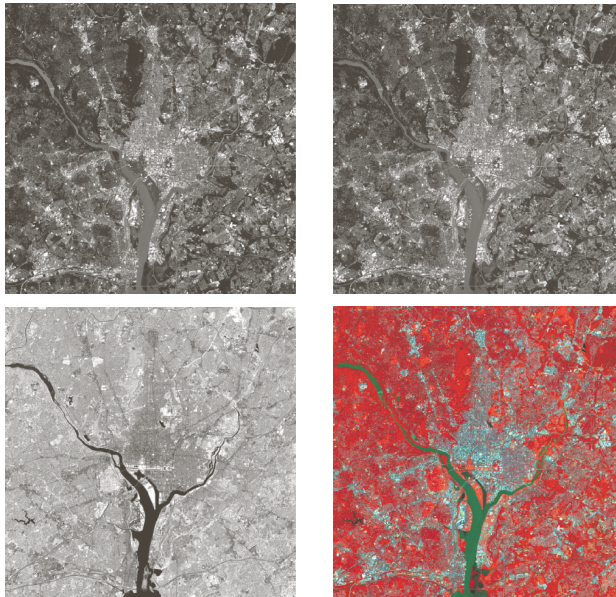
Intensity to color transformation (4)



a	b
c	d

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

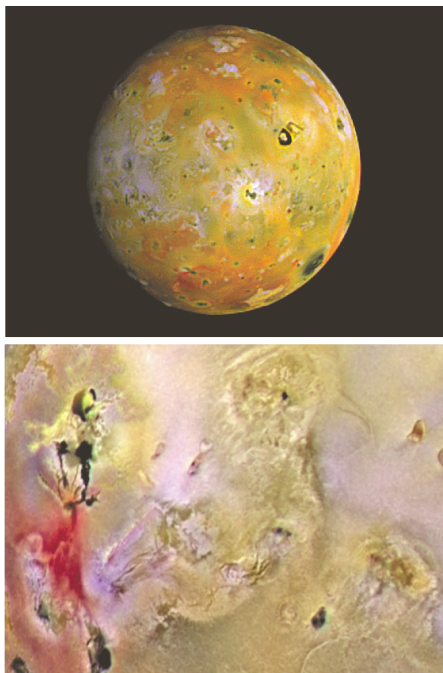
Intensity to color transformation (5)



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)



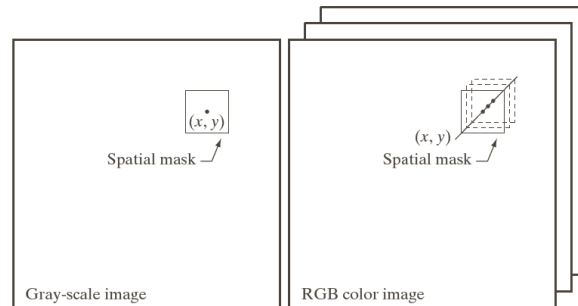
a
b

Chemical composition remapped onto color space.

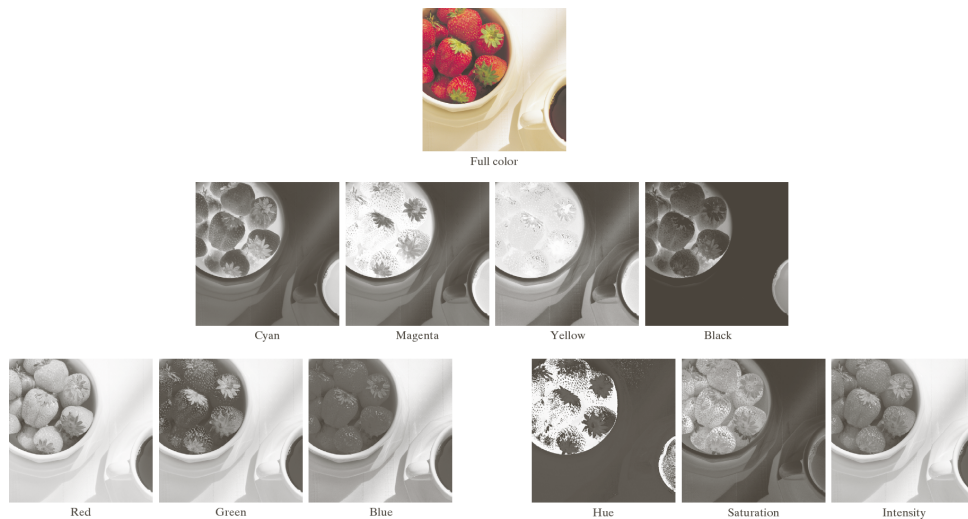
- (a) Io, a Jupiter moon;
- (b) material newly ejected from a volcano is depicted in red, while older material is yellowish.

Color image processing

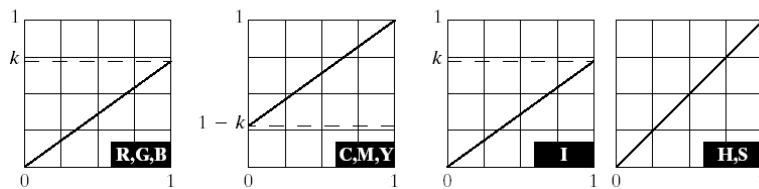
- ▶ The concept of spatial mask can be generalized for color images.



Representation in different color spaces

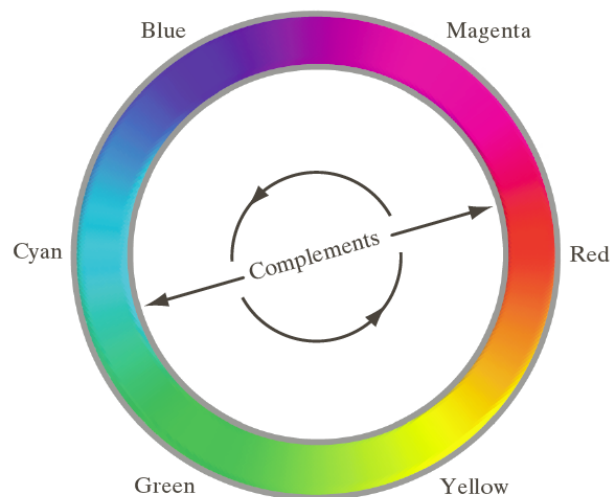


Intensity adjustment



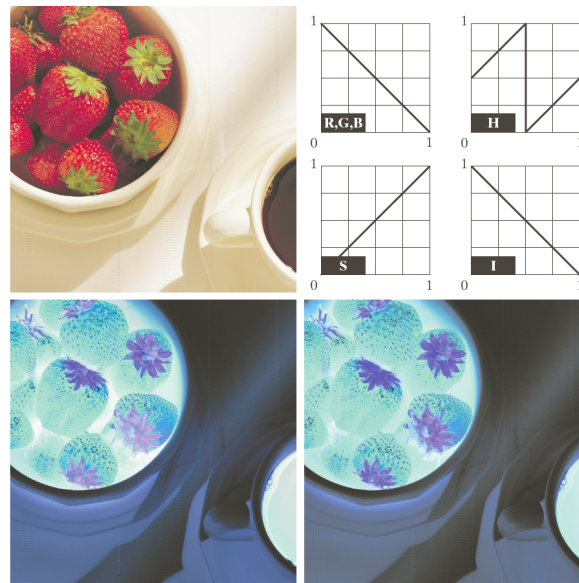
- The same processing can be operated in different color spaces.

Complement



- Complement is the generalization of the negative intensity transformation.

Complement (2)

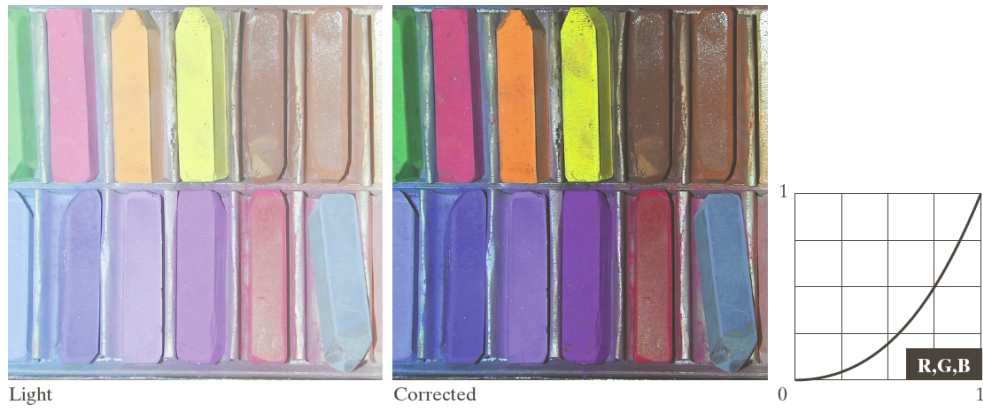


- ▶ Complement can be obtained both in RGB and HSI space.
 - ▶ Although in RGB it is more simply expressed.

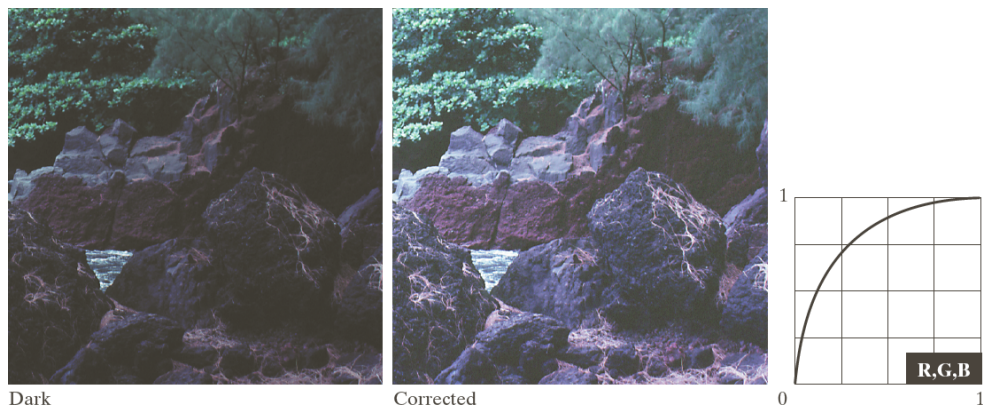
Tonal correction



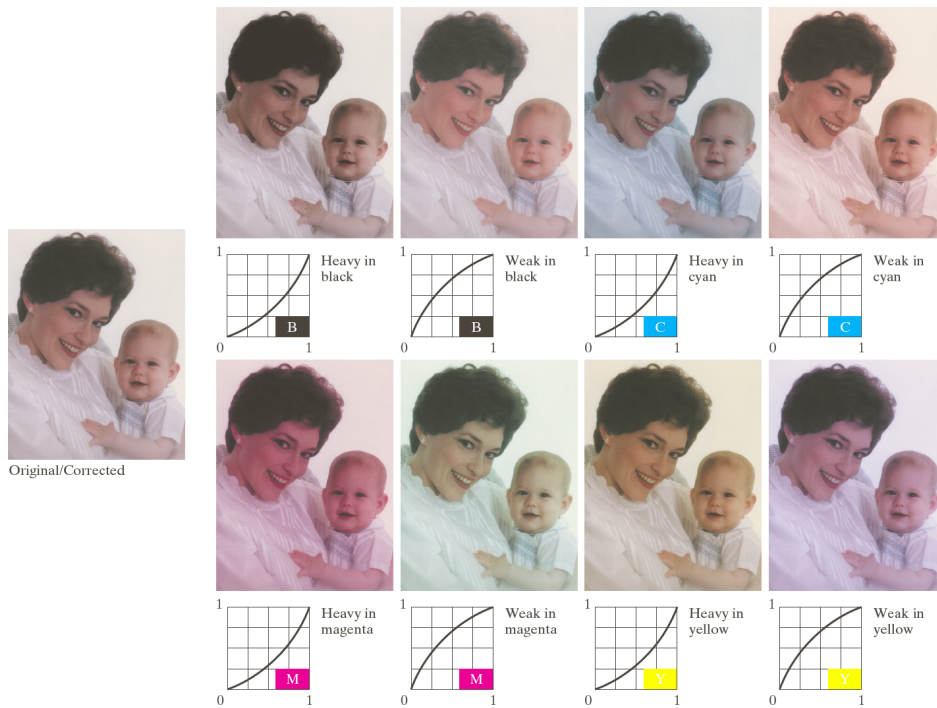
Tonal correction (2)



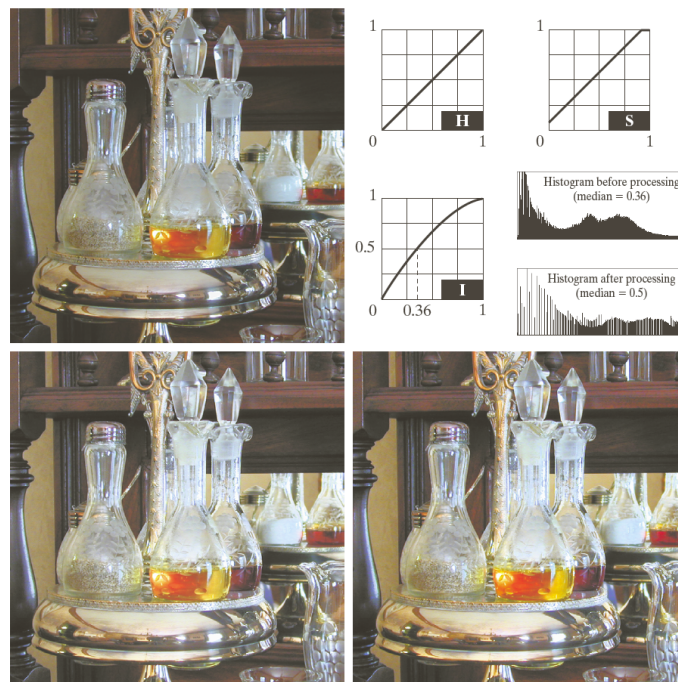
Tonal correction (3)



Color balancing correction



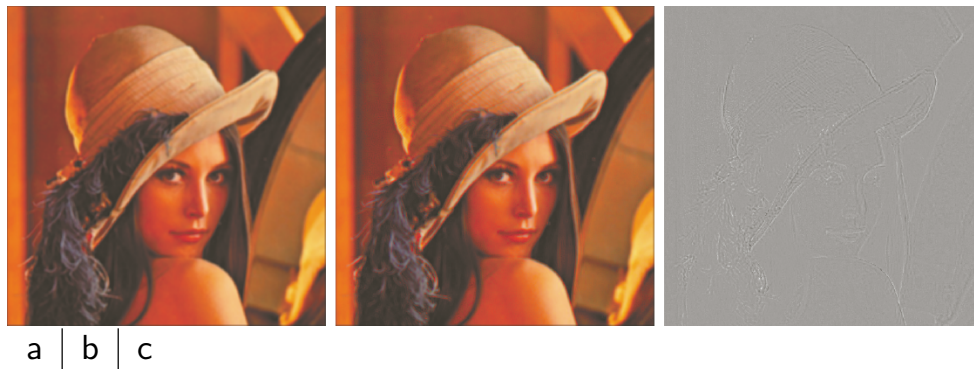
Histogram equalization



Lena

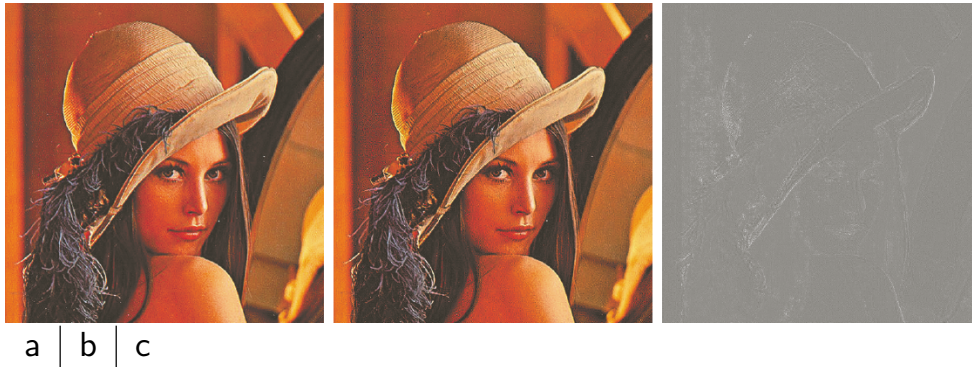


Smoothing



- (a) 5×5 smoothing applied to all the RGB channels.
- (b) 5×5 smoothing applied to the intensity channel.
- (c) Difference.

Laplacian



- (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>