Digital Image Processing

Lecture # 8
Color Processing & Segmentation

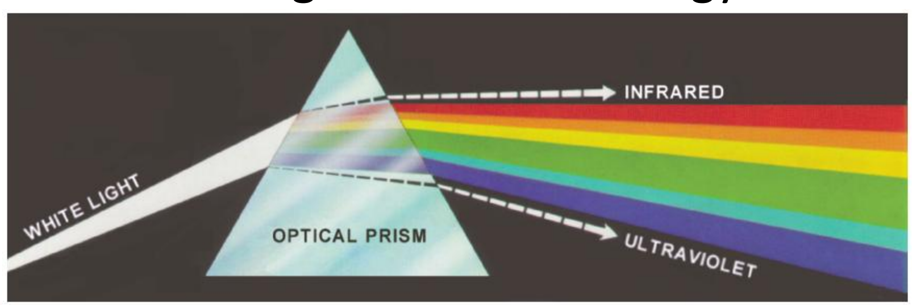
COLOR IMAGE PROCESSING

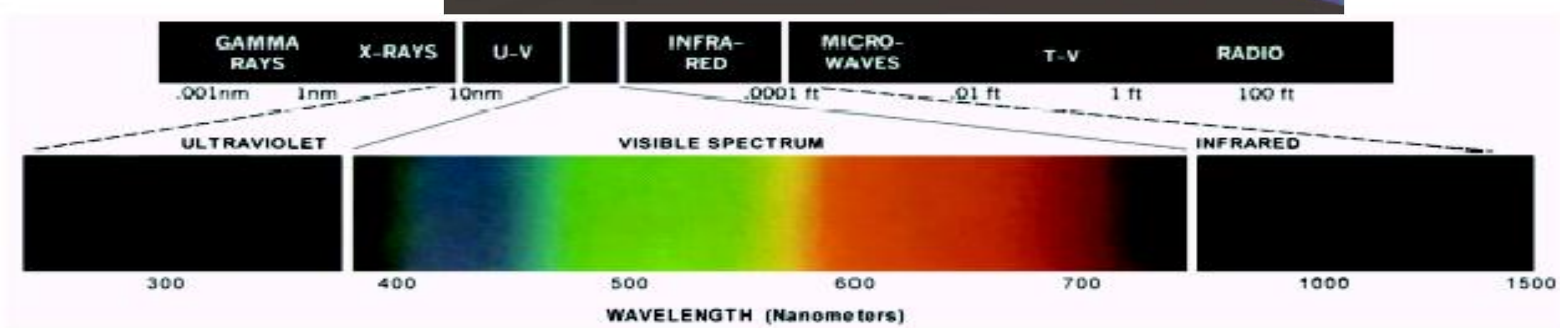
COLOR IMAGE PROCESSING

- Color Importance
  - Color is an excellent descriptor
    - Suitable for object Identification and Extraction
  - Discrimination
    - Humans can distinguish thousands of color shades and intensities but few shades of gray levels
- Color Image Processing
  - Full-Color Processing
    - Color is acquired with a full-color sensor
  - Pseudo-Color Processing
    - Assigning colors to monochrome images

COLOR FUNDAMENTALS

- Colors that humans perceive in an object are determined by the nature of the light reflected from the object
- Visible light is composed of a relatively narrow band of frequencies in the electromagnetic spectrum
- A body that reflects light that is balanced in all visible wavelengths appears white to the observer
- A body that favours reflectance in a limited range of the visible spectrum exhibits some shades of color
- Green objects reflect light with wavelengths primarily in the 500 to 570 nm range while absorbing most of the energy at other wavelengths





HUMAN PERSCEPTION OF COLOR

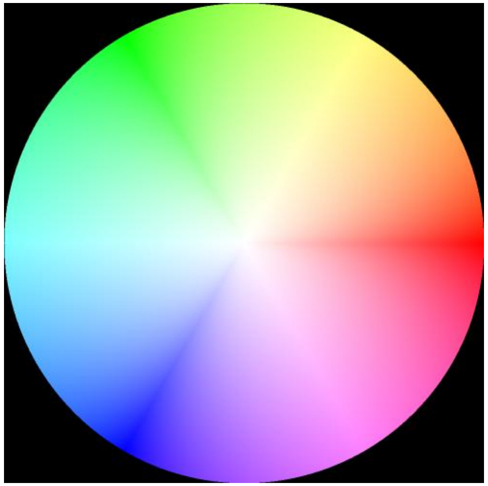
- Retina contains receptors
  - Cones
    - Day vision, can perceive color tone
    - Red, green, and blue cones
  - Rods
    - Night vision, perceive brightness only
- Color sensation
  - Luminance (brightness)
  - Chrominance
    - Hue (color tone)
    - Saturation (color purity)

Monochromatic images

- Image processing - static images -
- Monochromatic static image - continuous image function f(x,y)
  - arguments - two co-ordinates (x,y)
- Digital image functions - represented by matrices
  - co-ordinates = integer numbers
  - Cartesian (horizontal x axis, vertical y axis)
  - OR (row, column) matrices
- Monochromatic image function range
  - lowest value - black
  - highest value - white
- Limited brightness values = gray levels

Chromatic images

- Colour
  - Represented by vector not scalar
    - Red, Green, Blue (RGB)
    - Hue, Saturation, Value (HSV)
    - luminance, chrominance (Yuv , Luv)



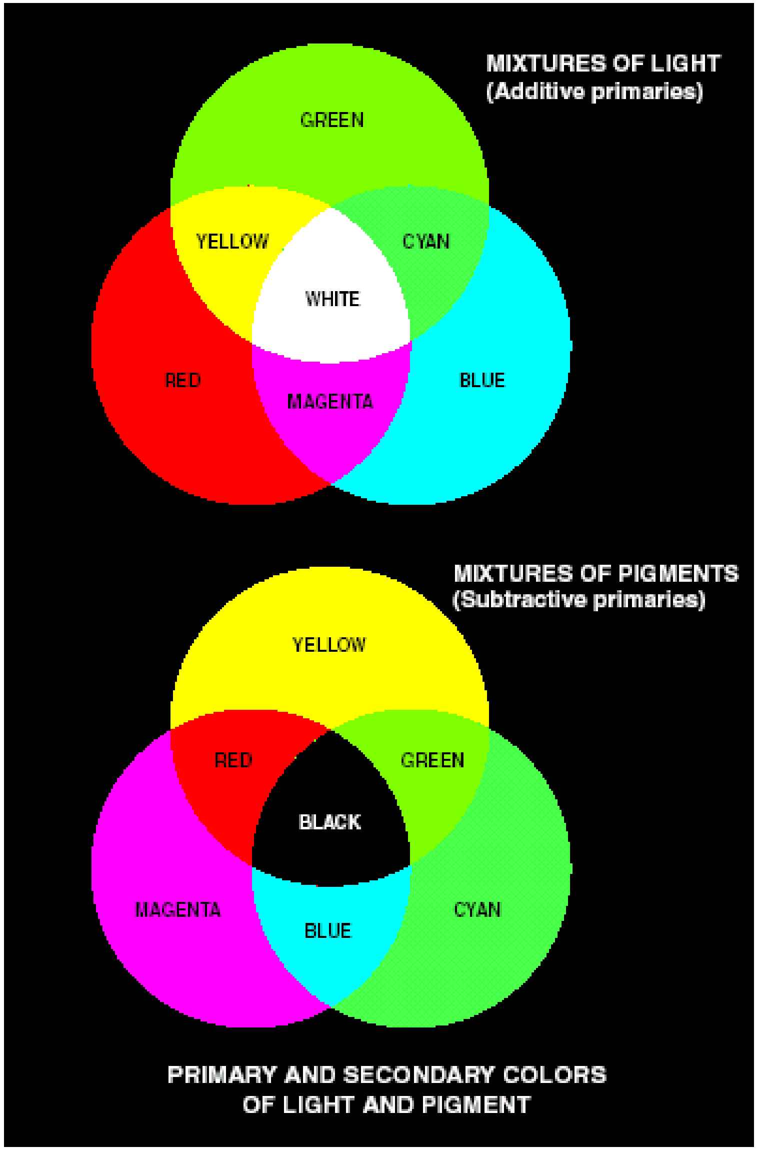
PRIMARY AND SECONDARY COLORS OF LIGHT AND PIGMENTS

- The primary colors can be added to produce the secondary colors of light
- The primary colors of light and primary colors of pigments are different

Magenta = Red + Blue
Cyan = Blue + Green
Yellow = Green + Red

- For pigments, a primary color is defined as one that absorbs a primary color of light and reflects the other two
- Therefore, the primary colors of pigments are magenta, cyan, and yellow

Magenta = White - Green
Cyan = White - Red
Yellow = White - Blue



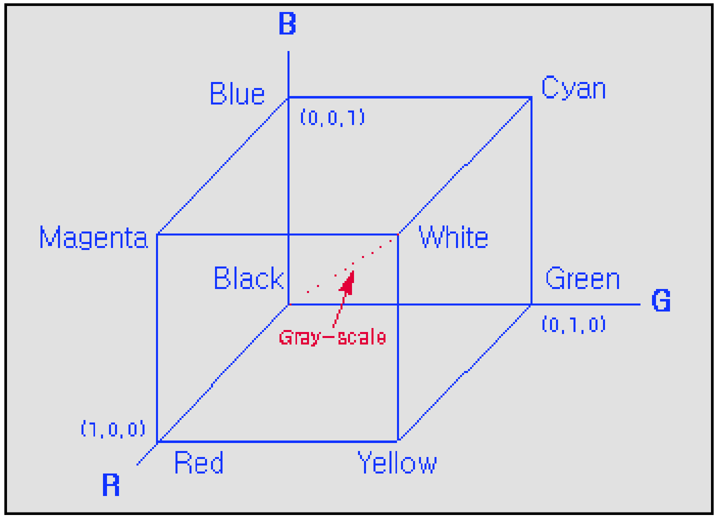
COLOR MODELS

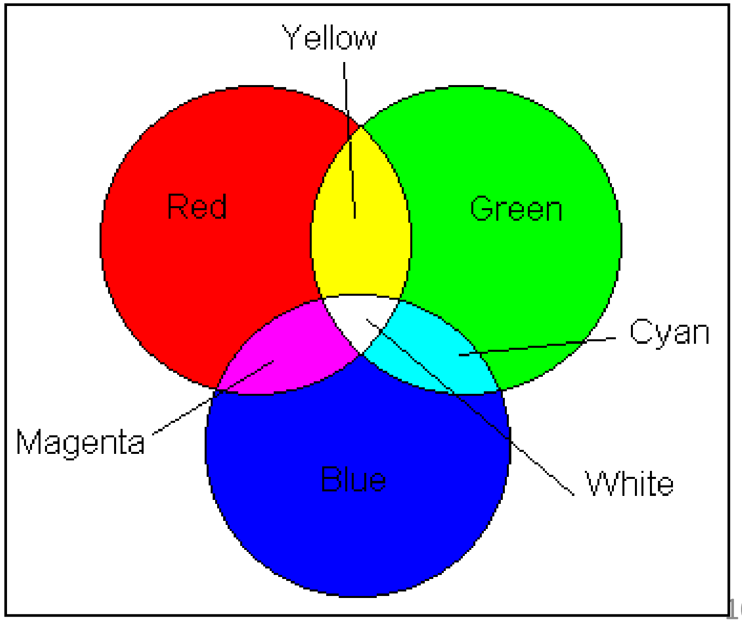
- Color Model
  - Specify colors in a standard way
  - A coordinate system that each color is represented by a single point.
- Most used models:
  - RGB model (Monitor/TV)
  - CMY model (3-color Printers)
  - HSI model (Color Image Processing and Description)

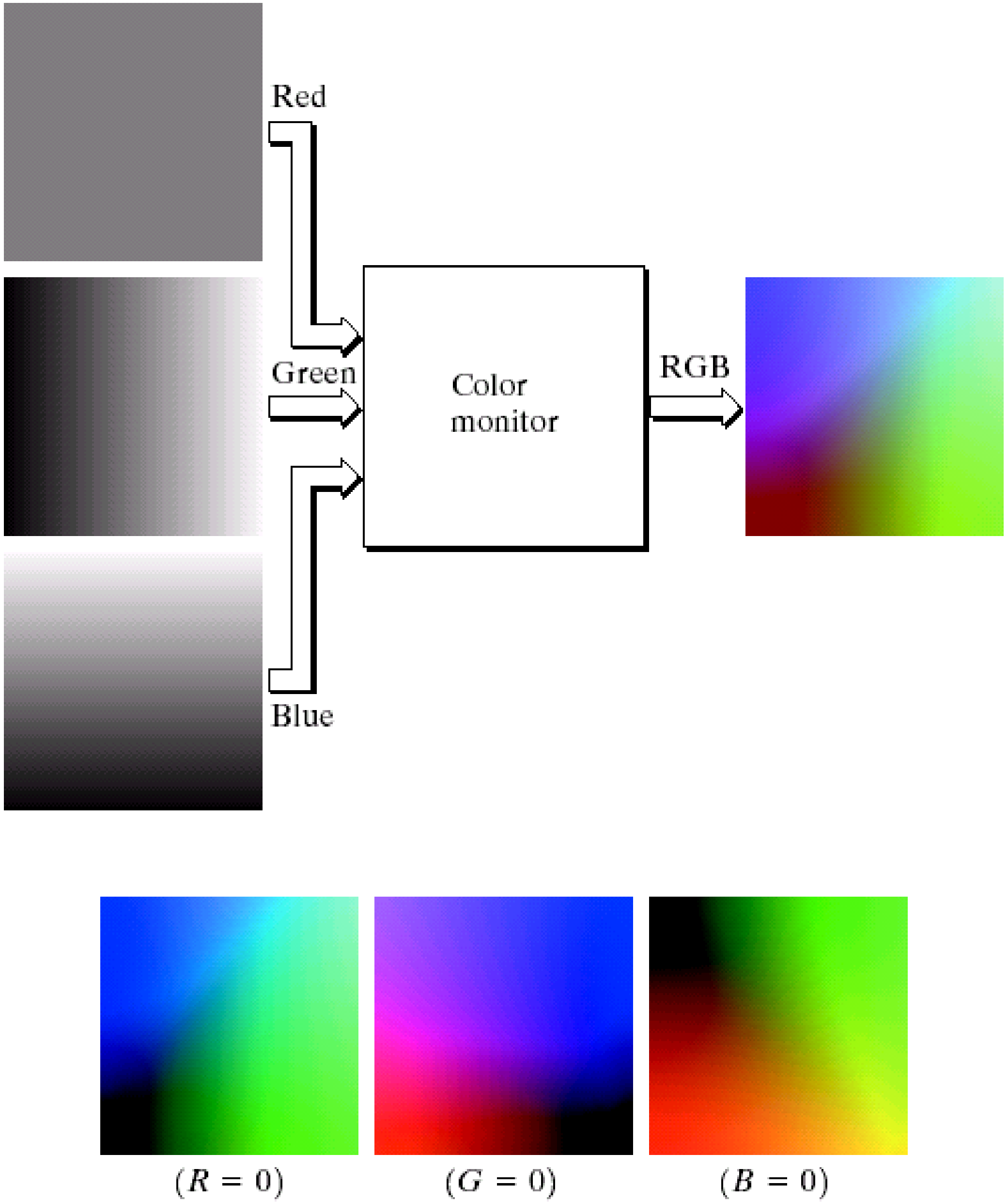
RGB COLOR MODEL

- Pixel Depth: The number of bits used to represent each pixel in RGB space.
- Full-color image: 24-bit RGB color image.
  - (R, G, B) = (8 bits, 8 bits, 8 bits)
  - Number of colors:

$$\left(2^8\right)^3 = 16{,}777{,}216$$







a
b

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.

COLOR IMAGE - RGB

Color Image

a b
c d

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

R-Channel

G-Channel

B-Channel

CMY Model

– Color Printer, Color Copier

– RGB data to CMY

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

HSI COLOR MODEL

- Human description of color is Hue, Saturation and Brightness:
- Hue
  - represents dominant color as perceived by an observer. It is an attribute associated with the dominant wavelength.
- Saturation
  - refers to the relative purity or the amount of white light mixed with a hue. The pure spectrum colors are fully saturated.
    - Pure colors are fully saturated.
    - Pink is less saturated.
- Intensity
  - reflects the brightness.

HSI Color Model

- The HSI model uses three measures to describe colors:
  - Hue: A color attribute that describes a pure color (pure yellow, orange or red)
  - Saturation: Gives a measure of how much a pure color is diluted with white light
  - Intensity: Intensity is the same achromatic notion that we have seen in grey level images

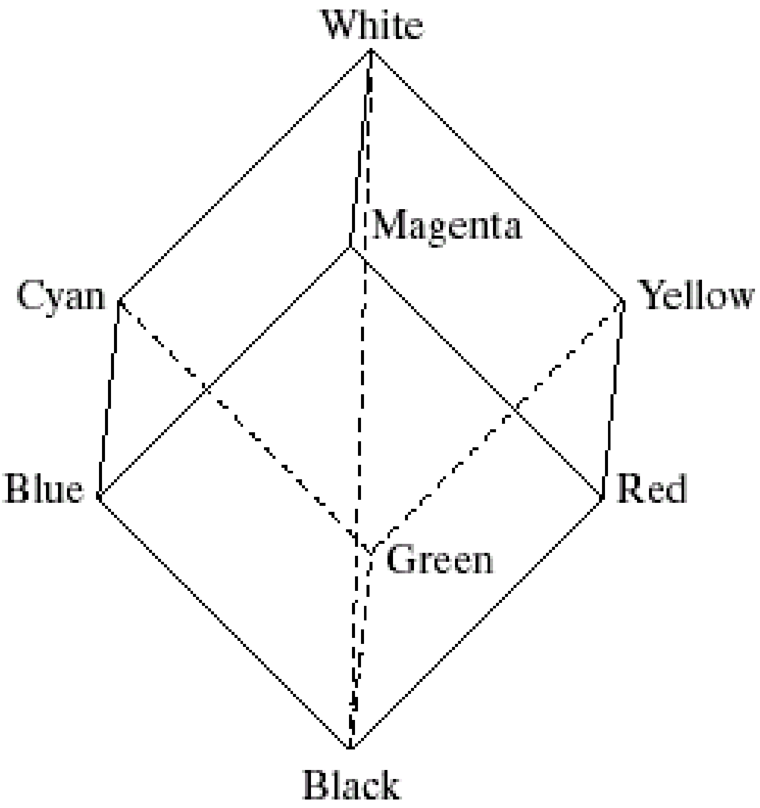
HSI Color Model

- Intensity can be extracted from RGB images
- Remember the diagonal on the RGB color cube that we saw previously ran from black to white
- Now consider if we stand this cube on the black vertex and position the white vertex directly above it

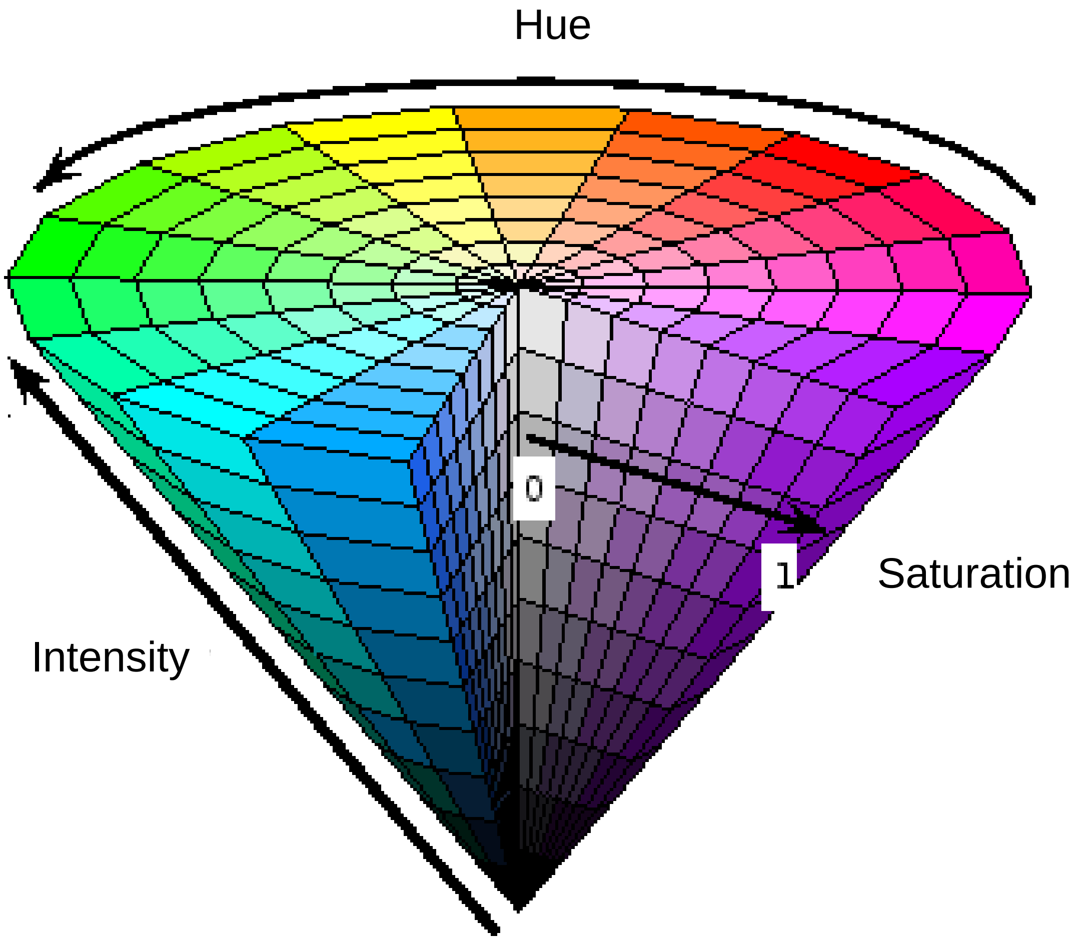
HSI Color Model

- The intensity component of any color can be determined by passing a plane *perpendicular* to the intensity axis and containing the color point

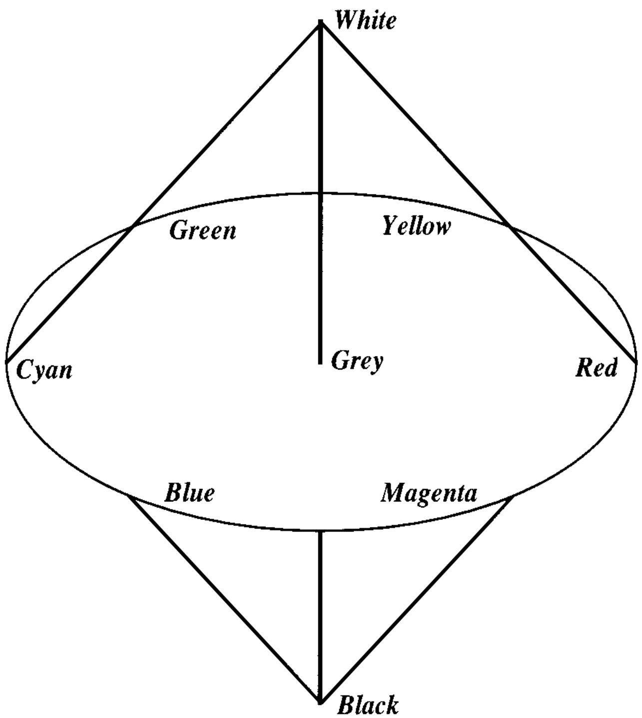
- The intersection of the plane with the intensity axis gives us the intensity component of the color

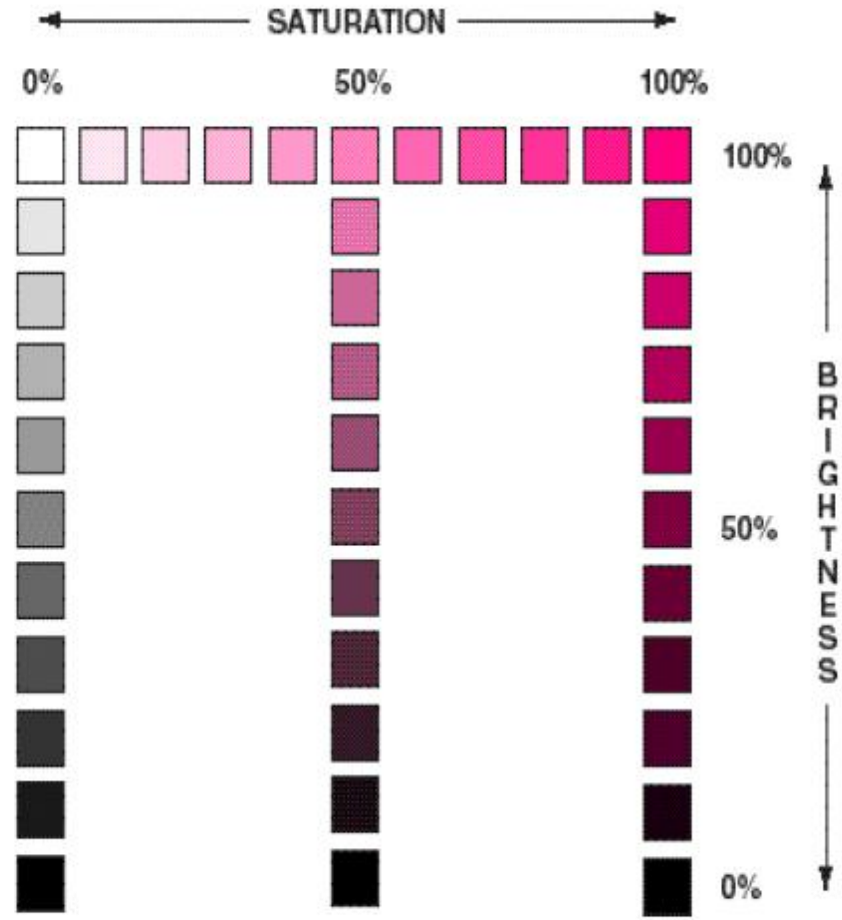


HSI Color Model



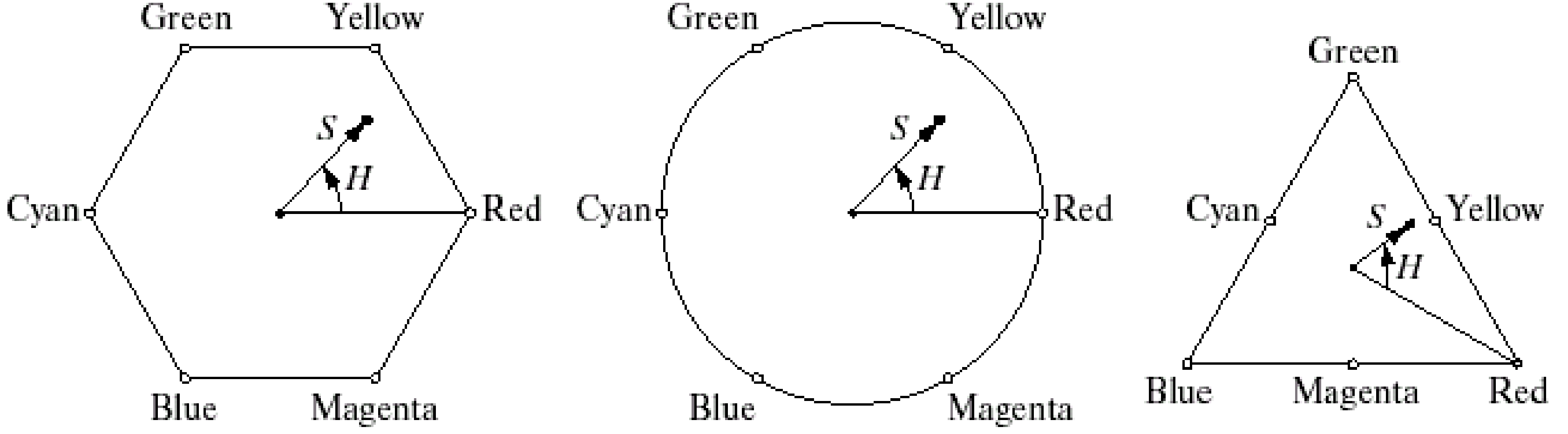
HSI COLOR MODEL- SINGLE HUE



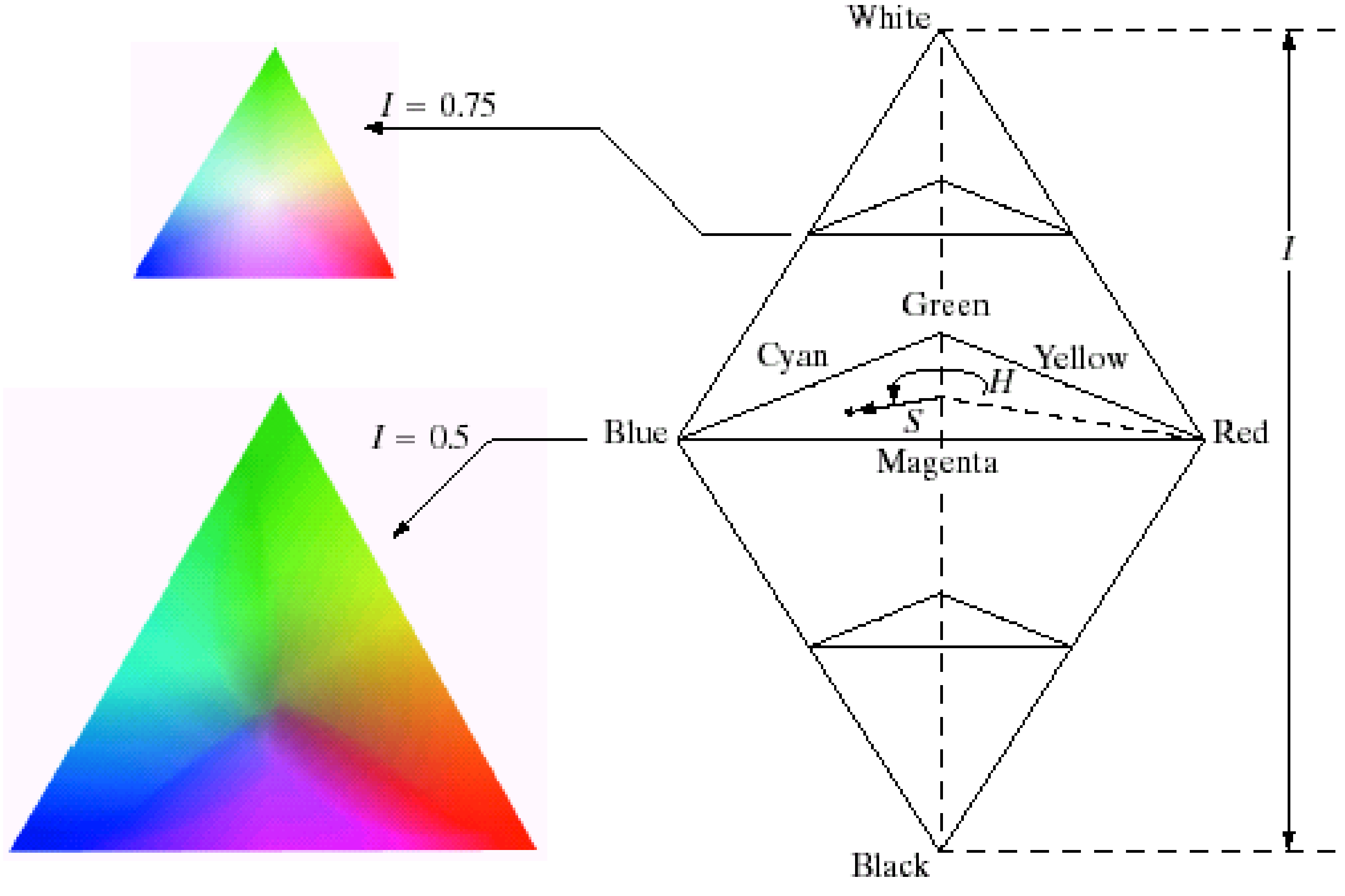


HSI Color Model

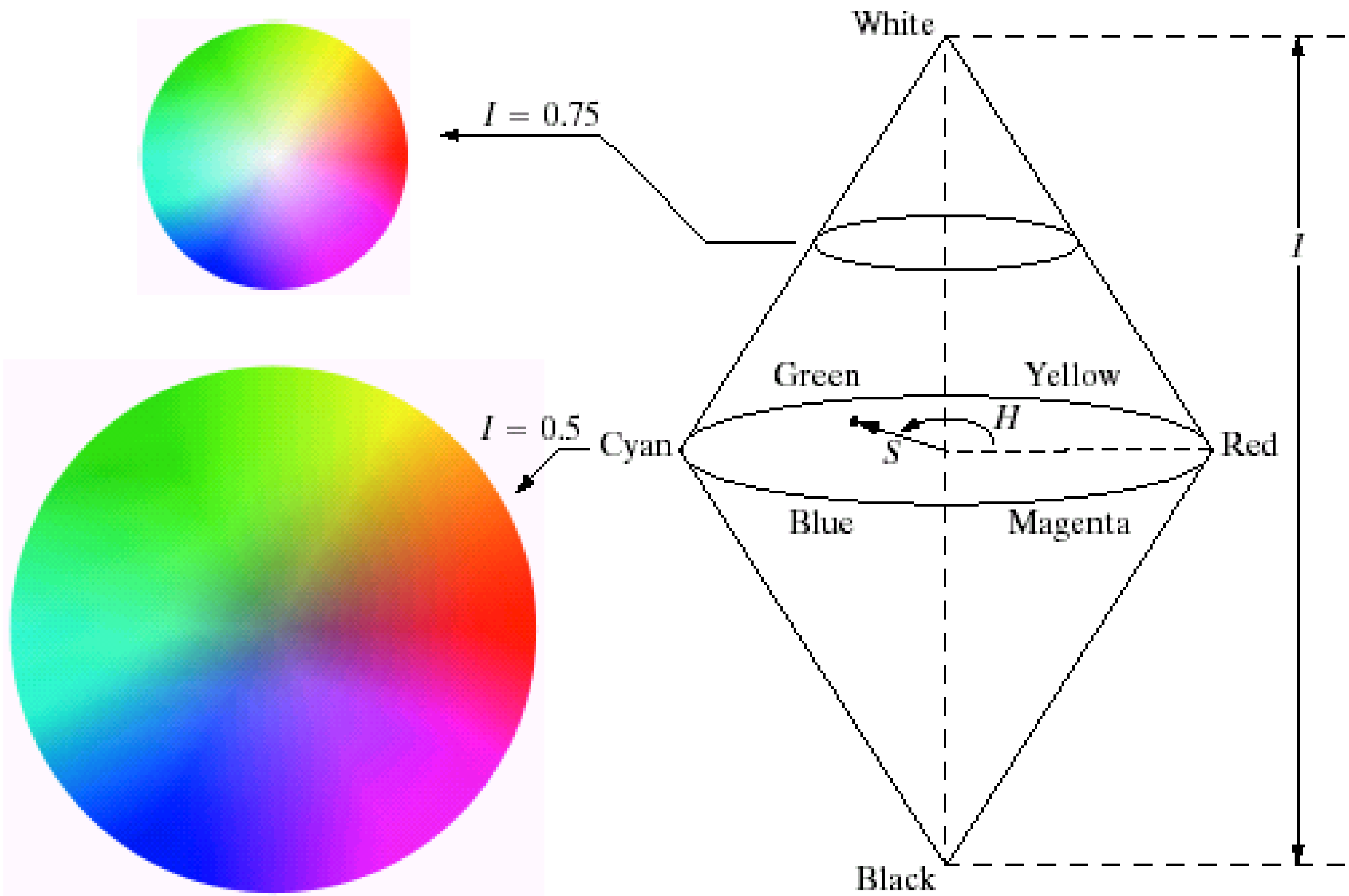
Because the only important things are the angle and the length of the saturation vector this plane is also often represented as a circle or a triangle



HSI Color Model



HSI Color Model



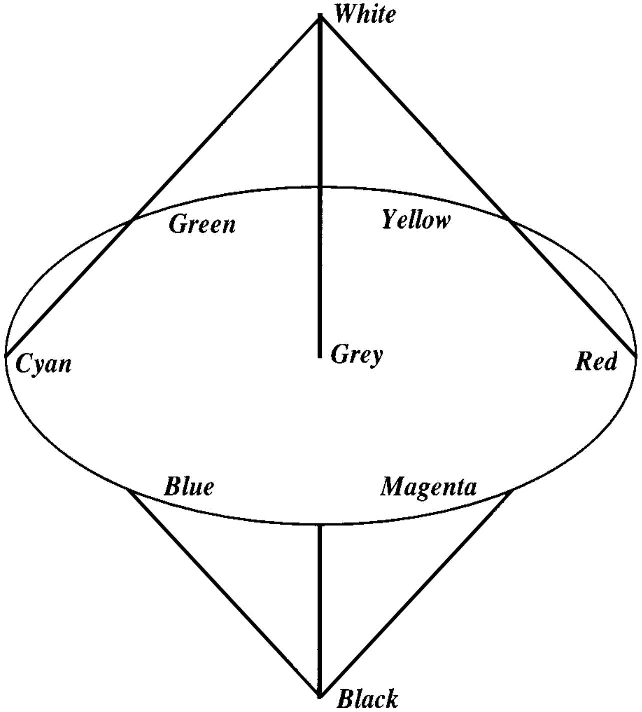
Converting from RGB to HSI

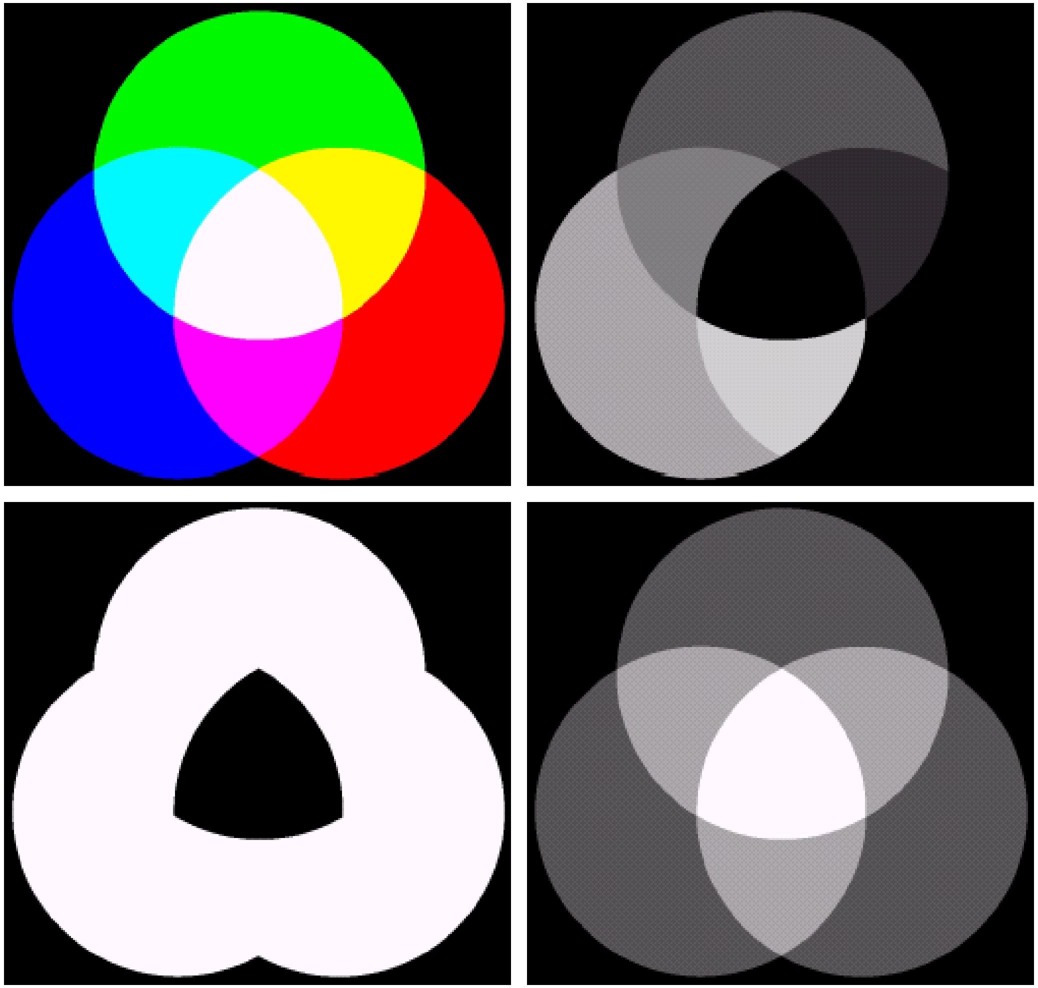
$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-G)^2+(R-B)(G-B)\right]^{\frac{1}{2}}} \right\}$$

$$H = \begin{cases} \theta & if\ B \leq G \\ 360-\theta & if\ B > G \end{cases}$$

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

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





a b
c d

FIGURE 6.16 (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.

COLOR IMAGE - HSI

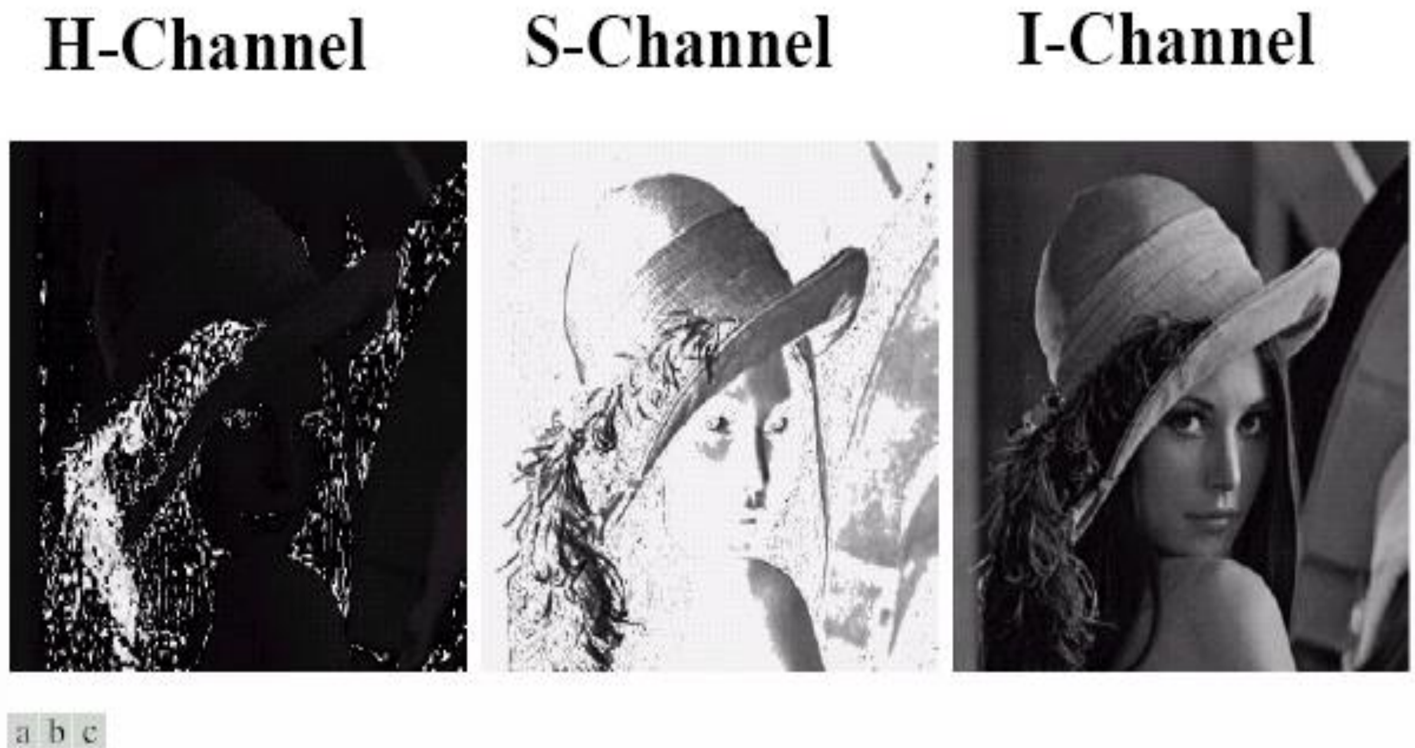
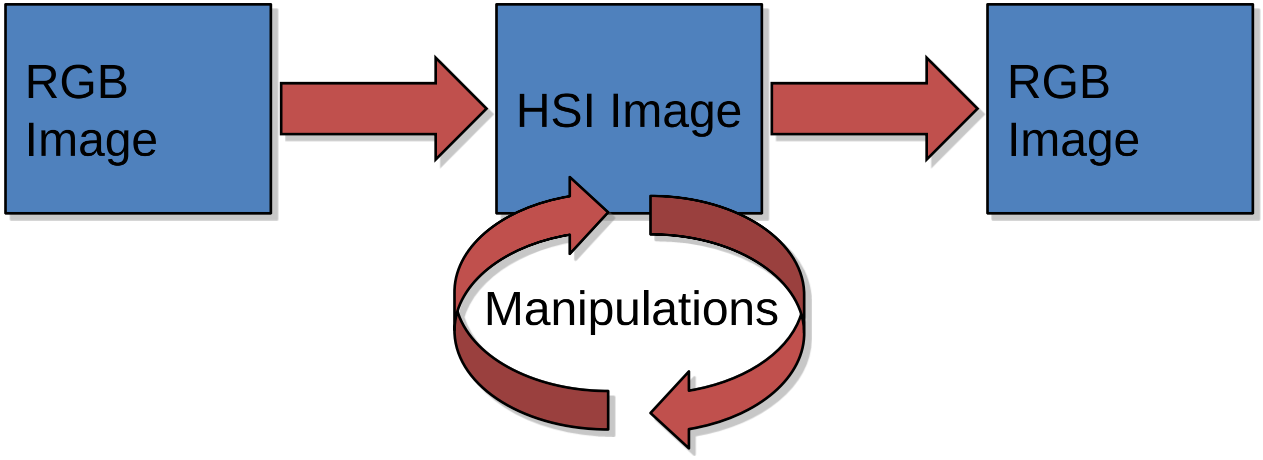


FIGURE 6.39 HSI components of the RGB color image in Fig. 6.38(a). (a) Hue. (b) Saturation. (c) Intensity.

Manipulating Images In The HSI Model

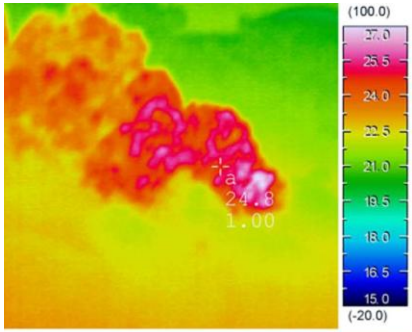
- In order to manipulate an image under the HSI model we:
  - First convert it from RGB to HSI
  - Perform our manipulations under HSI
  - Finally convert the image back from HSI to RGB

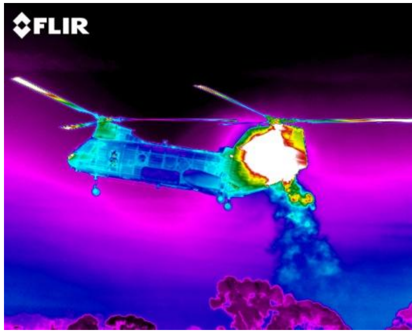


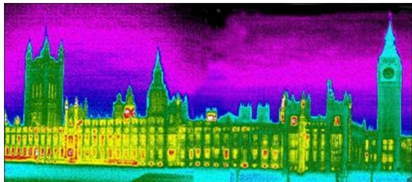
Pseudocolor Image Processing

- Pseudocolor (also called false color) image processing consists of assigning colors to grey values based on a specific criterion

- The principle use of pseudocolor image processing is for human visualization



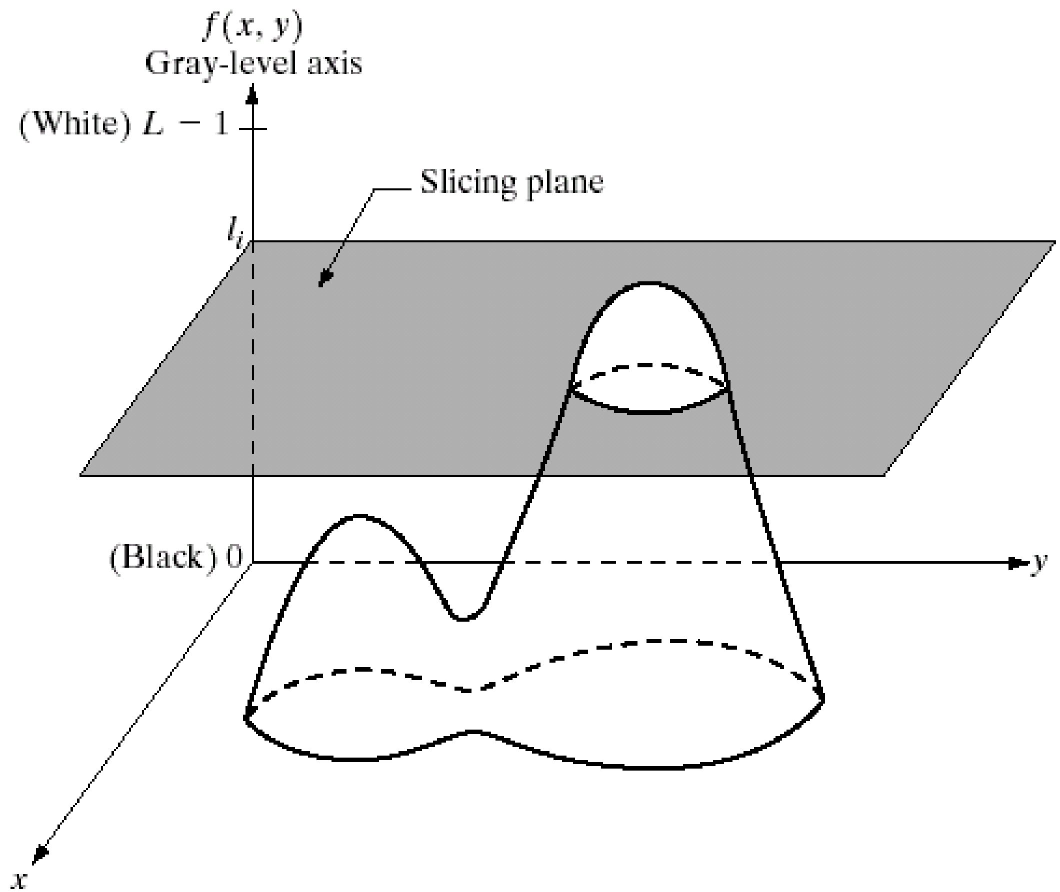




Pseudo Color Image Processing – Intensity Slicing

- Intensity slicing and color coding is one of the simplest kinds of pseudocolor image processing
- First we consider an image as a 3D function mapping spatial coordinates to intensities (that we can consider heights)
- Now consider placing planes at certain levels parallel to the coordinate plane
- If a value is one side of such a plane it is rendered in one color, and a different color if on the other side

Pseudo Color Image Processing – Intensity Slicing



Pseudo Color Image Processing – Intensity Slicing

- In general intensity slicing can be summarized as:
  - Let [$0, L-1$] represent the grey scale
  - Let l_0 represent black [$f(x, y) = 0$] and let l_{L-1} represent white [$f(x, y) = L-1$]
  - Suppose P planes perpendicular to the intensity axis are defined at levels $l_1, l_2, \dots, l_p$
  - Assuming that $0 < P < L-1$ then the P planes partition the grey scale into $P + 1$ intervals $V_1, V_2, \dots, V_{P+1}$

Pseudo Color Image Processing – Intensity Slicing

– Grey level color assignments can then be made according to the relation:

$$f(x,y) = c_k \qquad \text{if } f(x,y) \in V_k$$

– where c_k is the color associated with the k^{th} intensity level V_k defined by the partitioning planes at $l = k - 1$ and $l = k$

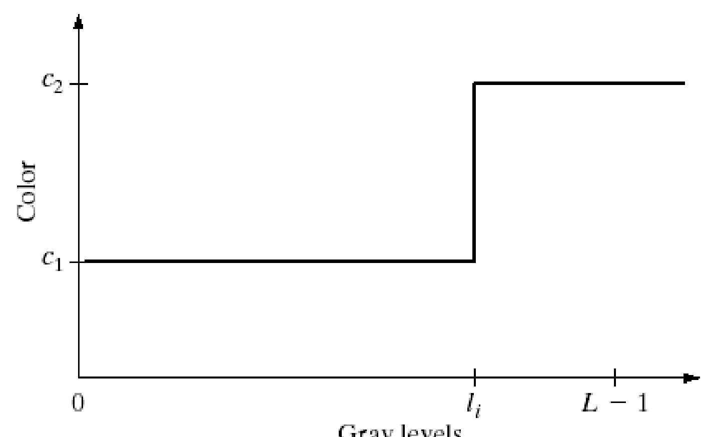
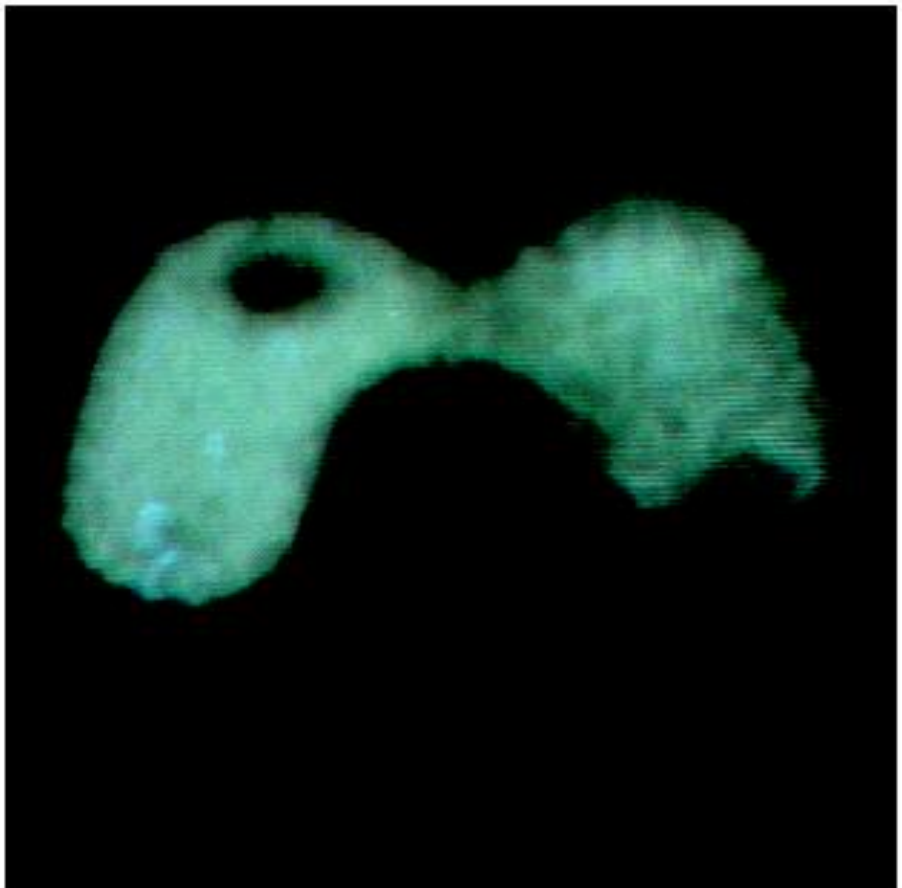
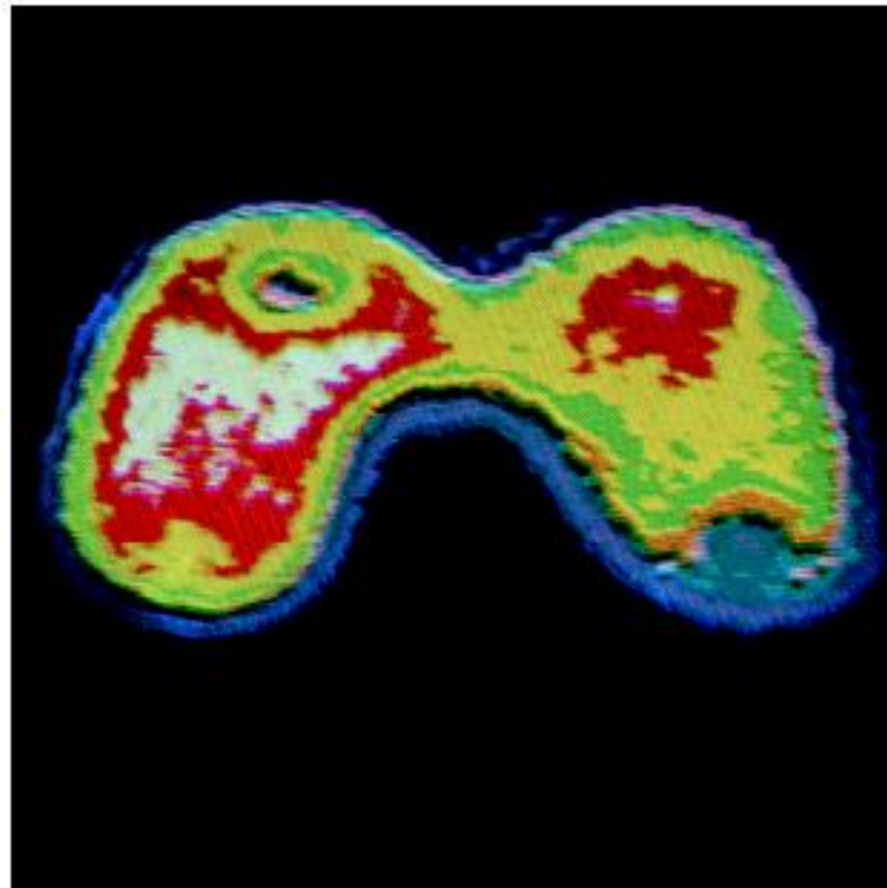


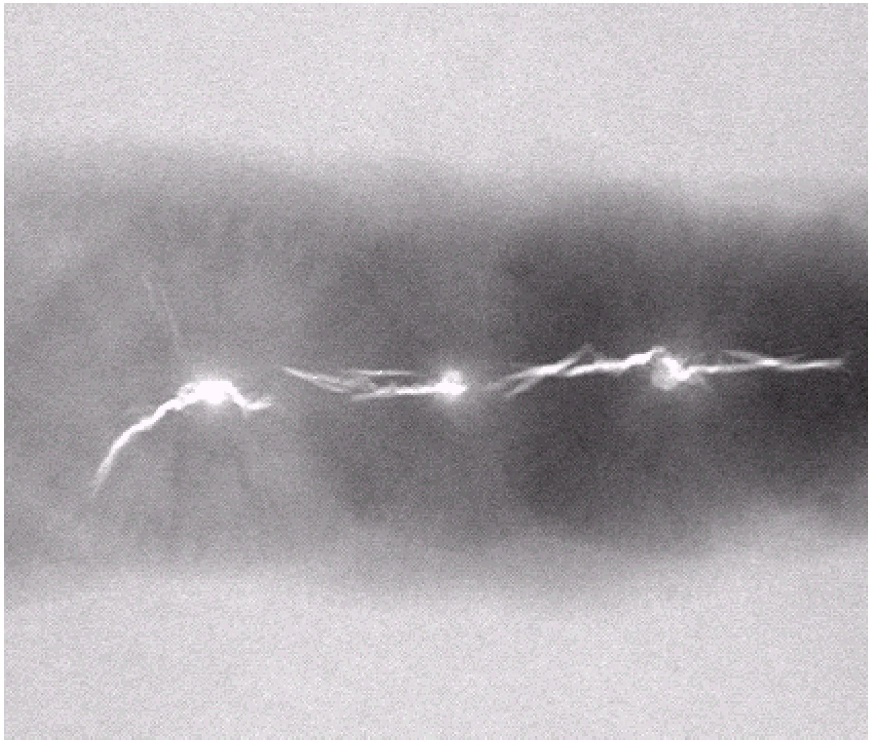
FIGURE 6.19 An alternative representation of the intensity-slicing technique.

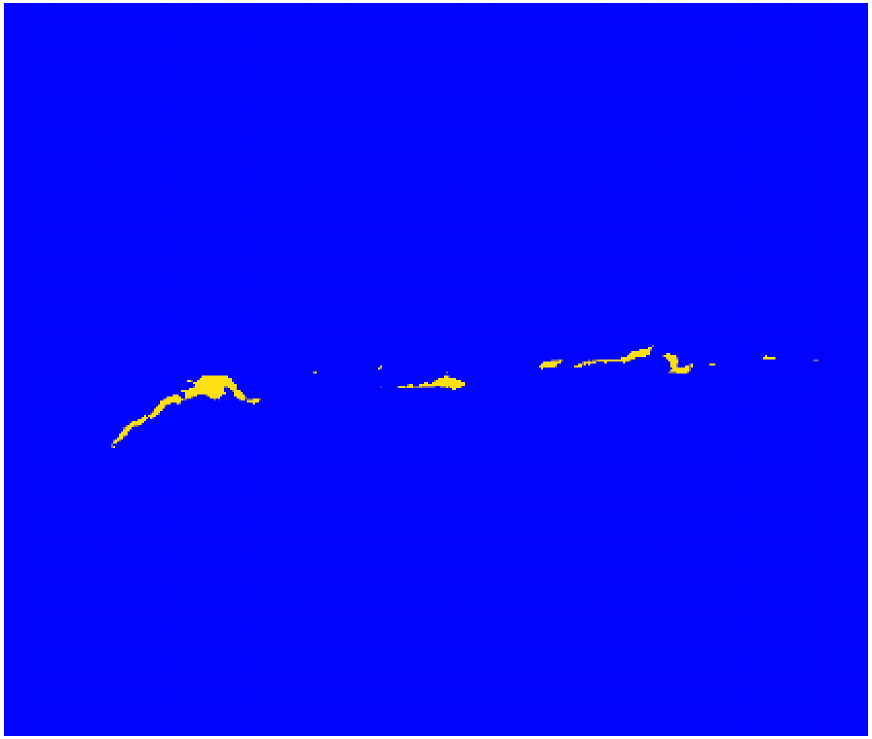
Pseudo Color Image Processing – Intensity Slicing





Pseudo Color Image Processing – Intensity Slicing





COLOR IMAGE - SMOOTHING

- Smoothing can be viewed as a spatial filtering operation in which the coefficients of the filtering mask are all 1's
- This concept can be easily extended to the processing of full-color images
- Simply smooth each of the RGB color planes and then combine the processed planes to form a smoothed full-color result

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

Image Segmentation

Image Segmentation

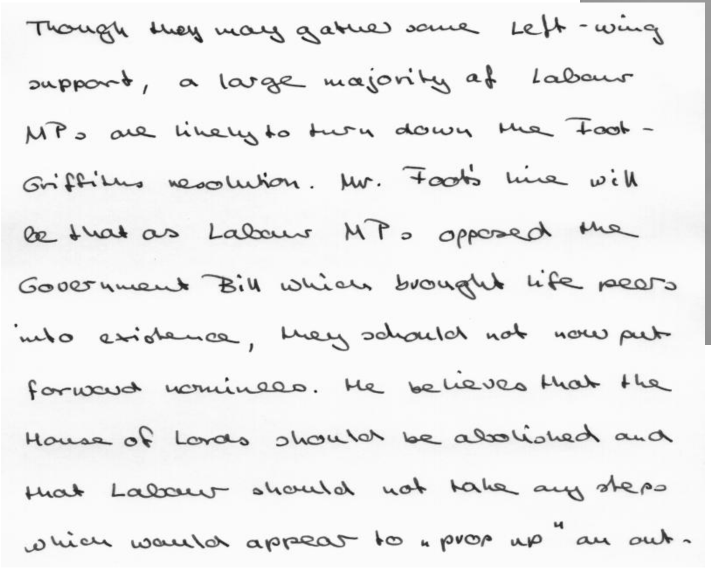
- Group similar components (such as, pixels in an image, image frames in a video)
- Applications: Finding tumors, veins, etc. in medical images, finding targets in satellite/aerial images, finding people in surveillance images, summarizing video, etc.

Image Segmentation

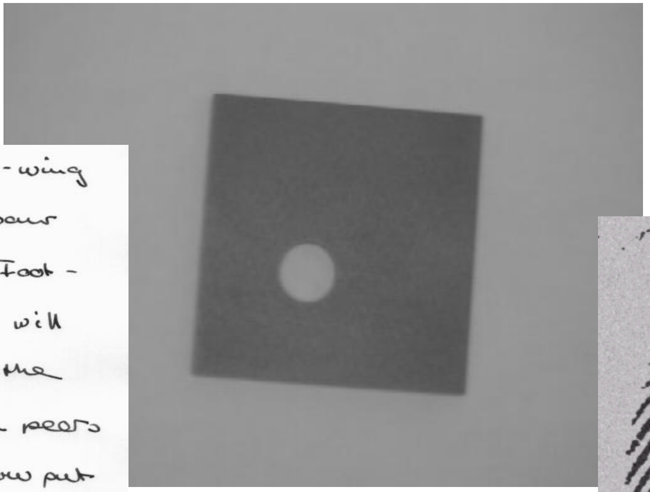
- Segmentation algorithms are based on one of two basic properties of gray-scale values:
  - Discontinuity
    - Partition an image based on abrupt changes in gray-scale levels.
    - Detection of isolated points, lines, and edges in an image.
  - Similarity
    - Thresholding, region growing, and region splitting/merging.

Thresholding

- Segmentation into two classes/groups
  - Foreground (Objects)
  - Background



Though they may gather some Left-wing
support, a large majority of Labour
MPs are likely to turn down the Foot-
Griffiths resolution. Mr. Foot's line will
be that as Labour MPs opposed the
Government Bill which brought life peers
into existence, they should not now put
forward nominees. He believes that the
House of Lords should be abolished and
that Labour should not take any steps
which would appear to "prop up" an out-



Thresholding

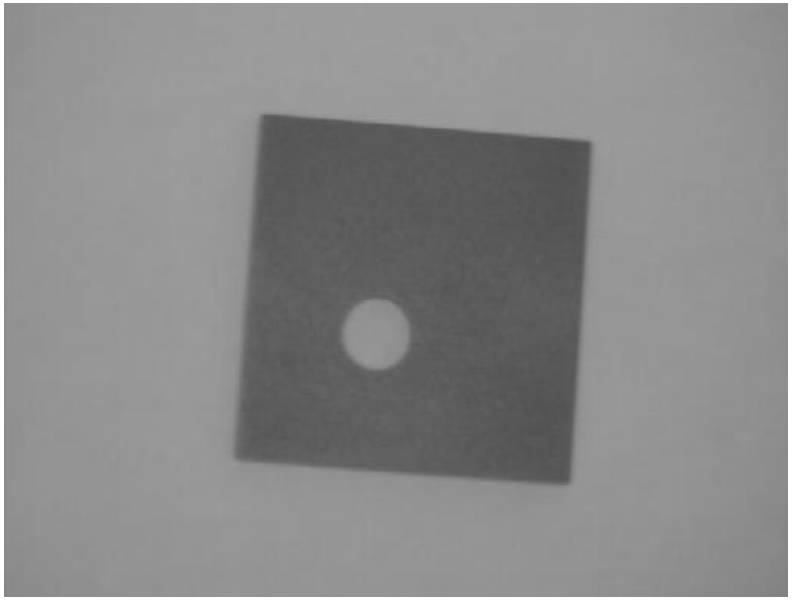
$$g(x,y)=\begin{cases}1 & if \;\; f(x,y)>T \\ 0 & if \;\; f(x,y)\le T\end{cases}$$

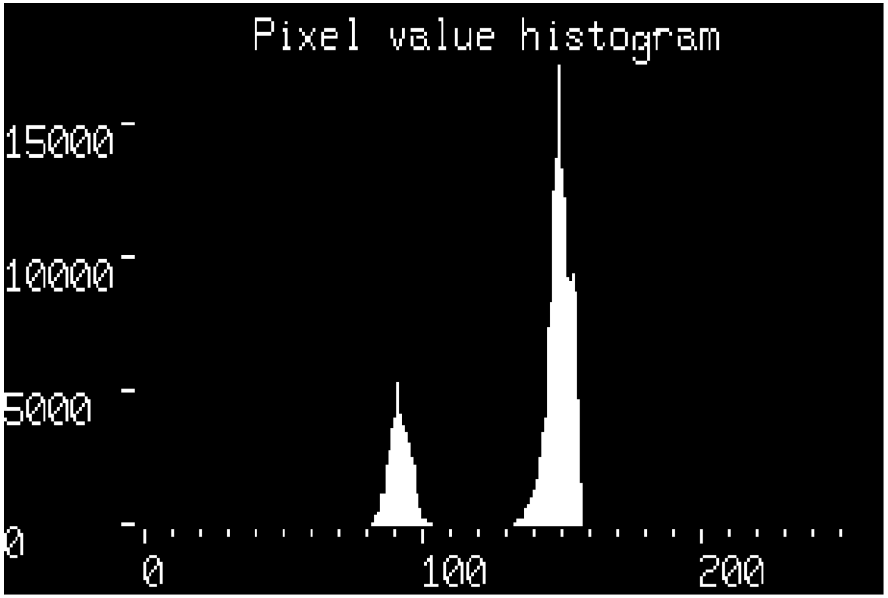
Objects & Background

- Global Thresholding
- Local/Adaptive Thresholding

Global Thresholding

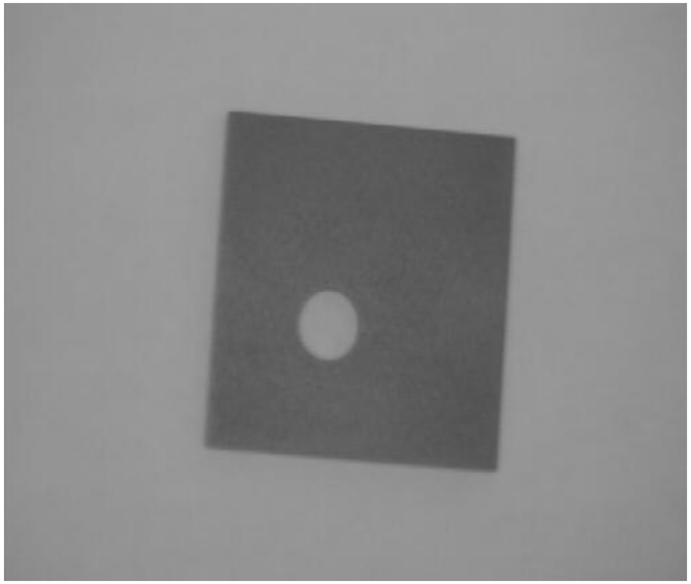
- Single threshold value for entire image
- Fixed ?
- Automatic
  - Intensity histogram

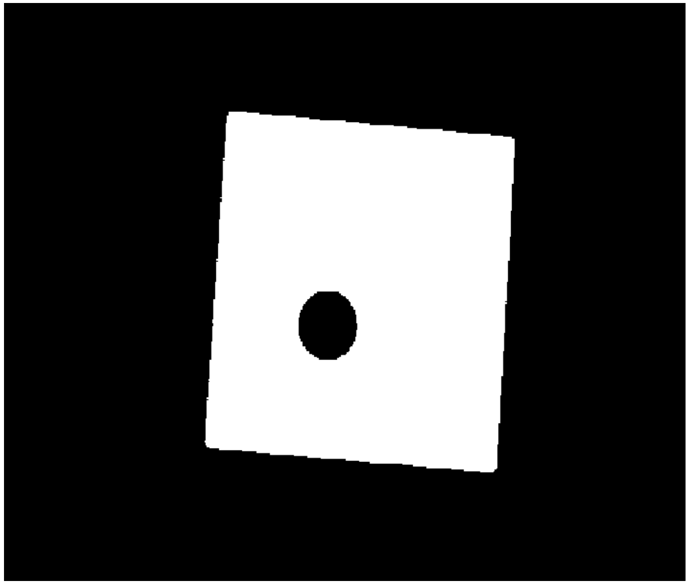




Global Thresholding

- Single threshold value for entire image
- Fixed ?
- Automatic
  - Intensity histogram

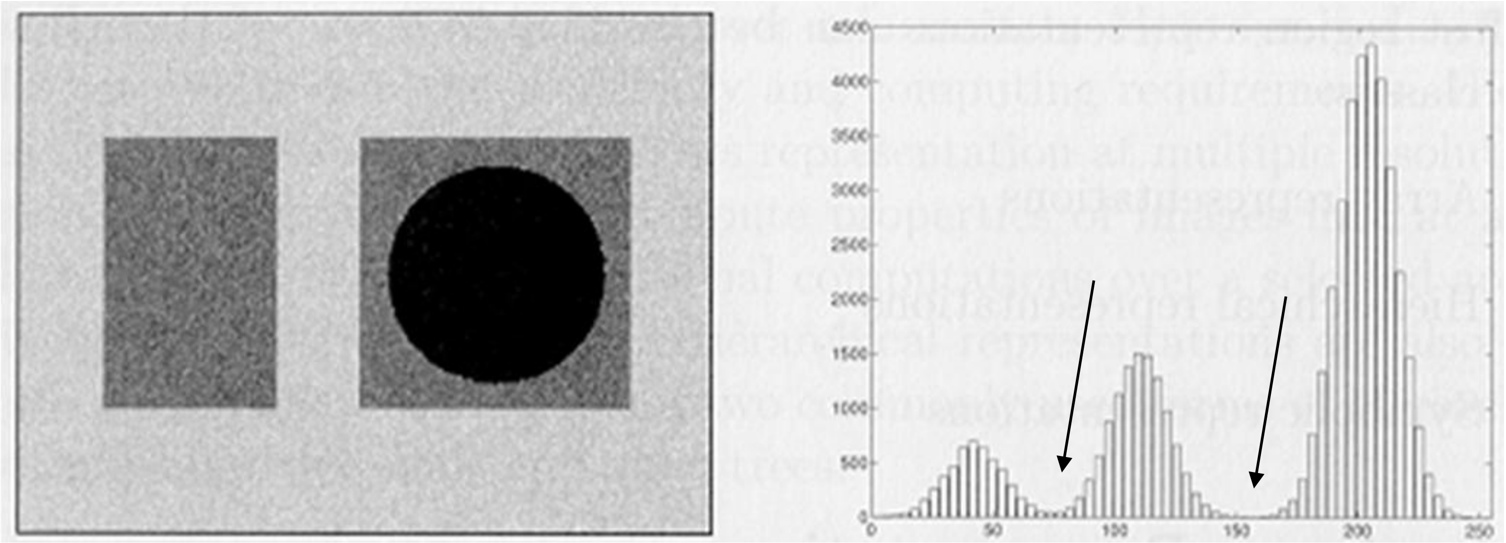




Global Thresholding

- Estimate an initial T
- Segment Image using T: Two groups of pixels G1 and G2
- Compute average gray values m1 and m2 of two groups
- Compute new threshold value T=1/2(m1+m2)
- Repeat steps 2 to 4 until: $abs(T_i – T_{i-1}) < epsilon$

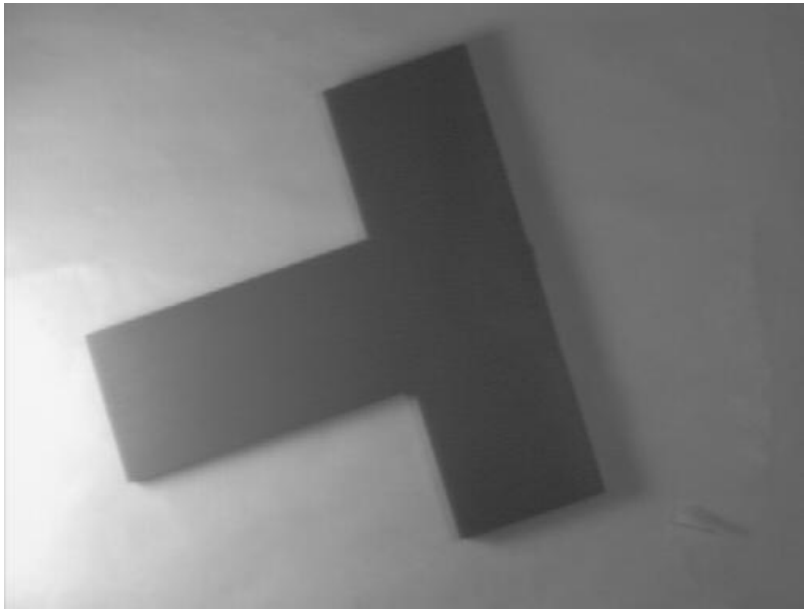
Global Thresholding

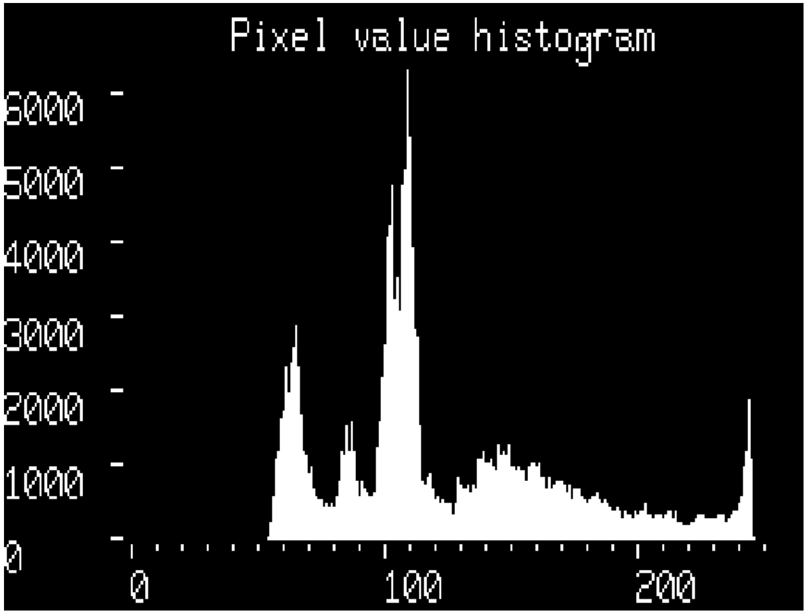


Multilevel thresholding

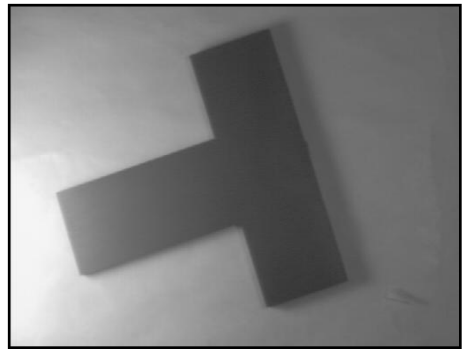
Thresholding

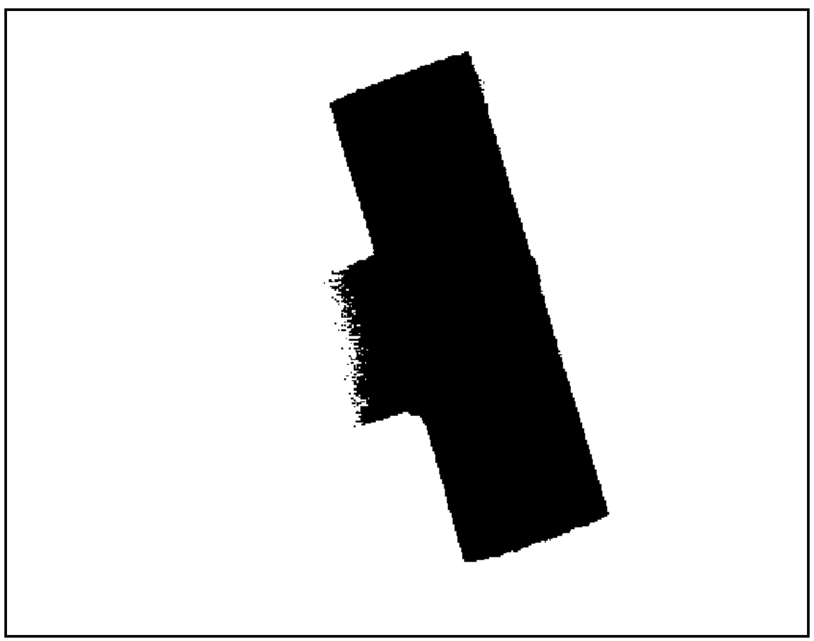
- Non-uniform illumination:

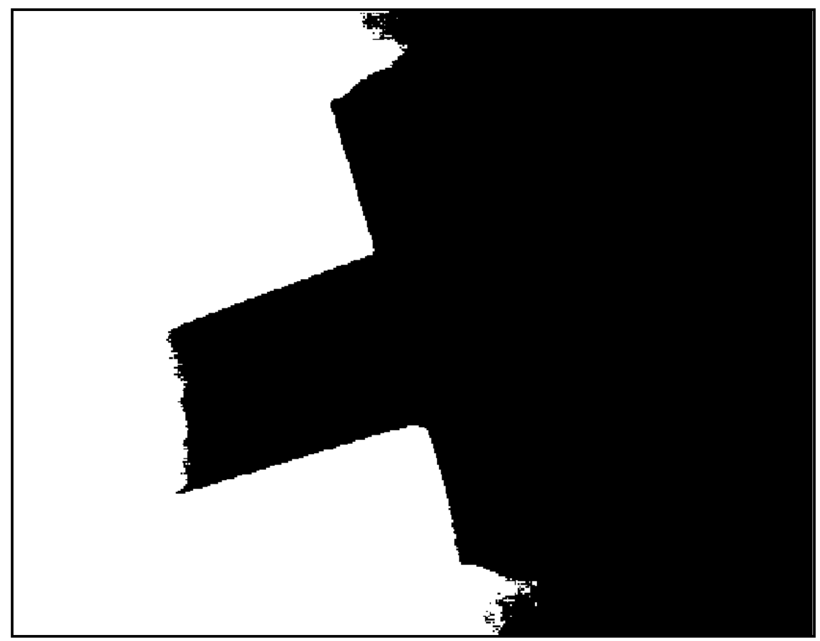




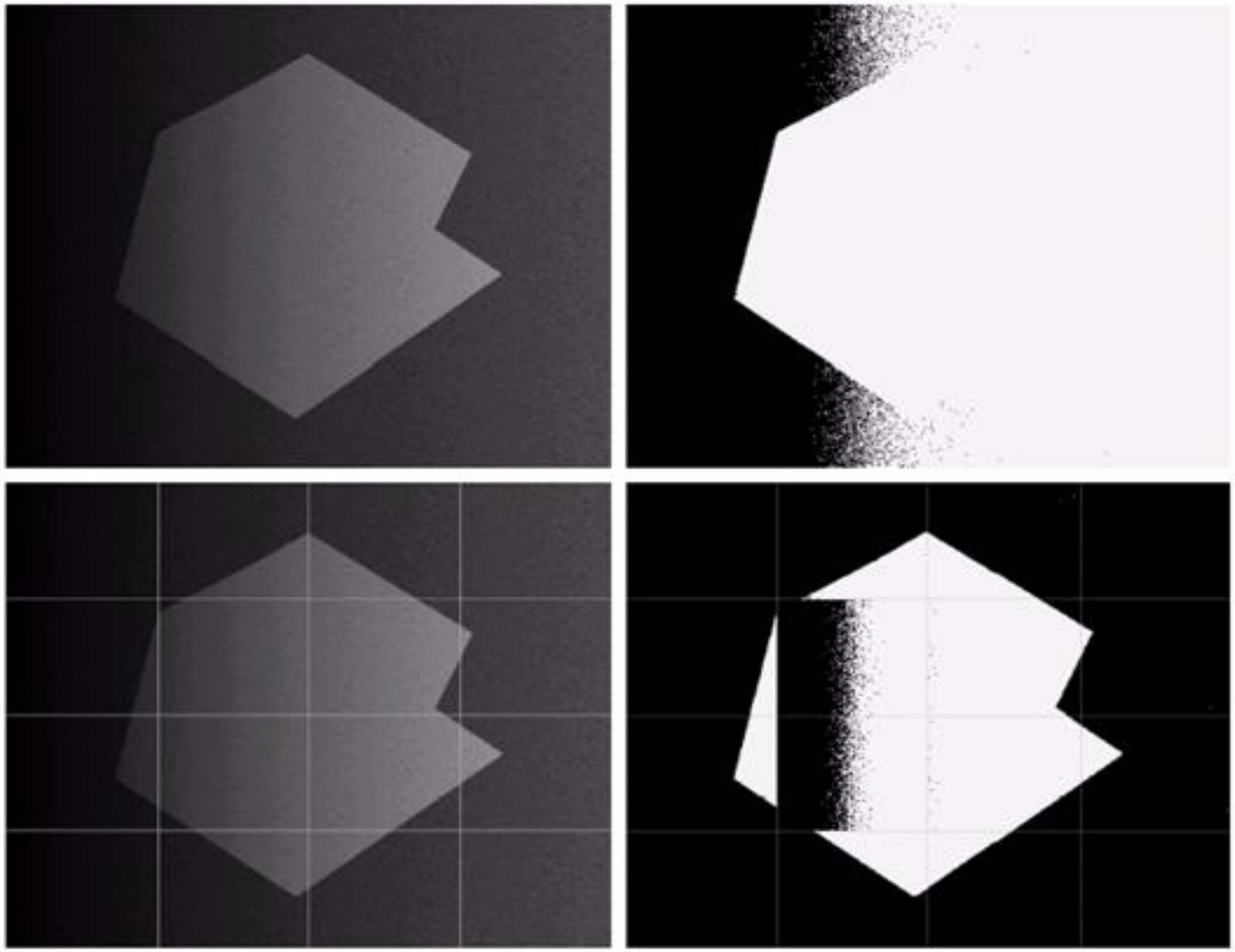
Global Thresholding







Adaptive Thresholding



Adaptive Thresholding

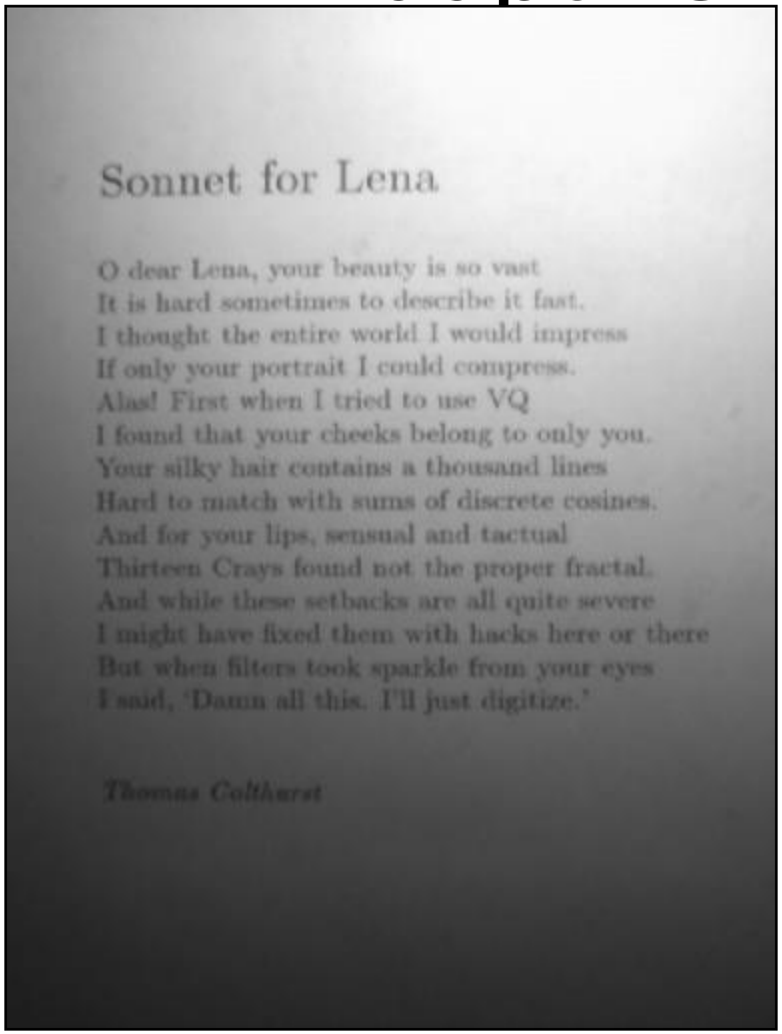
- Threshold: function of neighboring pixels

$$T = mean$$

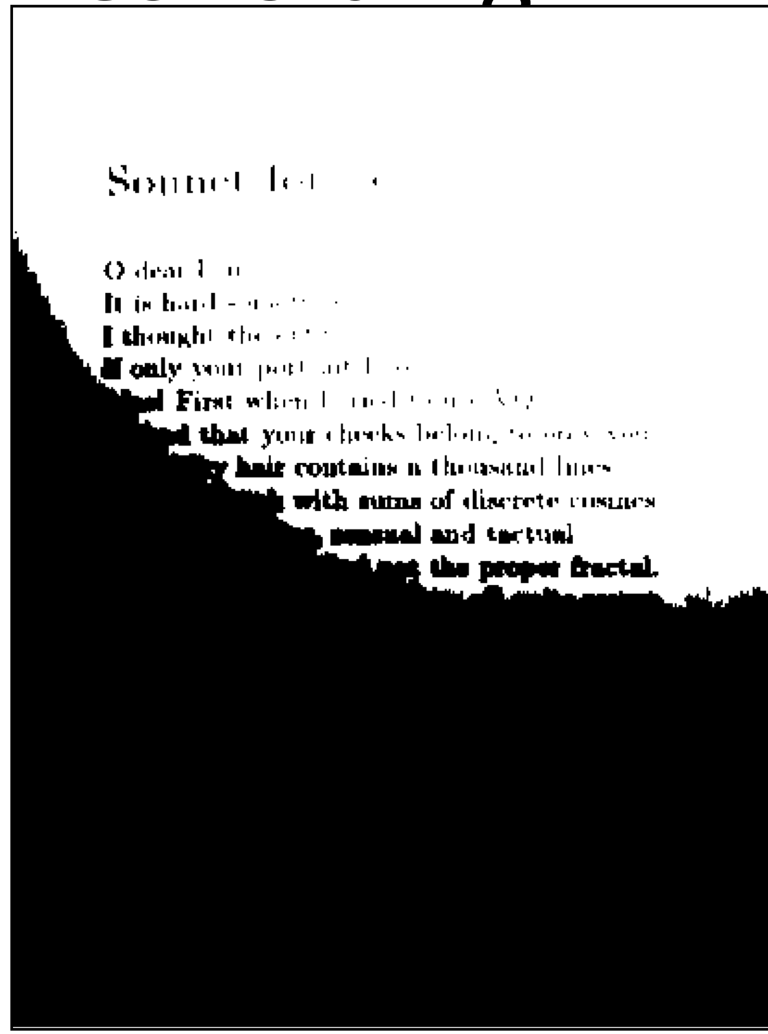
$$T = median$$

$$T = \frac{\max + \min}{2}$$

Adaptive Thresholding

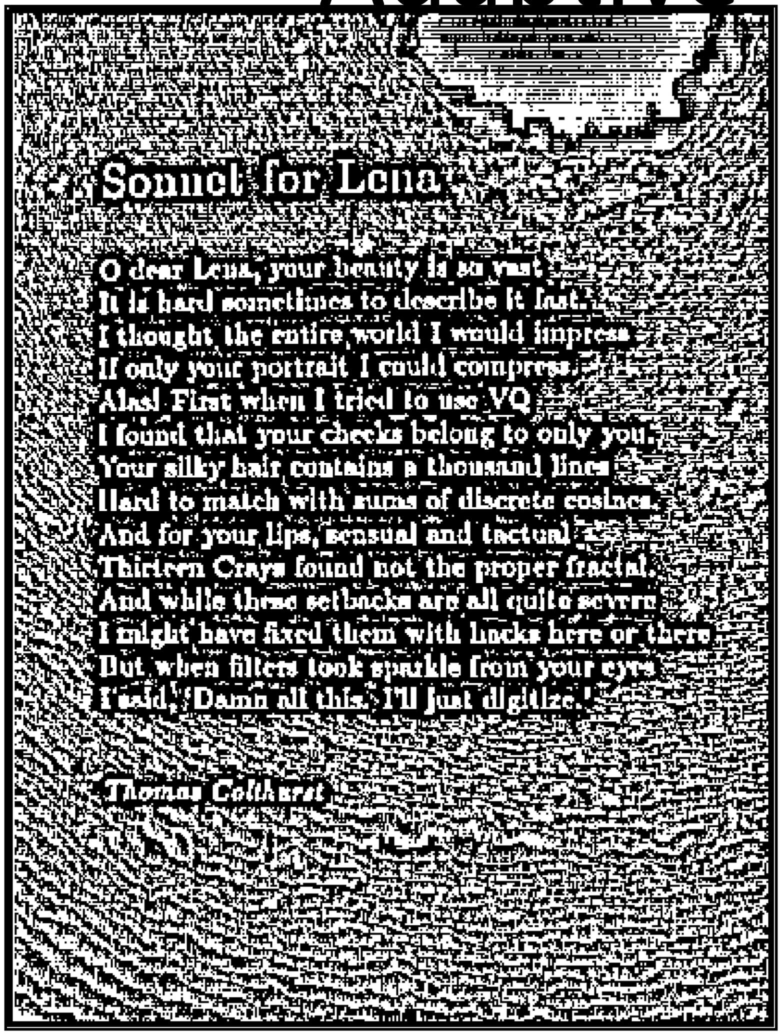


Original Image



Global Thresholding

Adaptive Thresholding

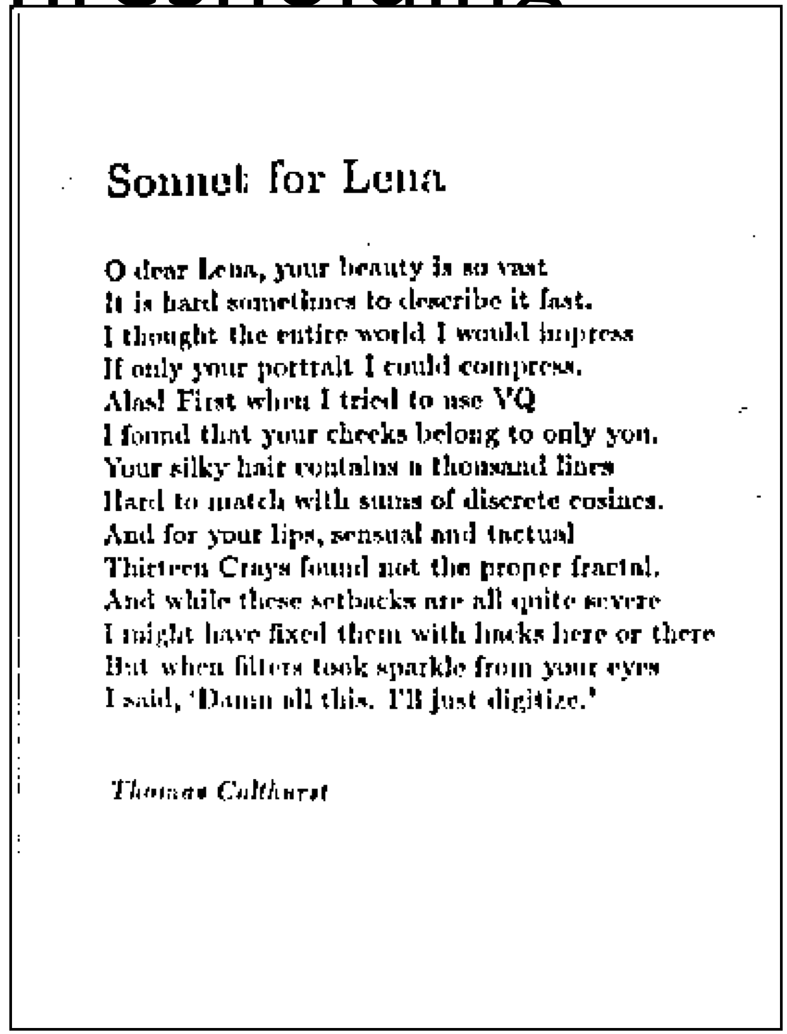


Sonnet for Lena

O dear Lena, your beauty is so vast
It is hard sometimes to describe it fast.
I thought the entire world I would impress
If only your portrait I could compress.
Alas! First when I tried to use VQ
I found that your cheeks belong to only you.
Your silky hair contains a thousand lines
Hard to match with sums of discrete cosines.
And for your lips, sensual and tactual
Thirteen Crays found not the proper fractal.
And while these setbacks are all quite severe
I might have fixed them with hacks here or there
But when filters took sparkle from your eyes
I said, 'Damn all this. I'll just digitize.'

Thomas Colthurst

T=mean, neighborhood=7x7



Sonnet for Lena

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And while these setbacks are all quite severe
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Thomas Colthurst

T=mean-Const., neighborhood=7x7

Adaptive Thresholding

- Niblack Algorithm

$$T = m + k \times s$$

$$m = \text{mean}$$

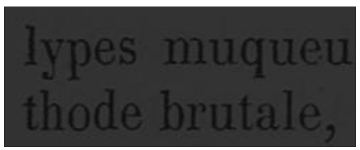
$$s = \text{standard deviations}$$

$$k = \text{ Niblack constant}$$

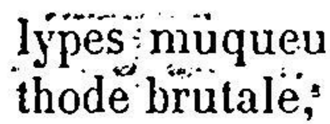
- Neighborhood size???

Document Binarization

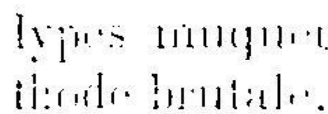
- Local Thresholding – Examples

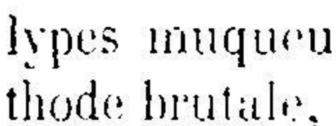


Original

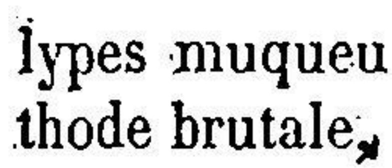


Niblack

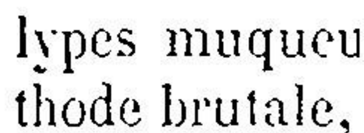

Sauvola



Wolf



Feng

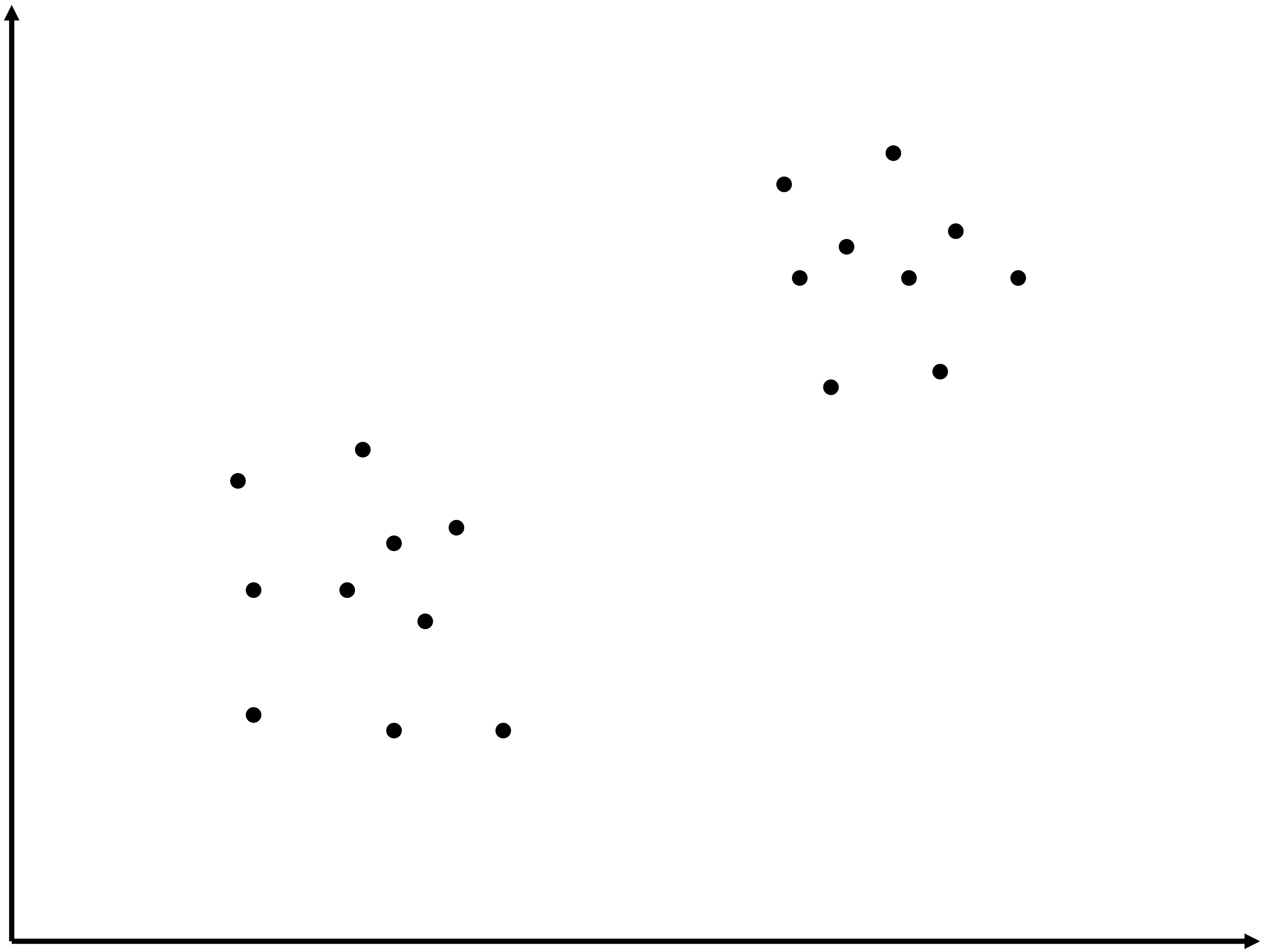


NICK

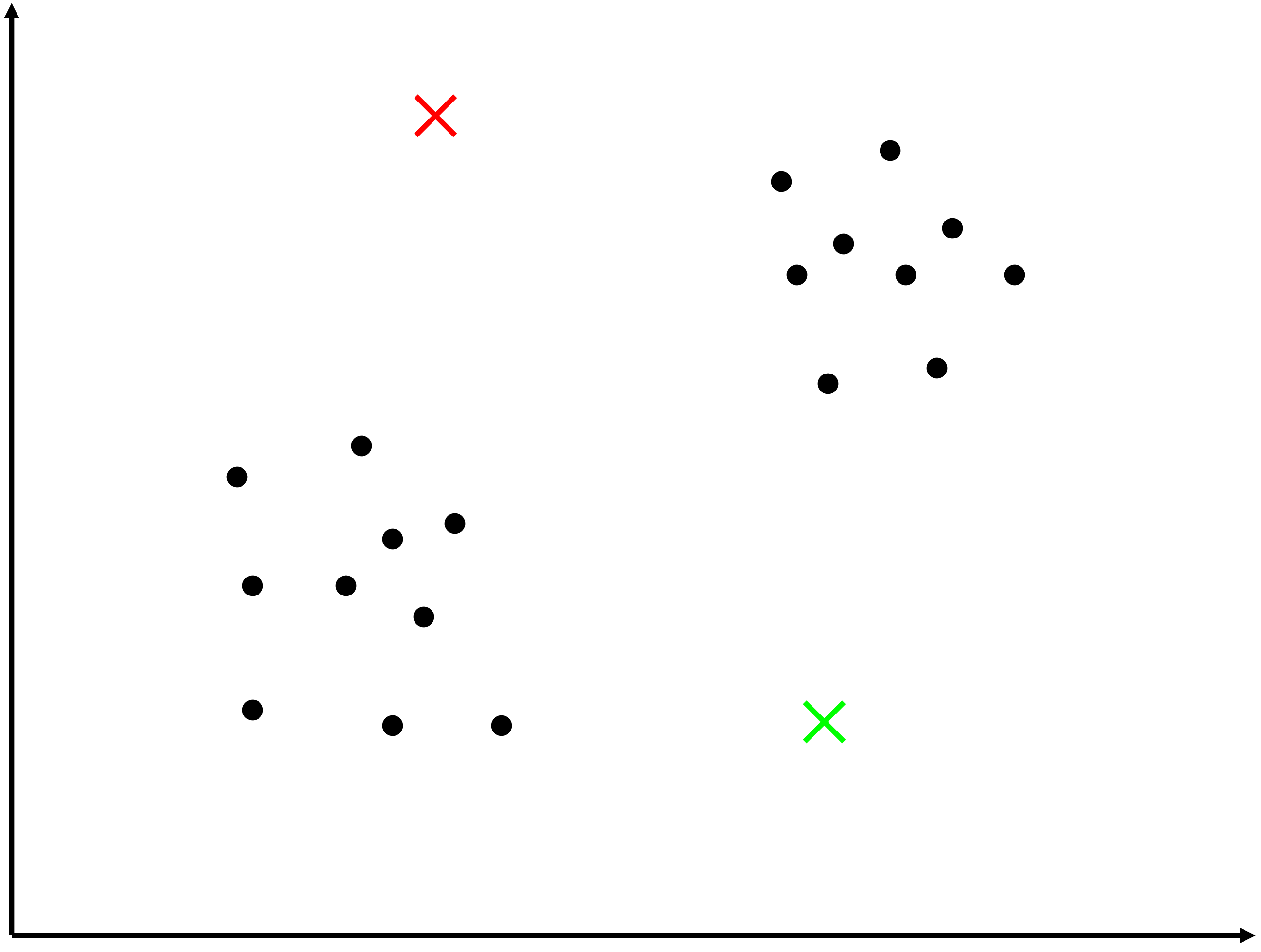
K-Means Clustering

1. Chose the number (K) of clusters and randomly select the centroids of each cluster.
2. For each data point:
   - Calculate the distance from the data point to each cluster.
   - Assign the data point to the closest cluster.
3. Recompute the centroid of each cluster.
4. Repeat steps 2 and 3 until there is no further change in the assignment of data points (or in the centroids).

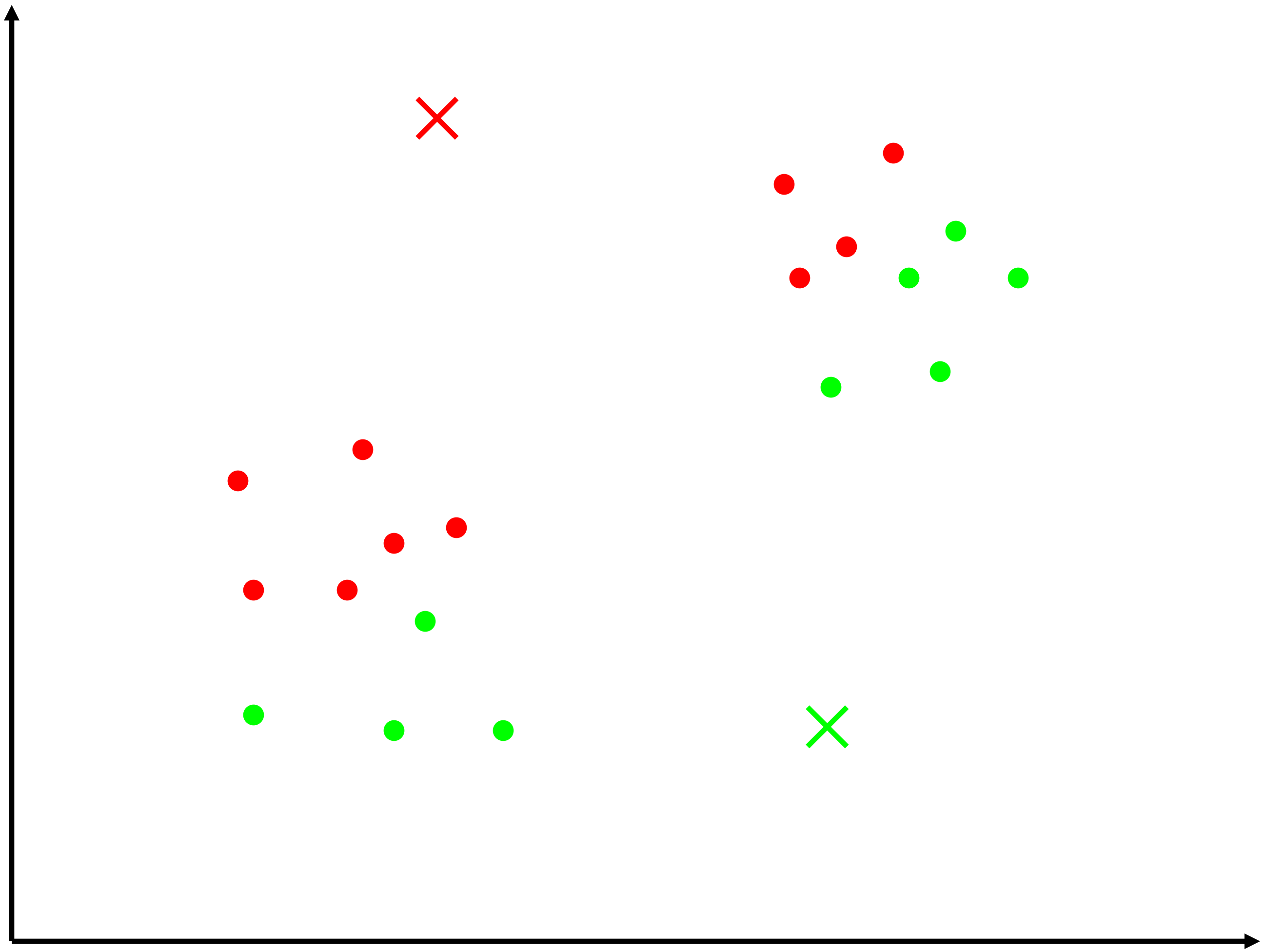
K-Means Clustering



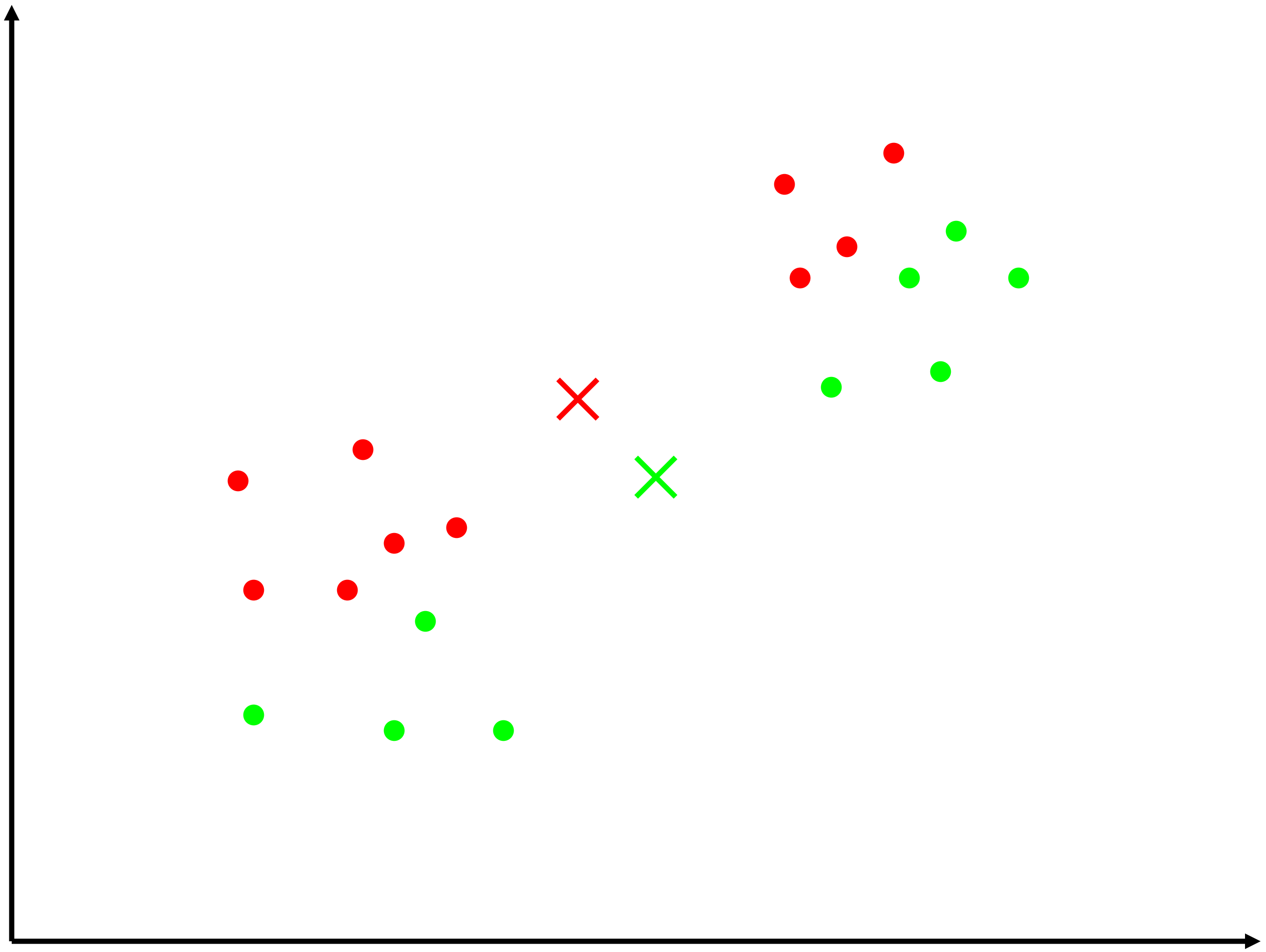
K-Means Clustering



K-Means Clustering



K-Means Clustering



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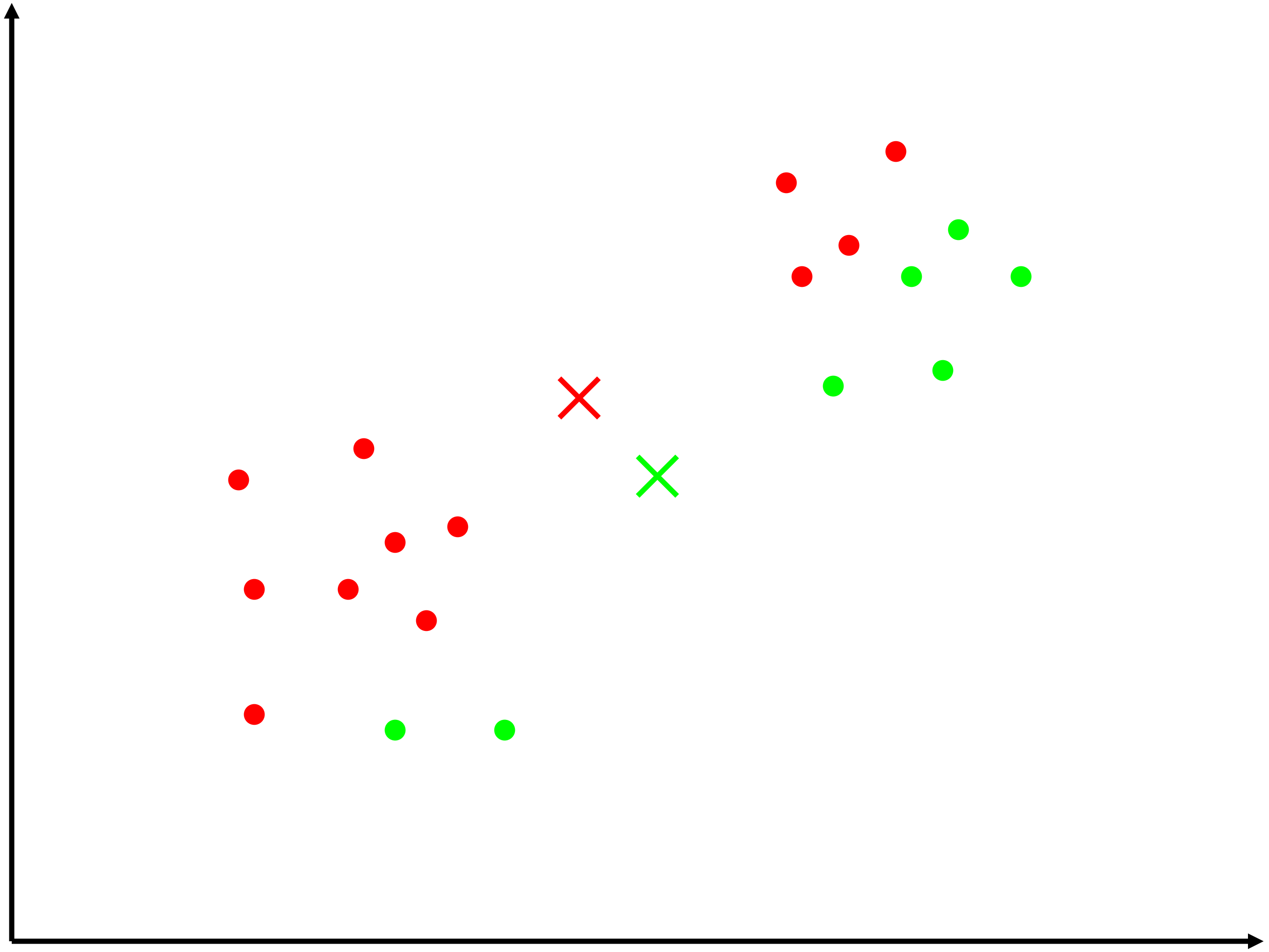
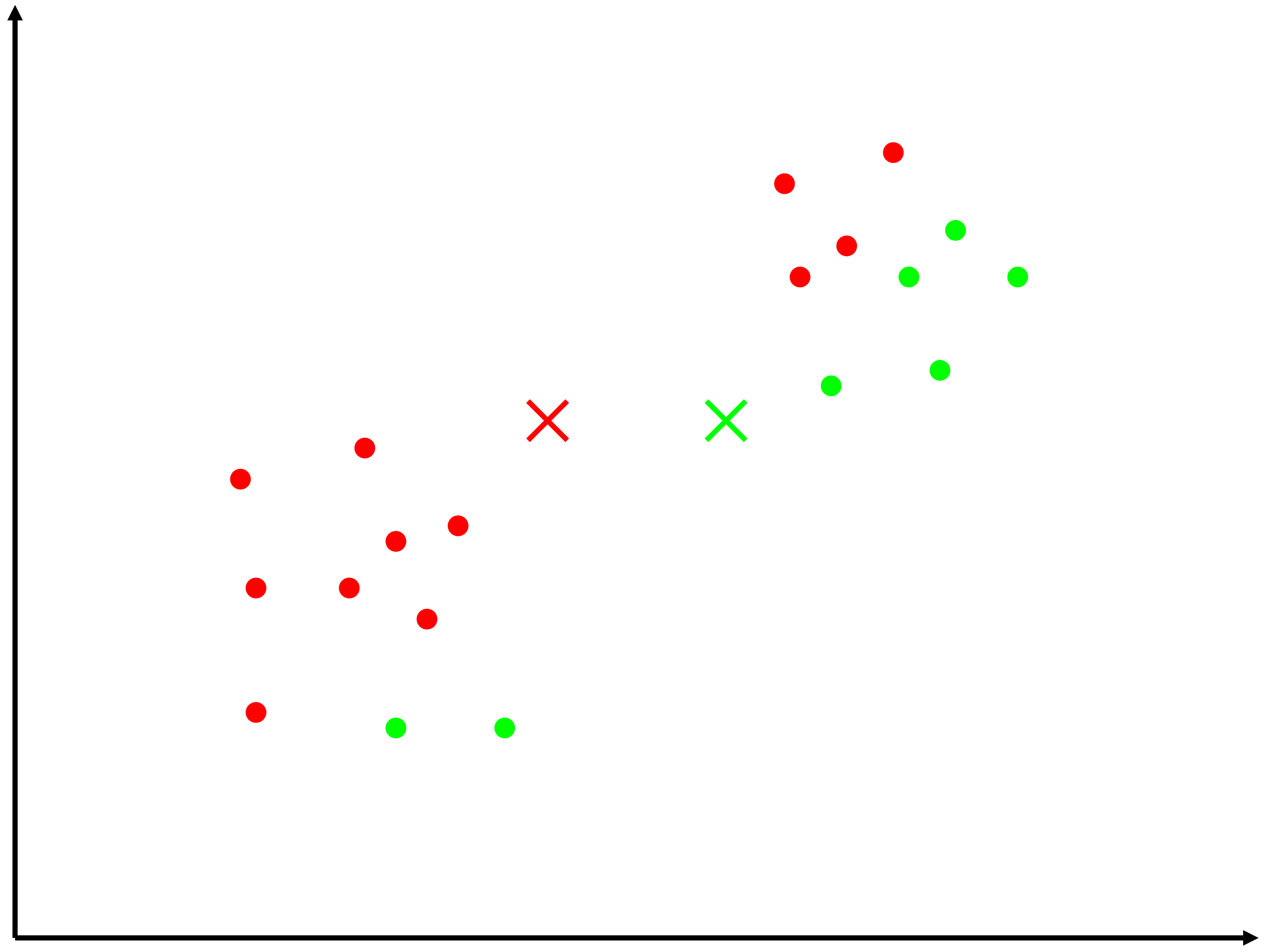


K-Means Clustering



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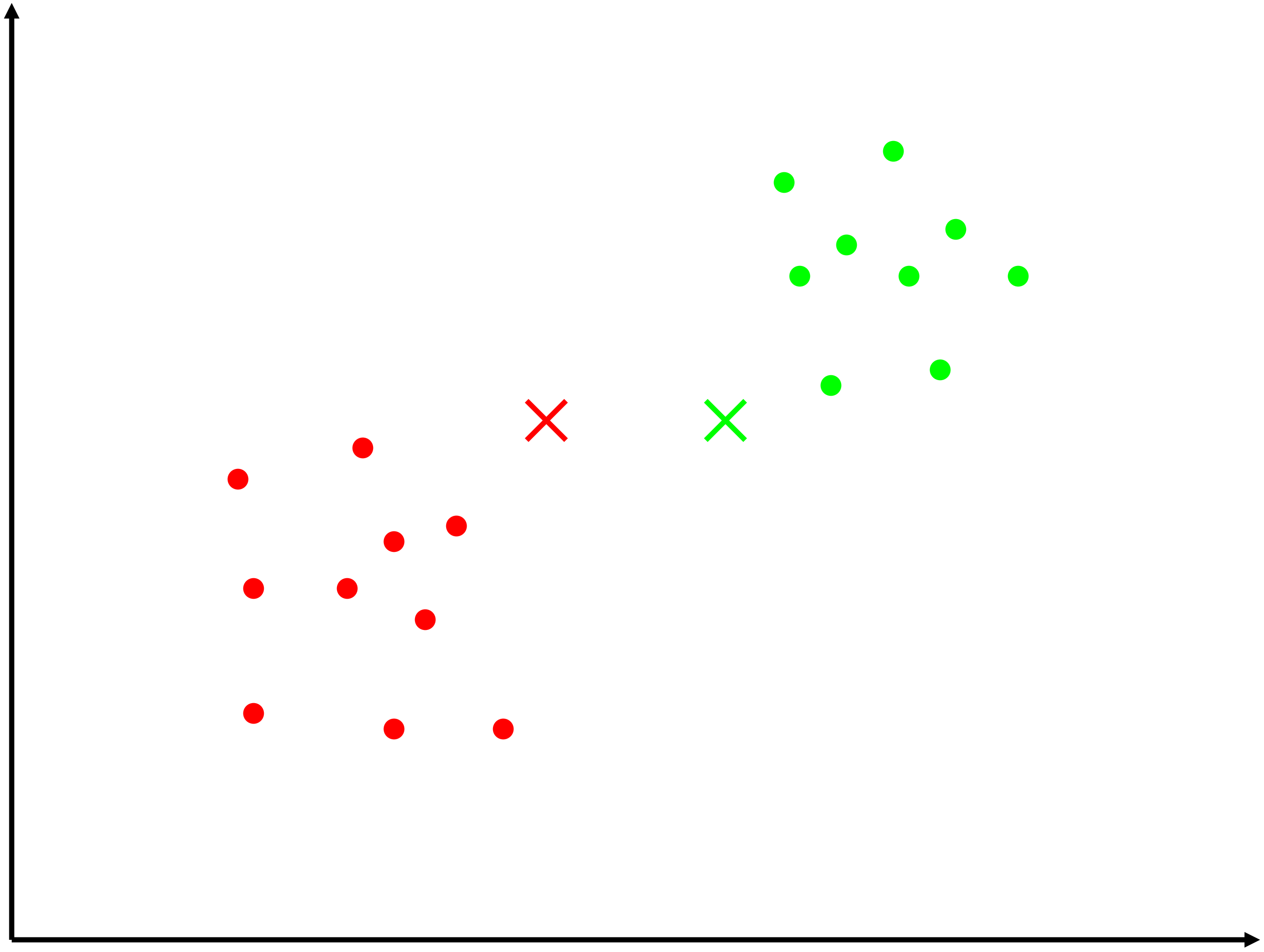
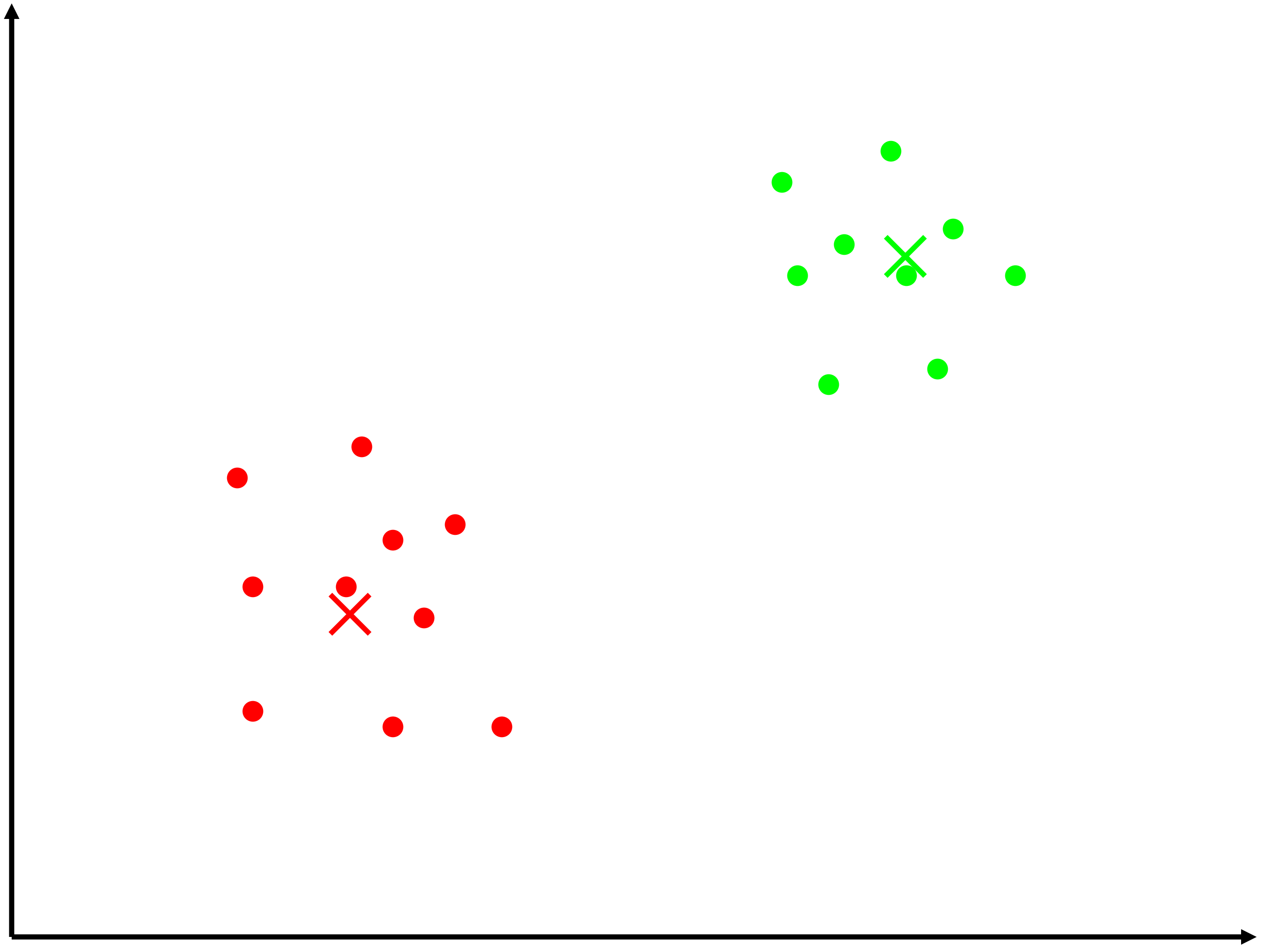
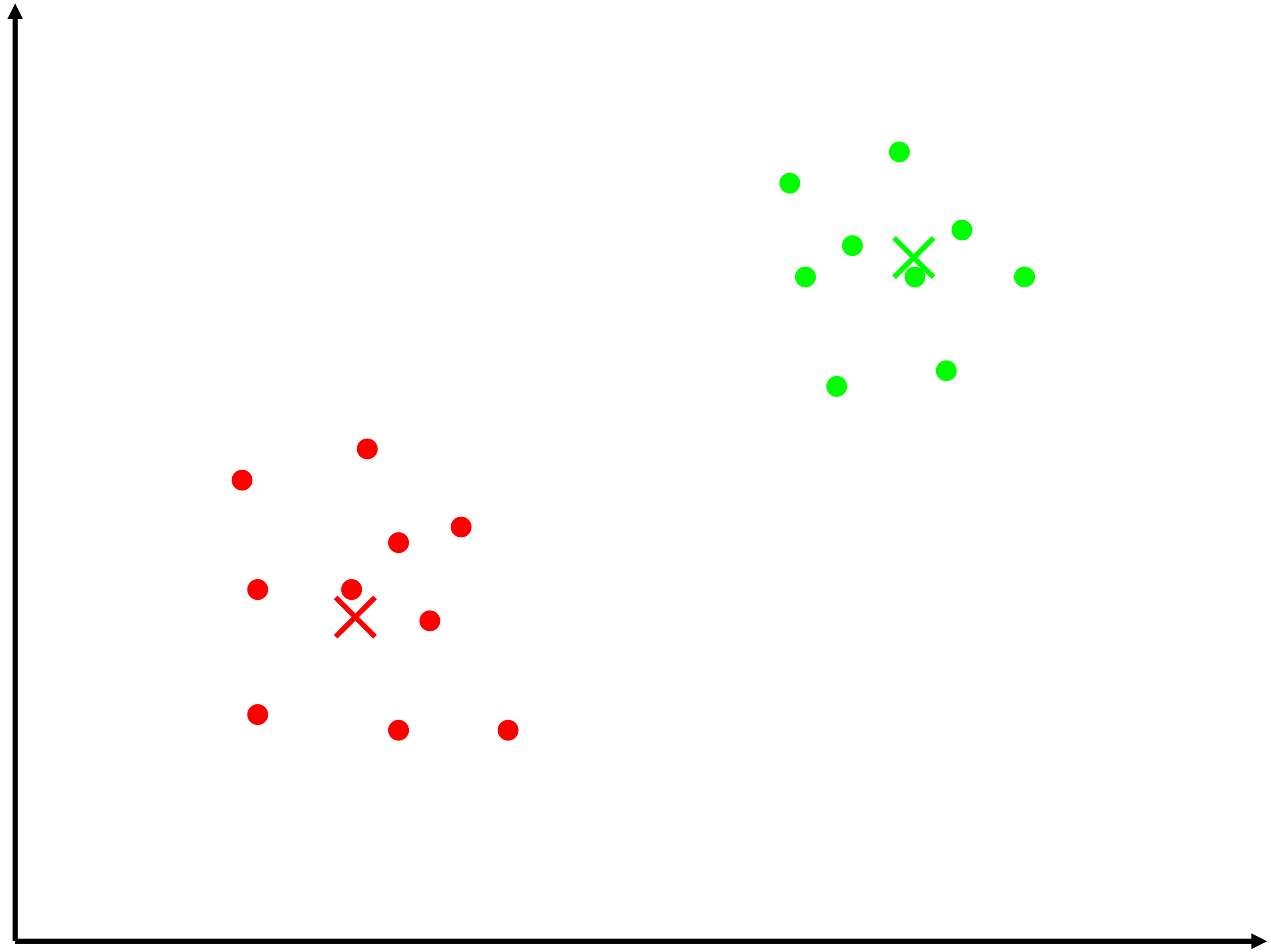


K-Means Clustering

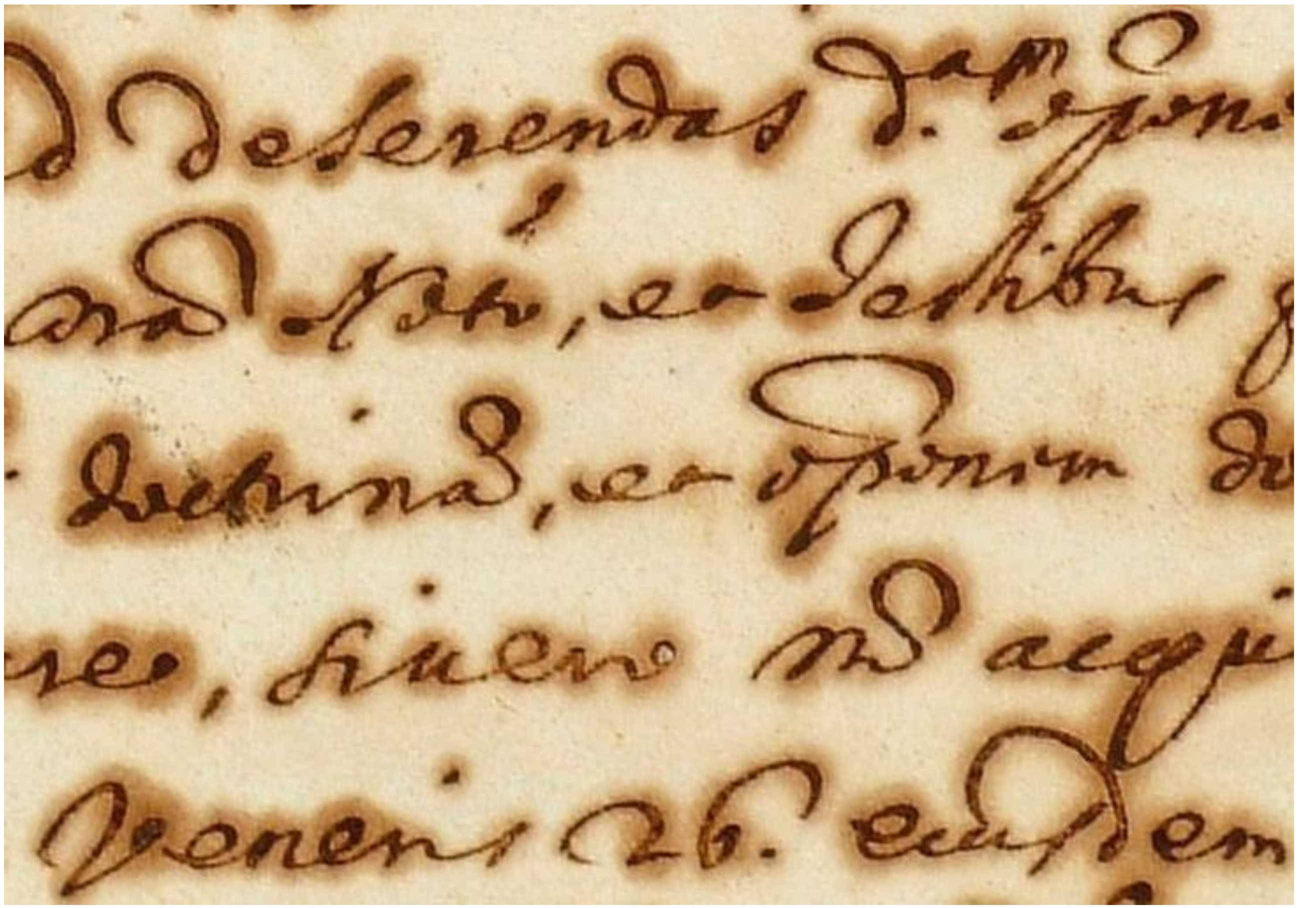


K-Means Clustering



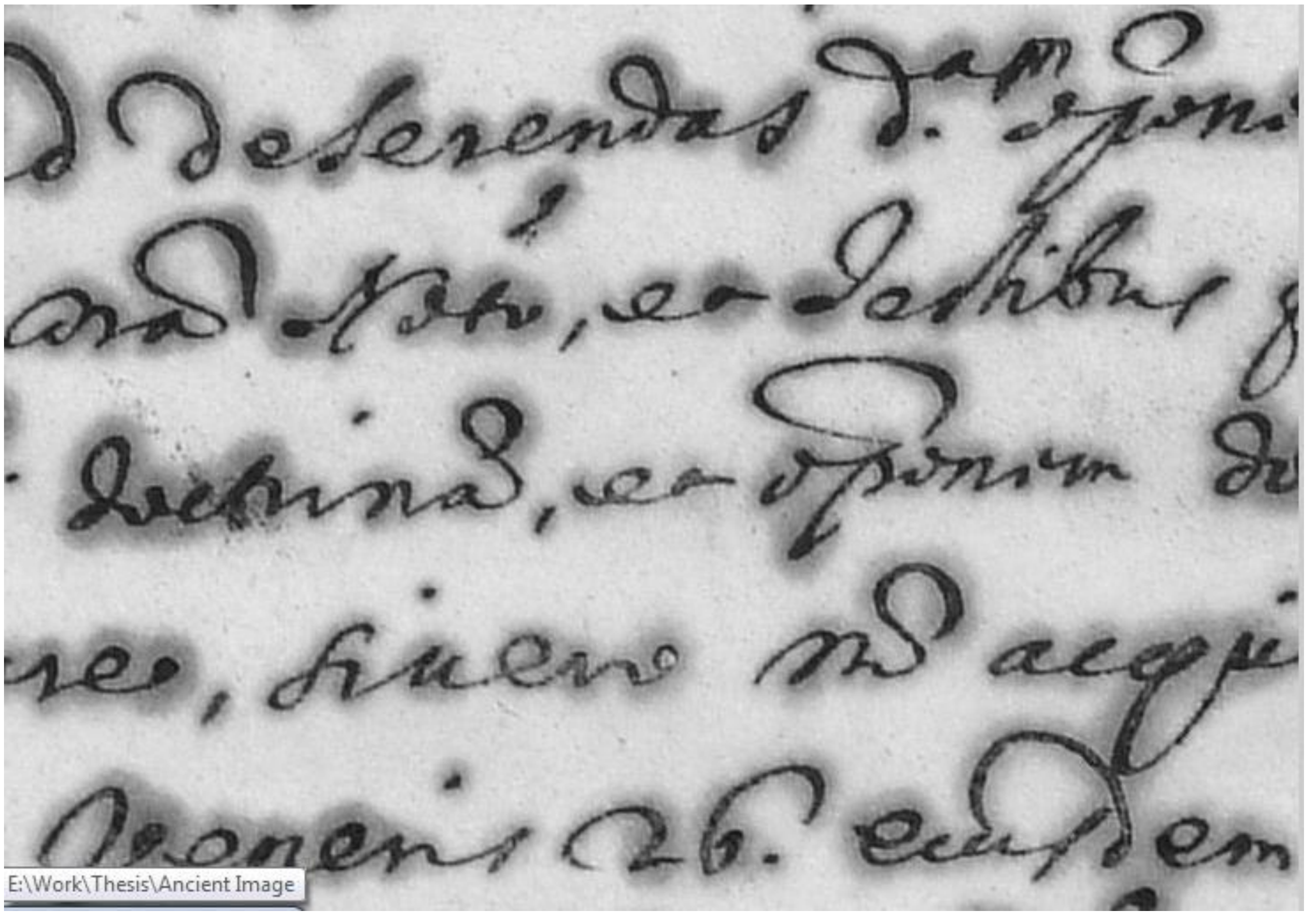
Clustering

- Example



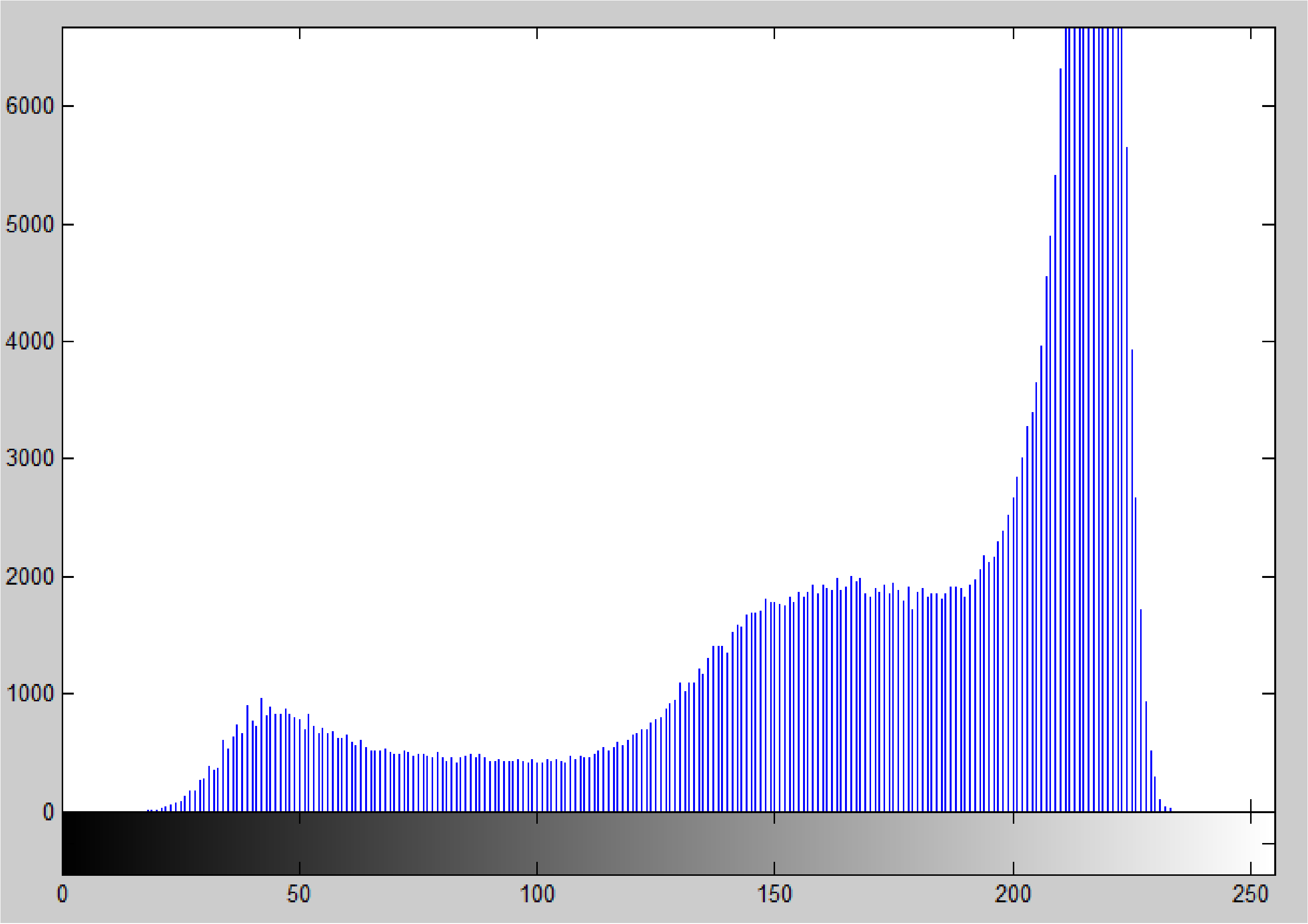
Clustering

- Example



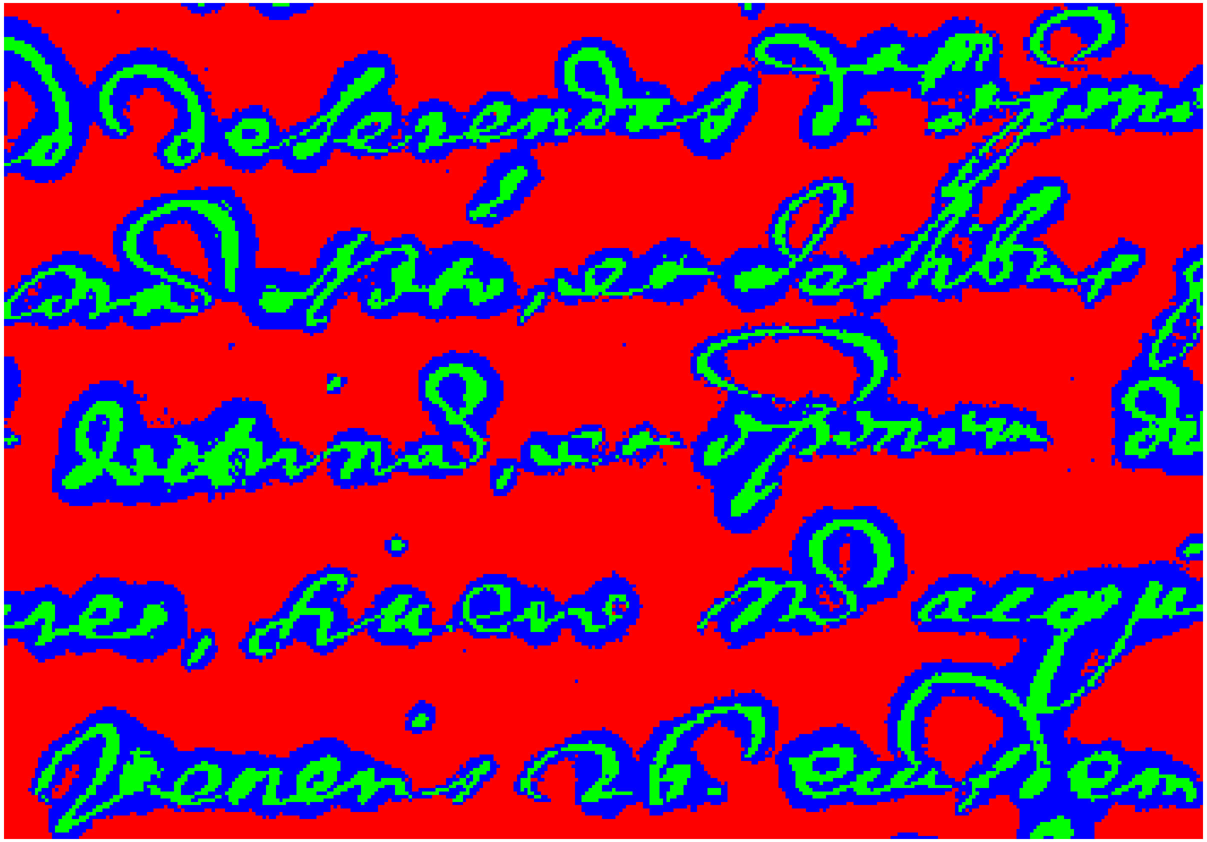
Clustering

- Example



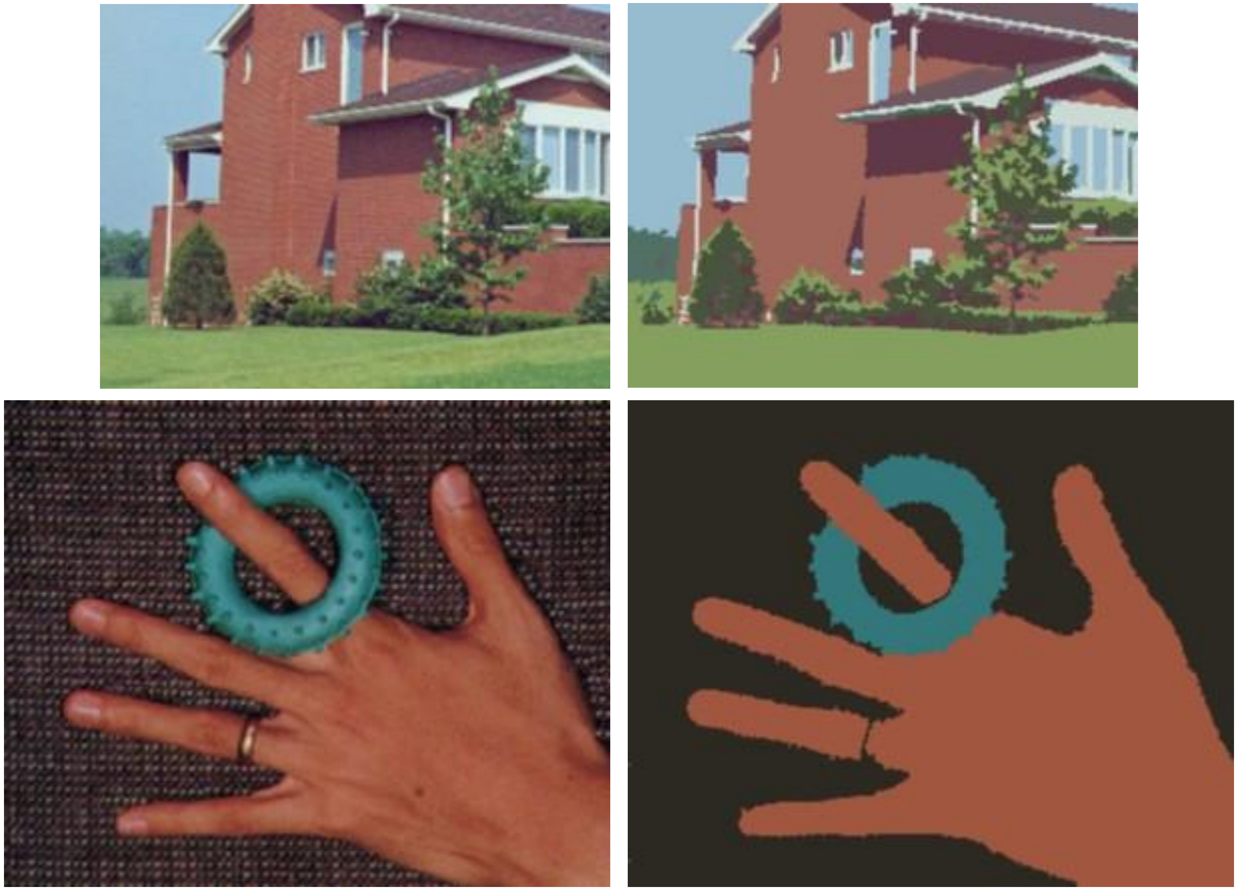
Clustering

- Example



Clustering

- Example



D. Comaniciu and P. Meer, *Robust Analysis of Feature Spaces: Color Image Segmentation*, 1997.

K-Means Clustering

- Example

Original

K=5

K=11

Mean Shift Segmentation Results:

Figure 5.18 Mean-shift color image segmentation with parameters $(h_s, h_r, M) = (16, 19, 40)$ (Comaniciu and Meer 2002) © 2002 IEEE.

Readings from Book (3^{rd} Edn.)

- Color Processing (Chapter – 6)
- Segmentation (Chapter – 10)

Acknowledgements

- Digital Image Processing", Rafael C. Gonzalez & Richard E. Woods, Addison-Wesley, 2002
- Computer Vision for Computer Graphics, Mark Borg

Material in these slides has been taken from, the following resources