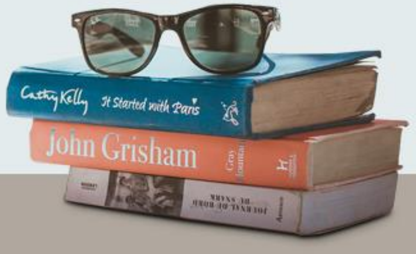
STQD6114
IMAGE DATA ANALYSIS

Not included in the test and final
just for coding part for image Dr iclude for exploration.

NOR HAMIZAH MISWAN

PART 1

- ❖Introduction to digital image and image data analysis
- ❖Phases of image processing



What’s a Digital Image?

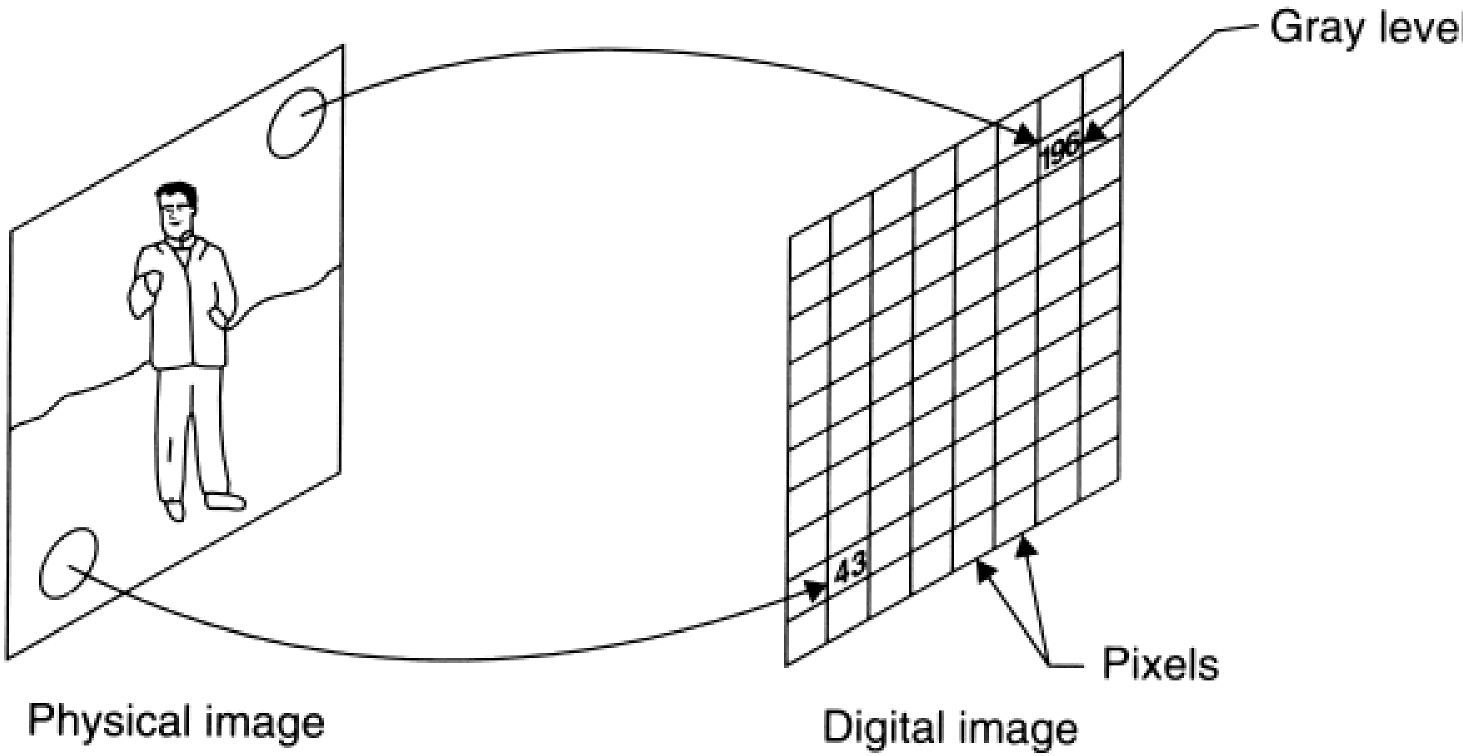
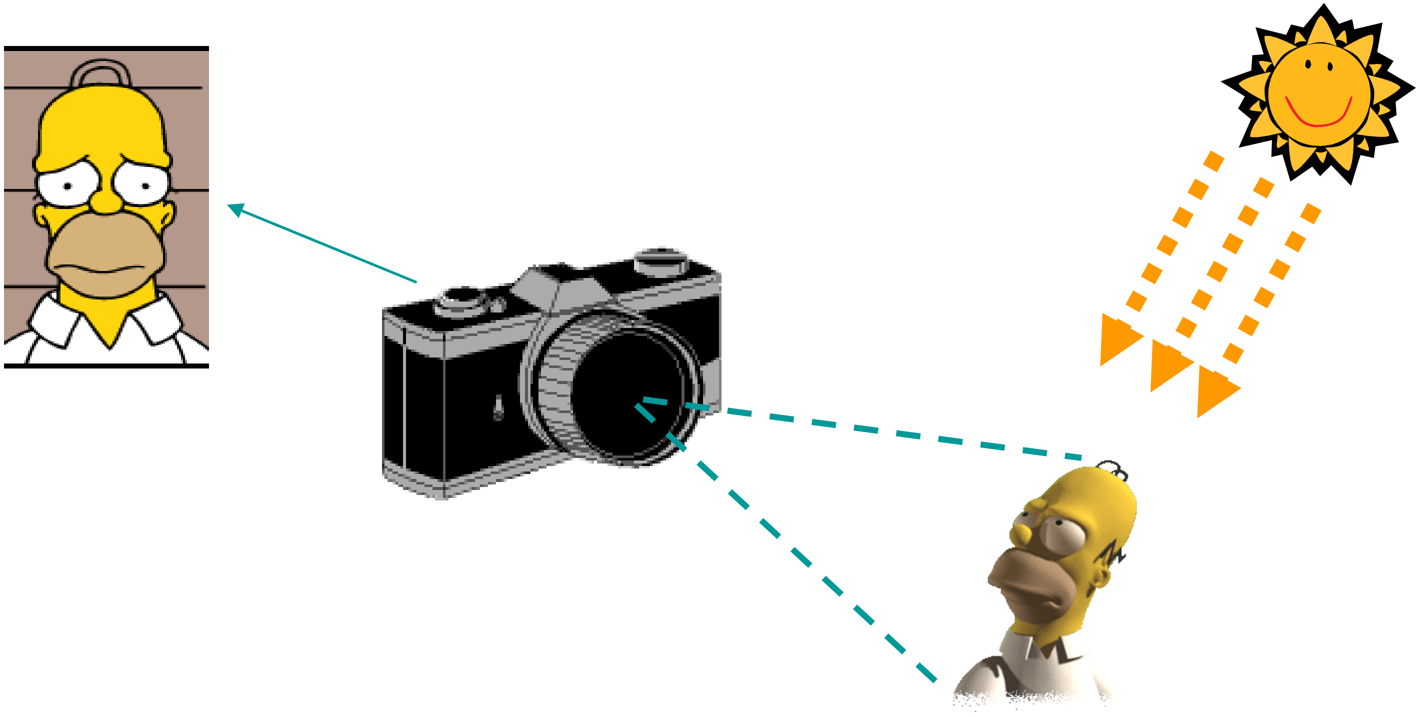


Figure 1–1 A physical image and a corresponding digital image

What is an Image ?

- An image is a projection of a 3D scene into a 2D *projection plane*.
- An image can be defined as a 2 variable function $f(x,y): R^2 \rightarrow R$, where for each position (x,y) in the projection plane, f(x,y) defines the light intensity at this point.



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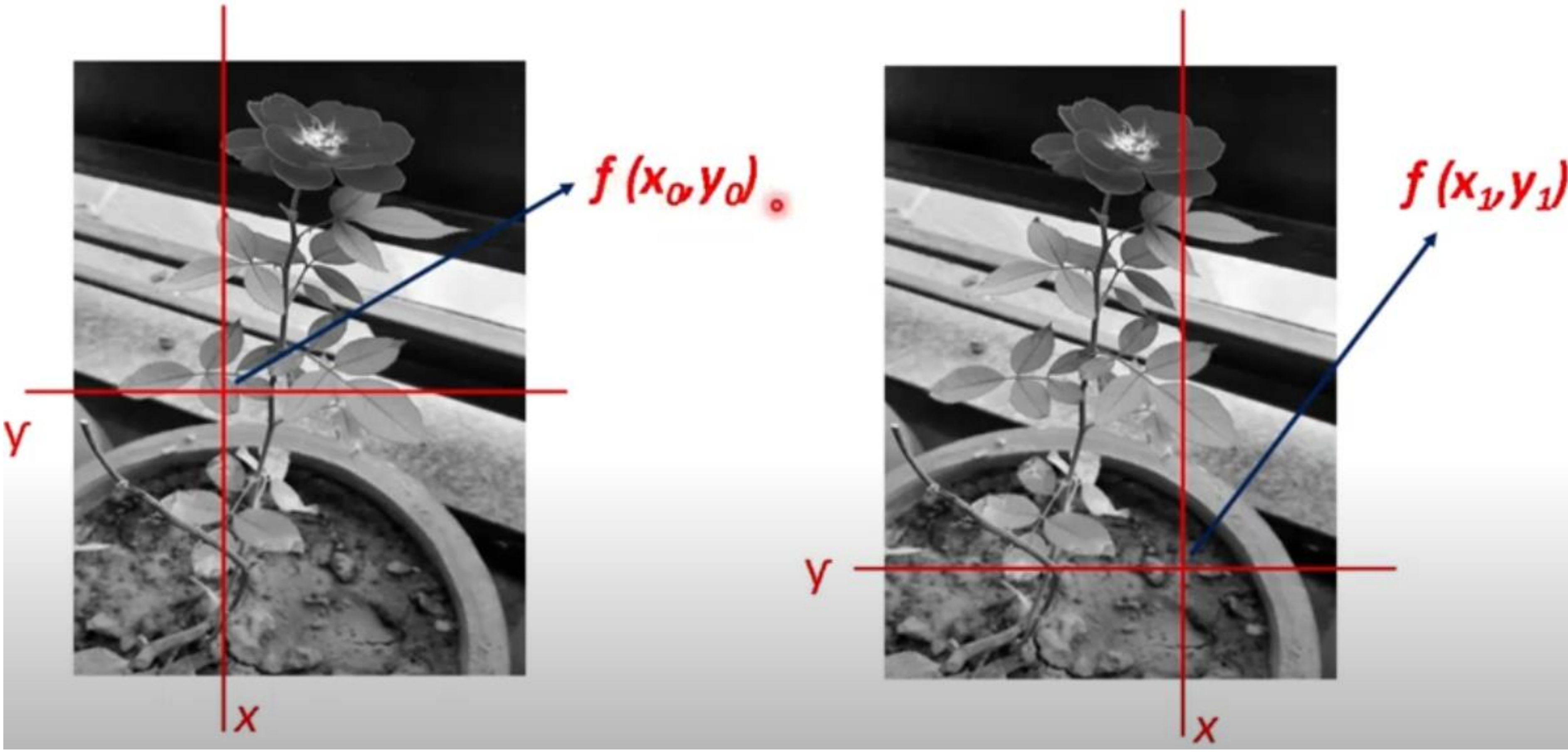
- If x, y and the values of f are finite and discrete quantities, we called the image a digital image. A digital image is composed of a finite number of elements called pixels, each of which has a particular location and value.

What is an Image ?



What is an Image ?

Pixel intensity value

$f(1,1) = 33$

Pixel location

still dark

rows columns

$f(645{:}650, 1323{:}1328) =$

83	82	132	132	131	130
82	82	132	132	131	130
82	82	132	132	131	130
82	82	132	132	132	131
80	79	133	133	132	131
80	79	133	133	132	131

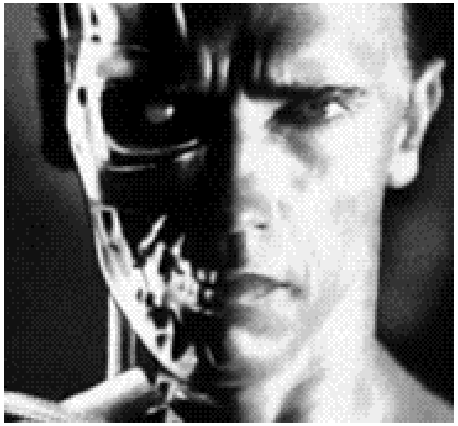
$f(2724, 2336) = 83$

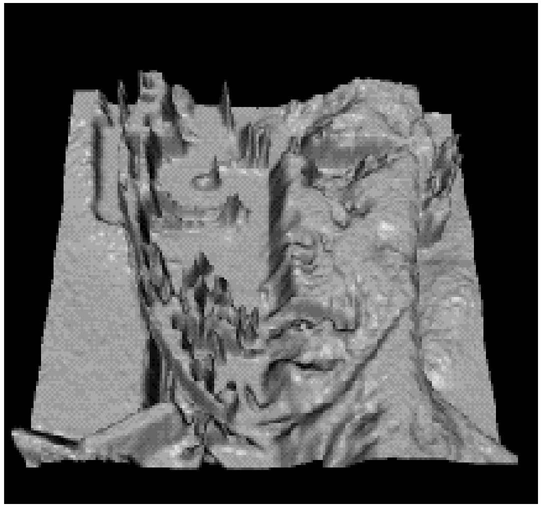
Consider the following image (2724x2336 pixels) to be 2D function or a matrix with rows and columns

In 8-bit representation Pixel intensity values change between 0 (Black) and 255 (White)

The higher the intensity the brighter the col image, the lower the intensity the darker the color image

Image as a function





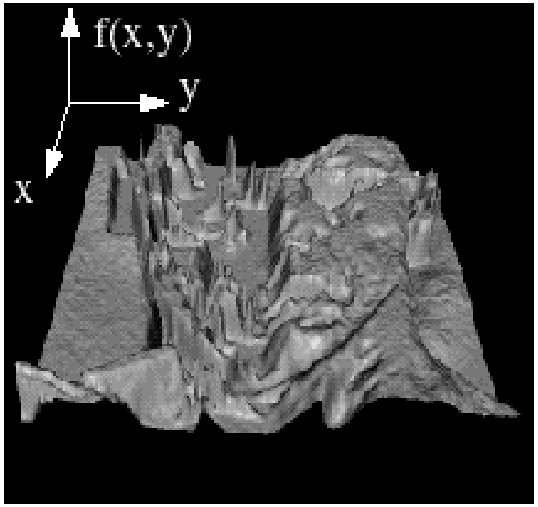
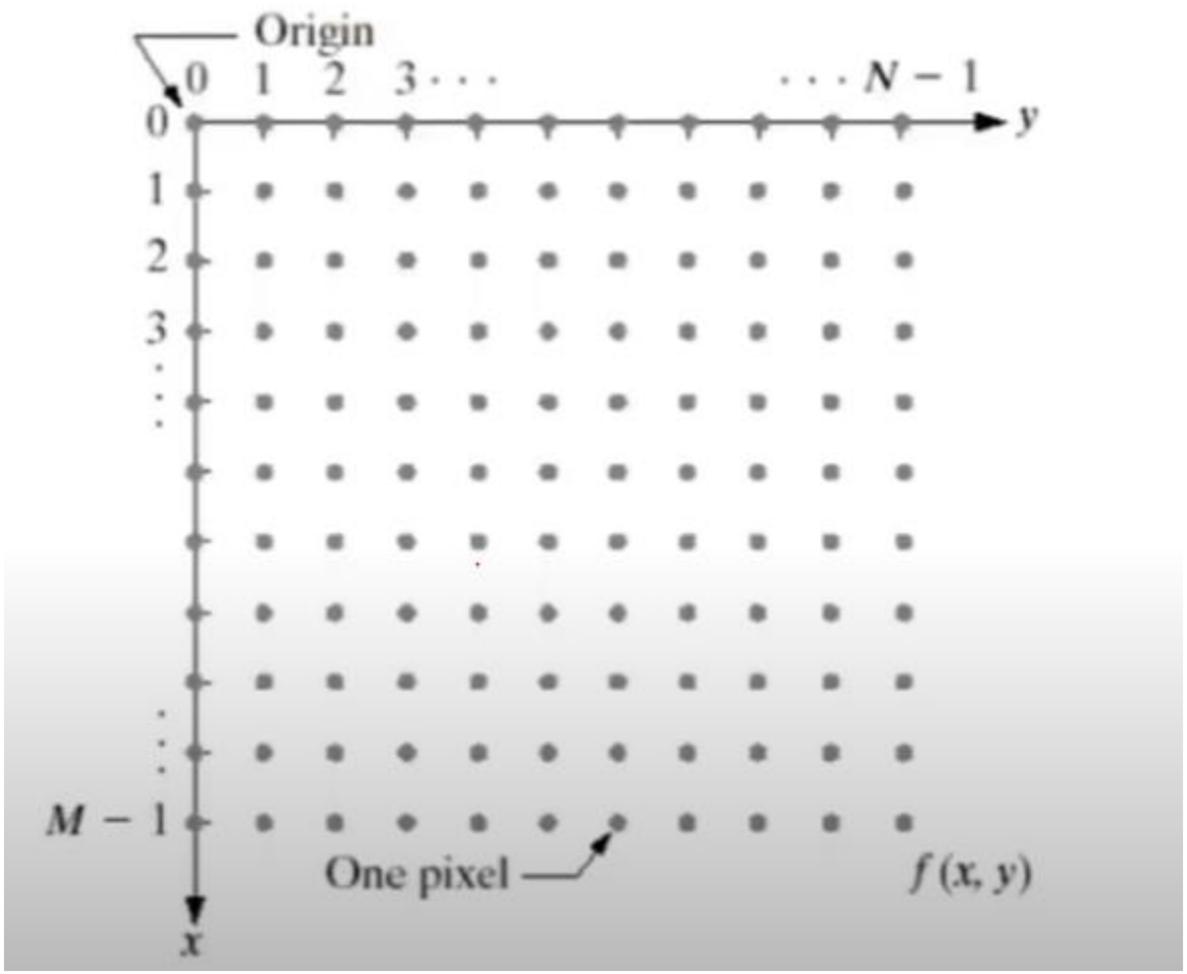


Image as a function



Conventional coordinate for image representation

Image Types

Three types of images:

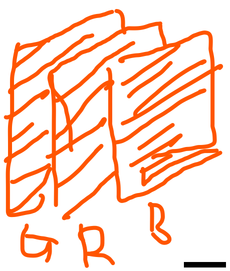
– Binary images 2^1 previously camera can only capture binary image

$$g(x,y) \in \{0\ ,\ 1\}$$

– Gray-scale images

$$g(x,y) \in C$$

typically $c=\{0,\ldots,255\}$



– Color Images

diff channel (RGB) at different intentsity value

three channels:

$g_R(x,y) \in C \qquad g_G(x,y) \in C \qquad g_B(x,y) \in C$

RGB value
Red, Green, Blue

Image Types

Binary image or black and white image

Each pixel contains one bit :

1 represent white

0 represents black

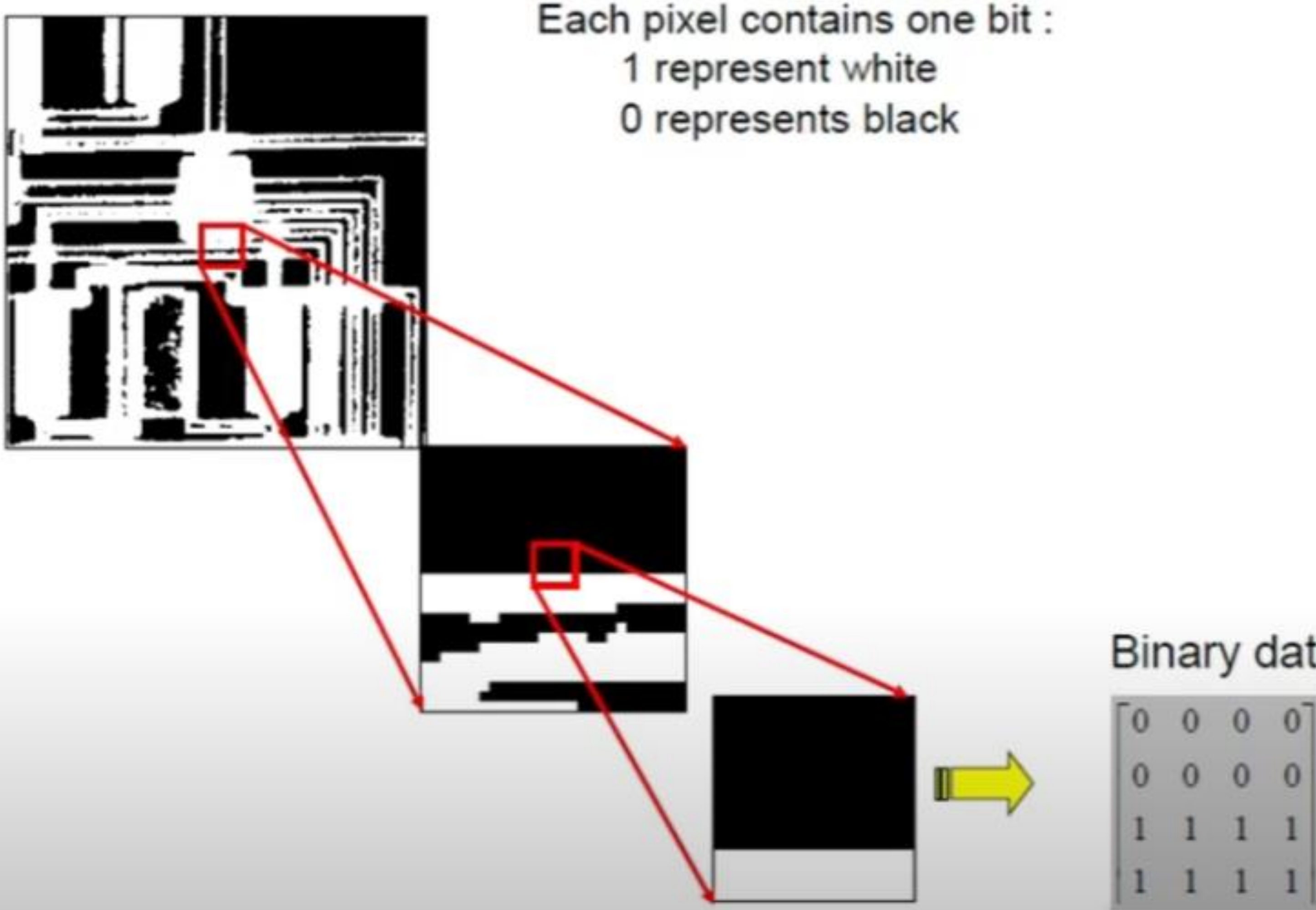
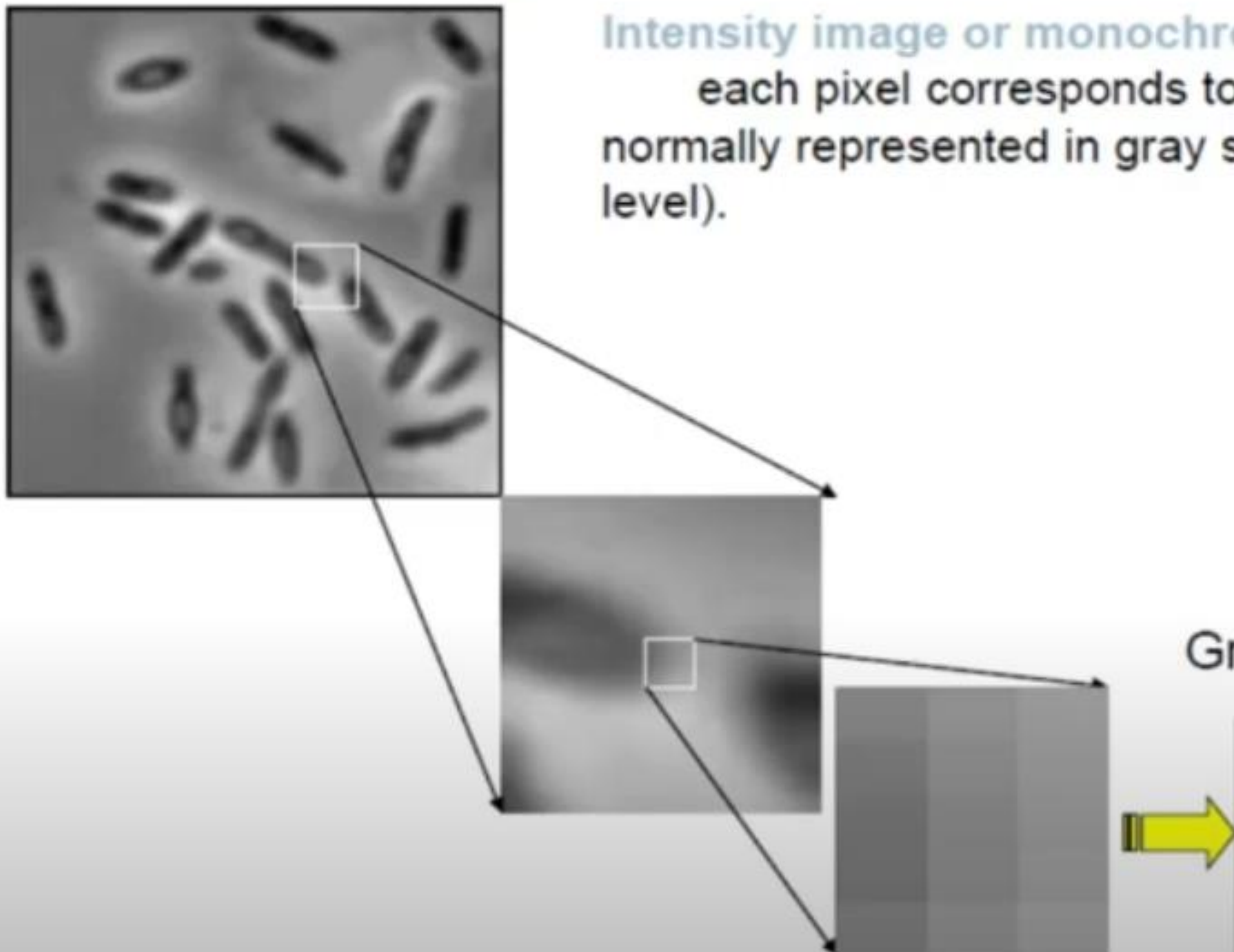


Image Types

Intensity image or monochrome image

each pixel corresponds to light intensity normally represented in gray scale (gray level).

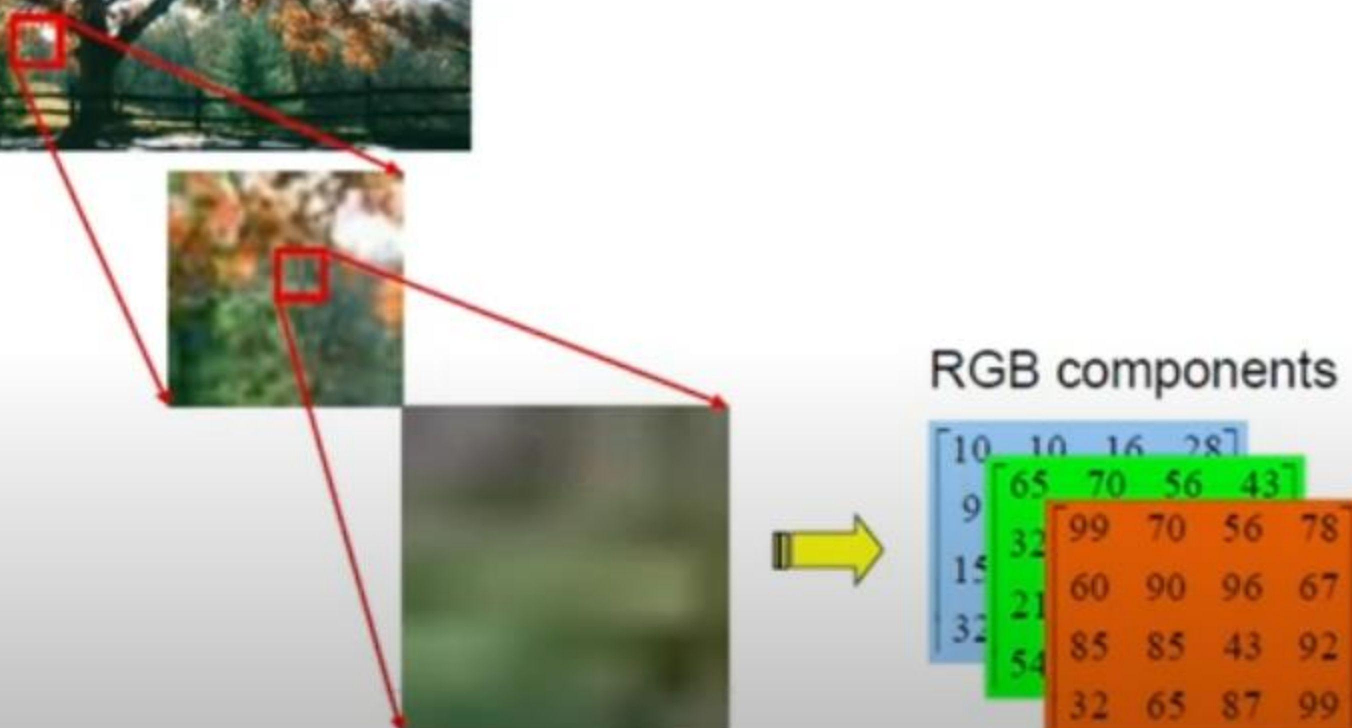


Gray scale values

$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 6 & 26 & 37 \\ 15 & 25 & 13 & 22 \\ 32 & 15 & 87 & 39 \end{bmatrix}$$

Image Types

Color image or RGB image: each pixel contains a vector representing red, green and blue components.



Digital Image Processing

- Method to perform some operations on an digital image, in order to get an enhanced image or to extract some useful information from it.
- It is a type of signal processing in which input is an image and output may be image or characteristics/ features associated with that image.
- The motivation of digital image processing
    - ➢ Improvement of picture information for interpretation.
    - ➢ Storage, transmission and representation of digital data for machine perception is possible.

Digital Image Processing

- Low level processing
  - Primitive operations such as noise reduction, image sharpening, enhancement, etc.
  - Input and output are images.
- Mid level processing will learn only some of it
  - Image segmentation, classification of individual objects, etc.
  - Input are images but output are attributes of images (e.g., edges of image).
- High level processing
  - Involves making sense of recognized objects and performing functions associated with visions.
  - For e.g., automatic character recognition, military recognition, autonomous navigation, etc.

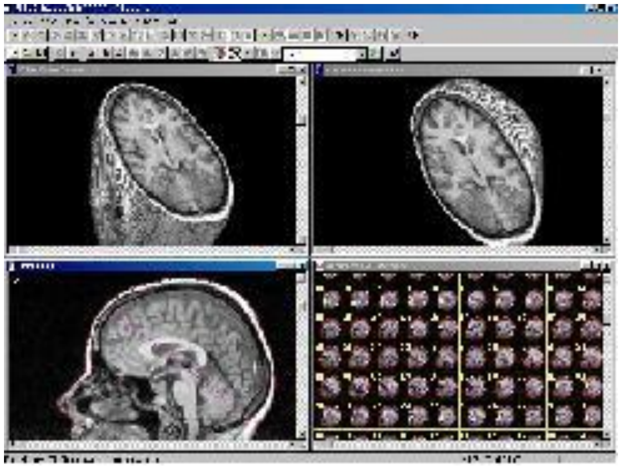
Industry and Applications

- Automobile driver assistance
  - Lane departure warning
  - Adaptive cruise control
  - Obstacle warning
- Digital Photography
  - Image Enhancement
  - Compression
  - Color manipulation
  - Image editing
  - Digital cameras
- Sports analysis
  - sports refereeing and commentary
  - 3D visualization and tracking sports actions

MobilEye system

Industry and Applications

- Film and Video
  - Editing
  - Special effects
- Image Database
  - Content based image retrieval
  - visual search of products
  - Face recognition
- Industrial Automation and Inspection
  - vision-guided robotics
  - Inspection systems
- Medical and Biomedical
  - Surgical assistance
  - Sensor fusion
  - Vision based diagnosis
- Astronomy
  - Astronomical Image Enhancement
  - Chemical/Spectral Analysis

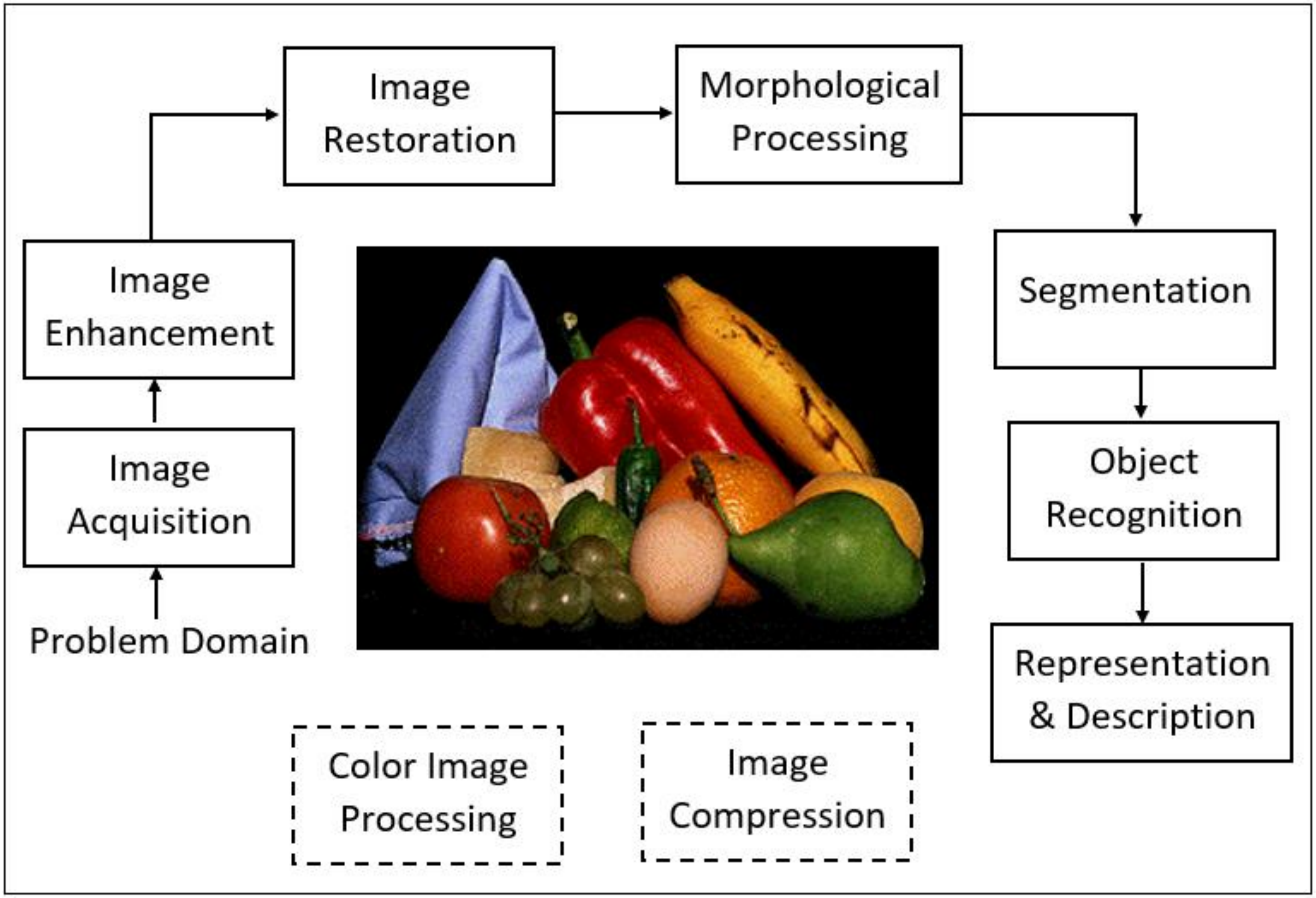


Industry and Applications

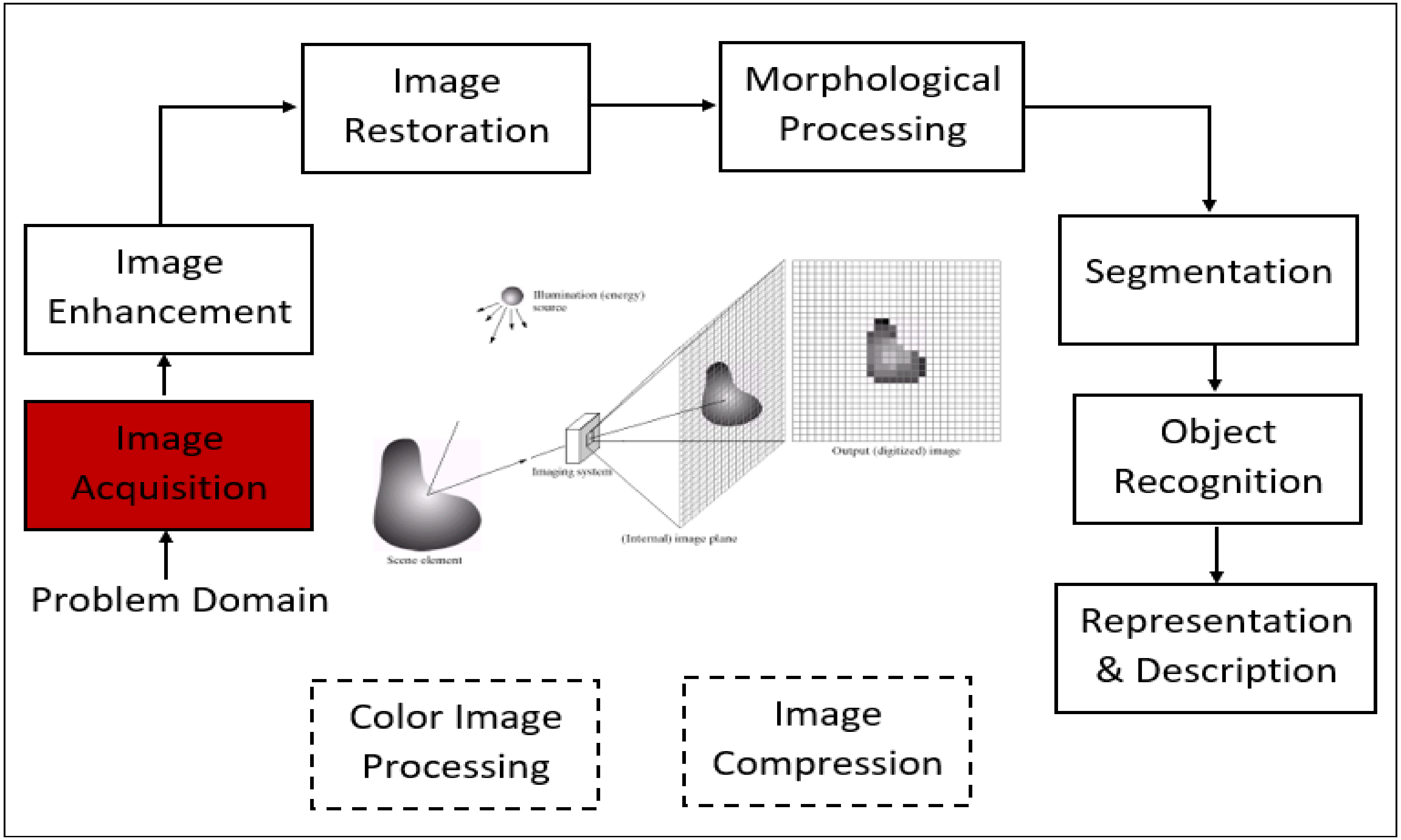
- Arial Photography
  - Image Enhancement
  - Missile Guidance
  - Geological Mapping
- Robotics
  - Autonomous Vehicles
- Security and Safety
  - Biometry verification (face, iris)
  - Surveillance (fences, swimming pools)
- Military
  - Tracking and localizing
  - Detection
  - Missile guidance
- Traffic and Road Monitoring
  - Traffic monitoring
  - Adaptive traffic lights

Cruise Missiles

Phases of Image Processing



Phases of Image Processing

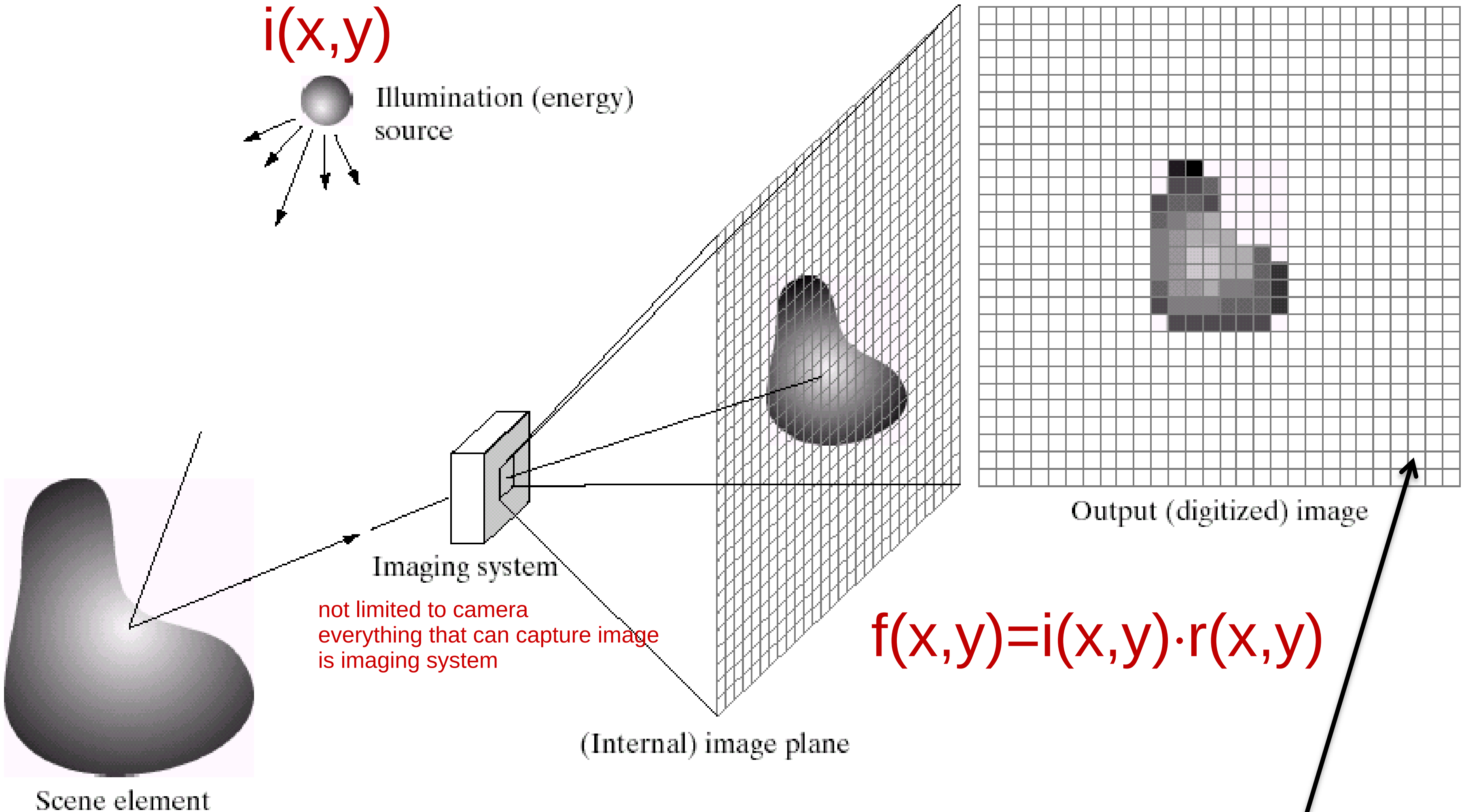


In this step, the image is captured by a camera and is digitized if not in digital form

Image Acquisition

g(i,j)

i(x,y)



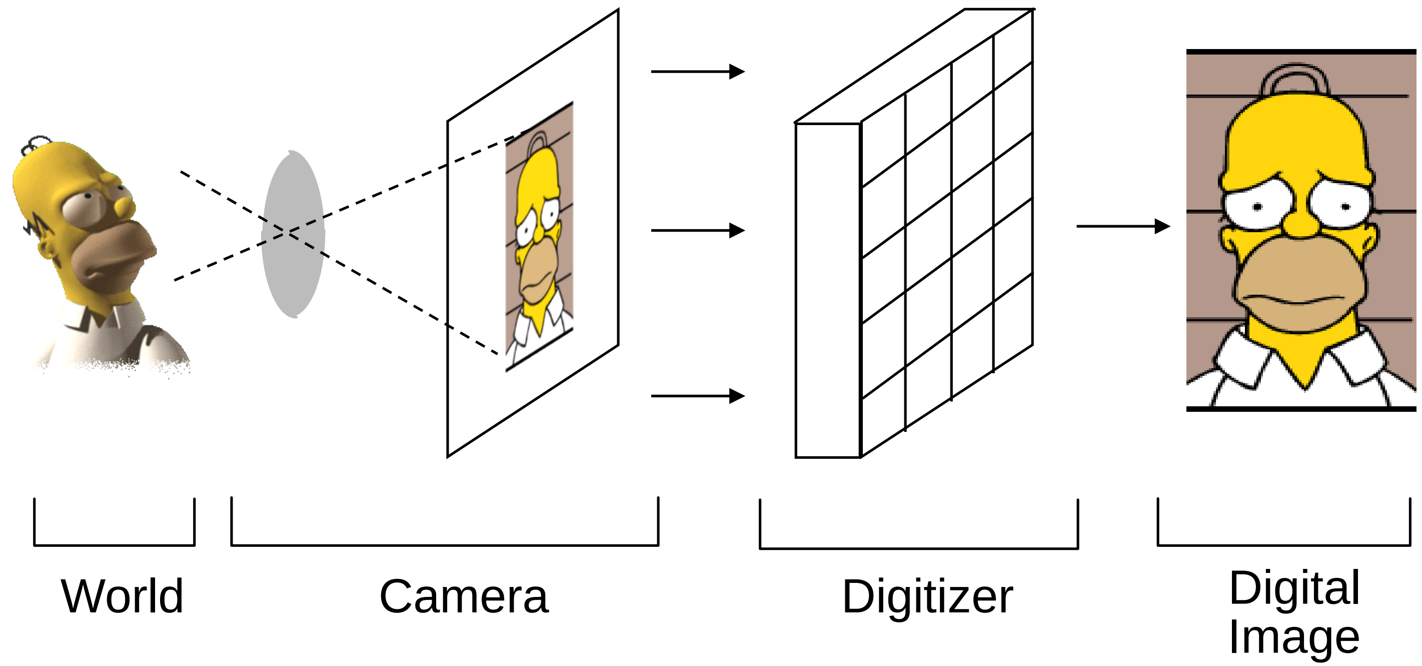
not limited to camera
everything that can capture image
is imaging system

$f(x,y)=i(x,y)\cdot r(x,y)$

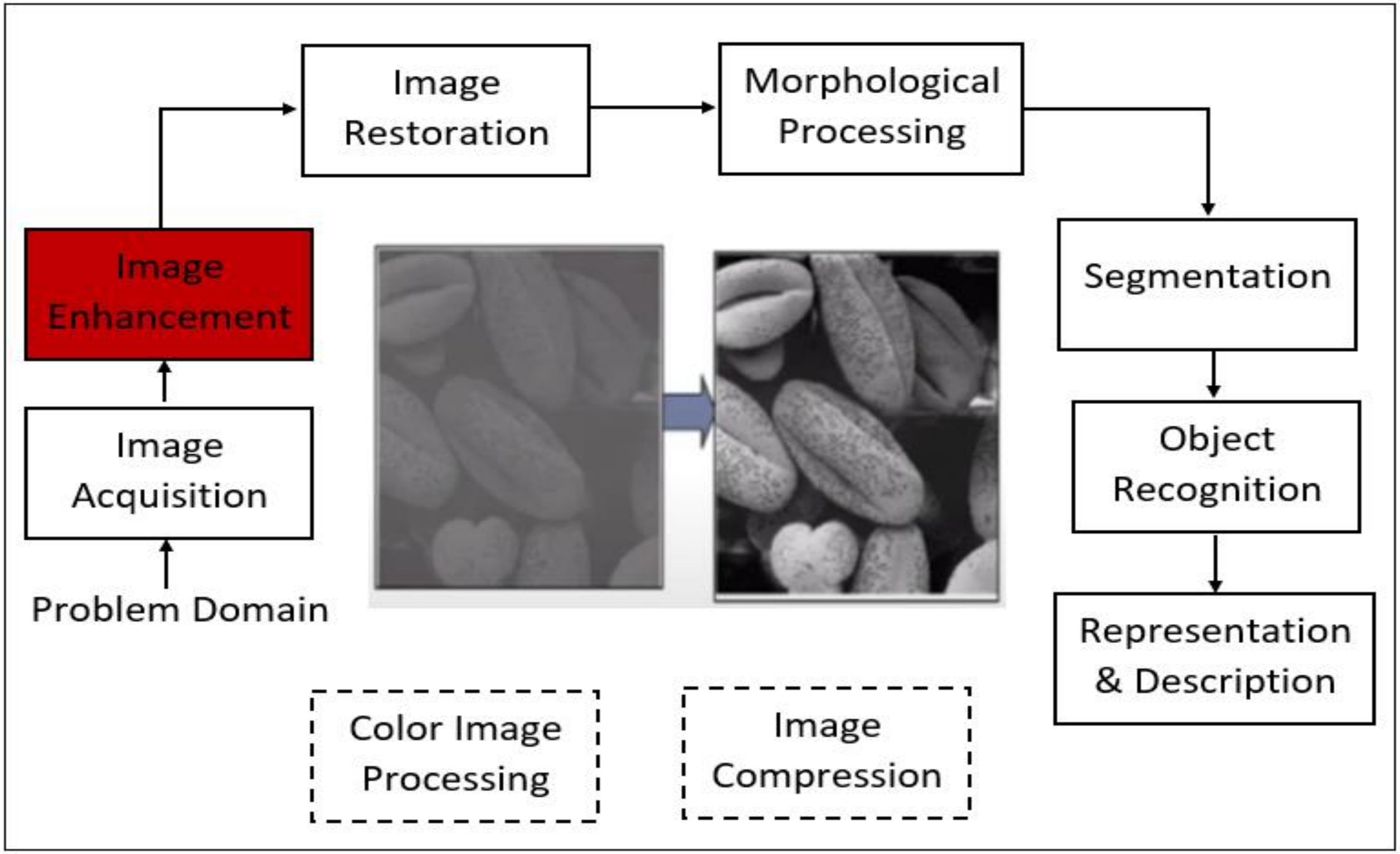
r(x,y)

pixel=picture element

Acquisition System



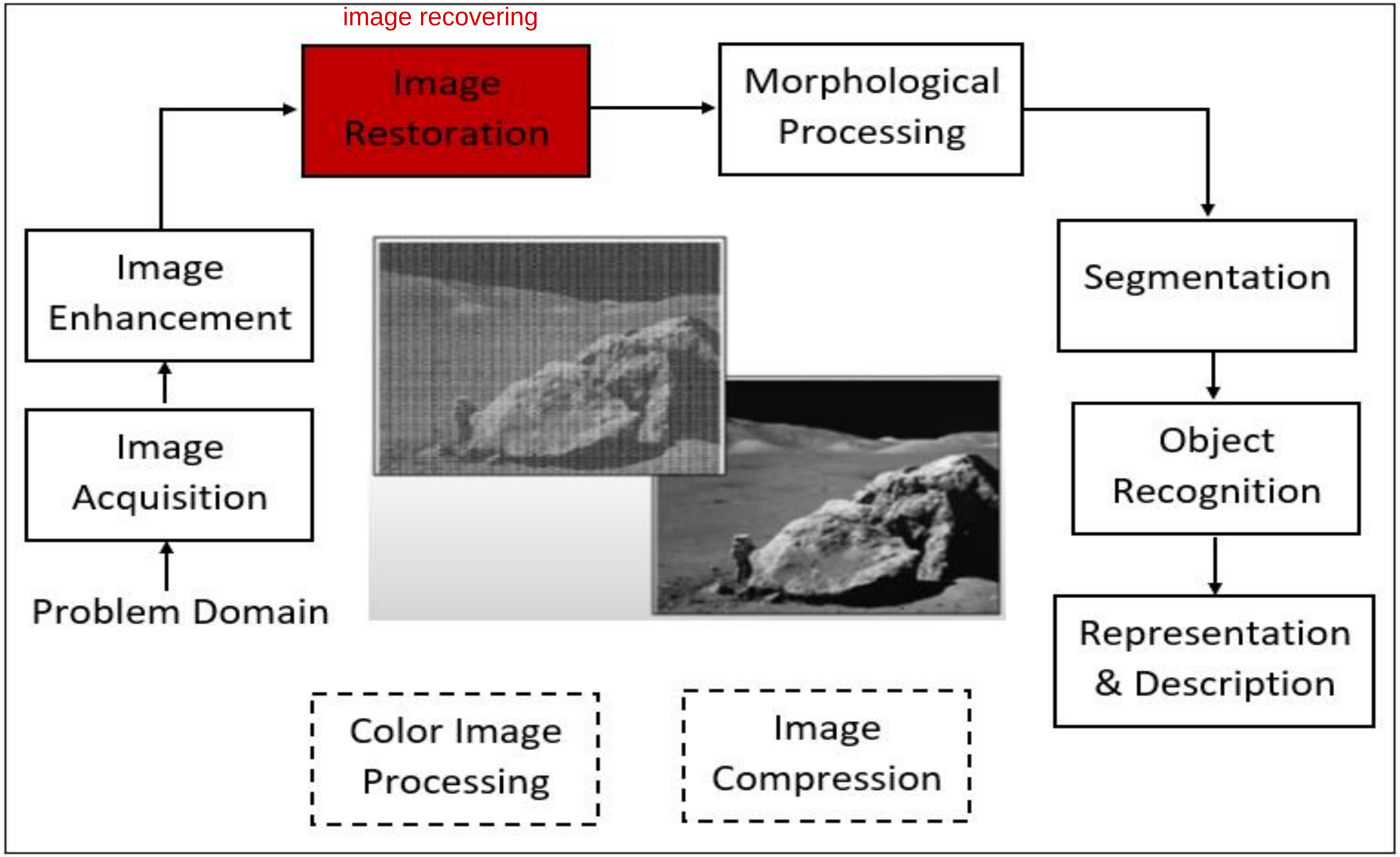
Phases of Image Processing



It is the process of manipulating an image so that the result is more suitable that the original for specific applications.

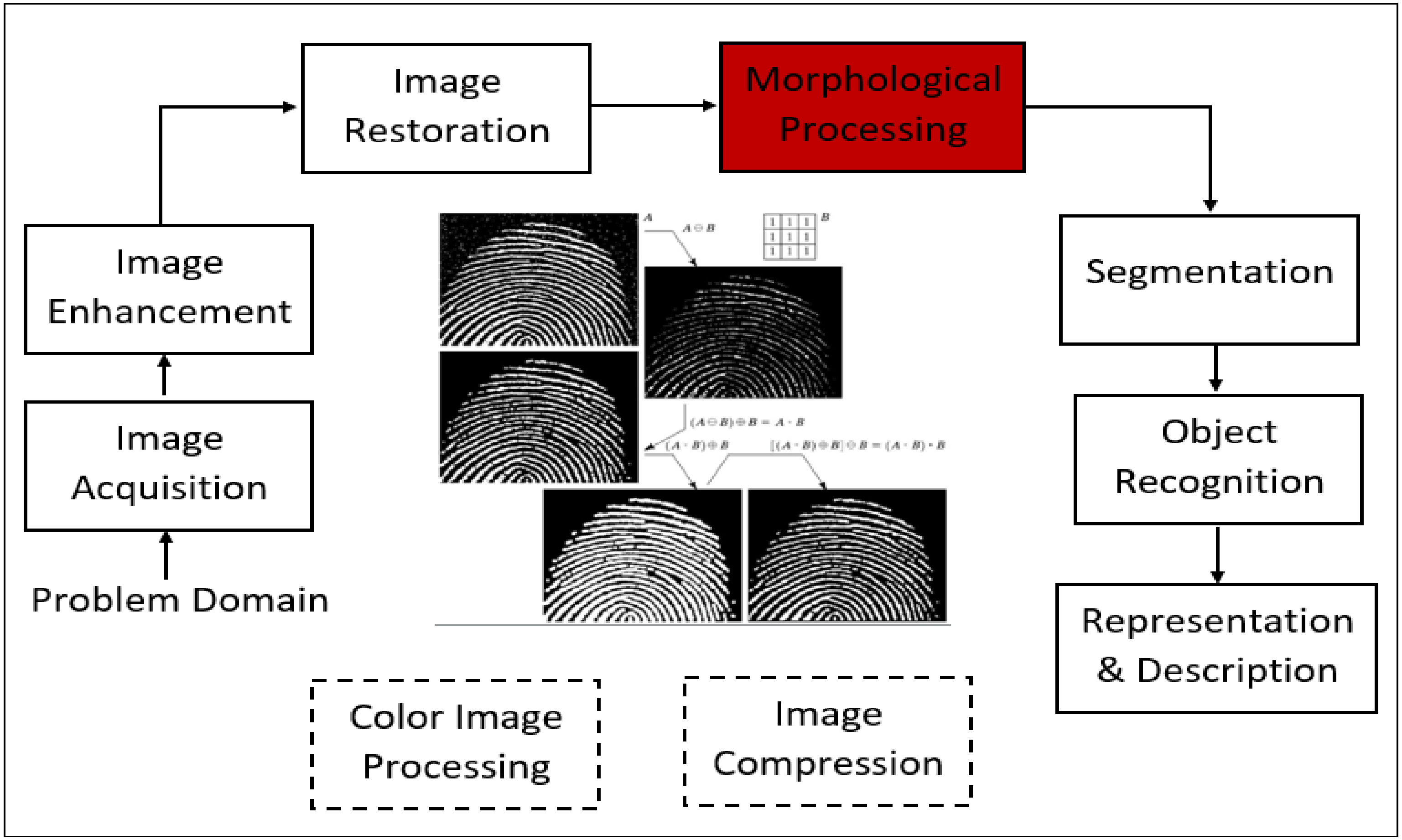
Image Enhancement

Phases of Image Processing



It is the process of recovering an image that has been degraded. It uses mathematical or probabilistic models.

Phases of Image Processing



Are the tools for extracting image components that are useful in the representation and description of shape.

Morphological Processing

cth nak hilangkan urat daun, buat erosion dulu, then nak pekatkan balik buat dialtion process

Original image

Dilated image

Eroded image

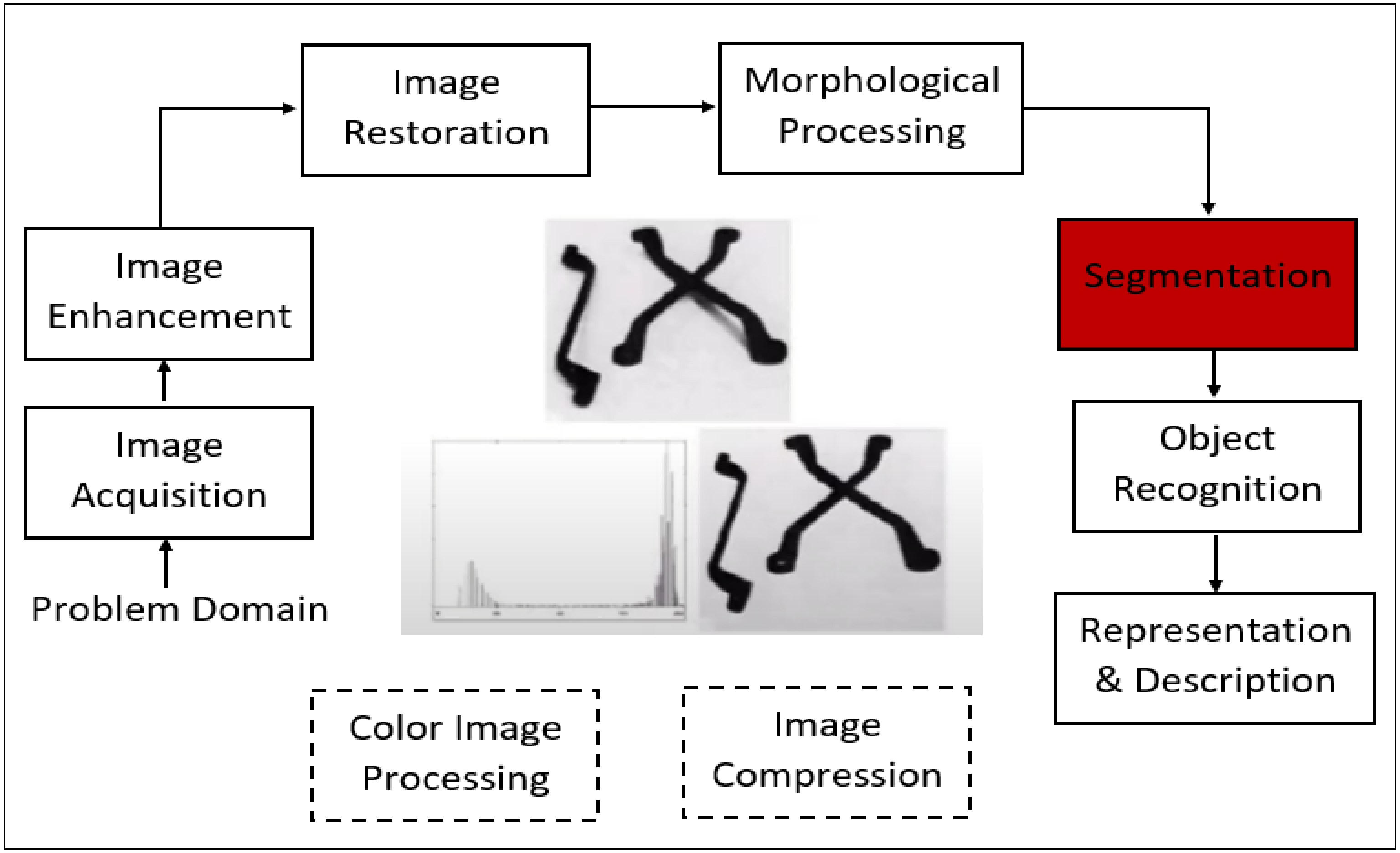
Opened image

Closed image

morphological processing involves
- dilation process and erosion image
-1) dilation add pixel to the edge
-2) erosion removes the pixel

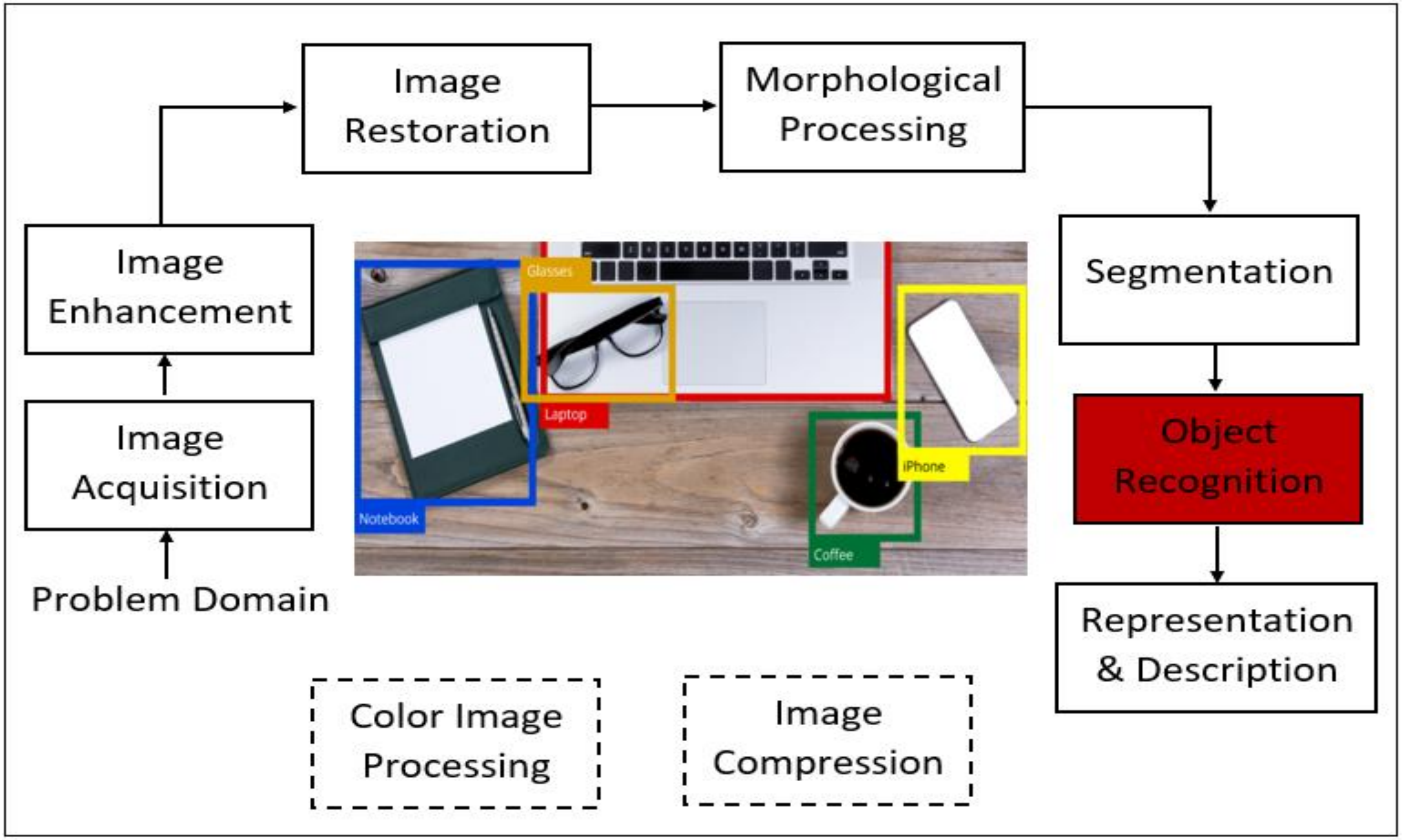
we use both dilation and erosion process
either one process will be the first step to occur

Phases of Image Processing



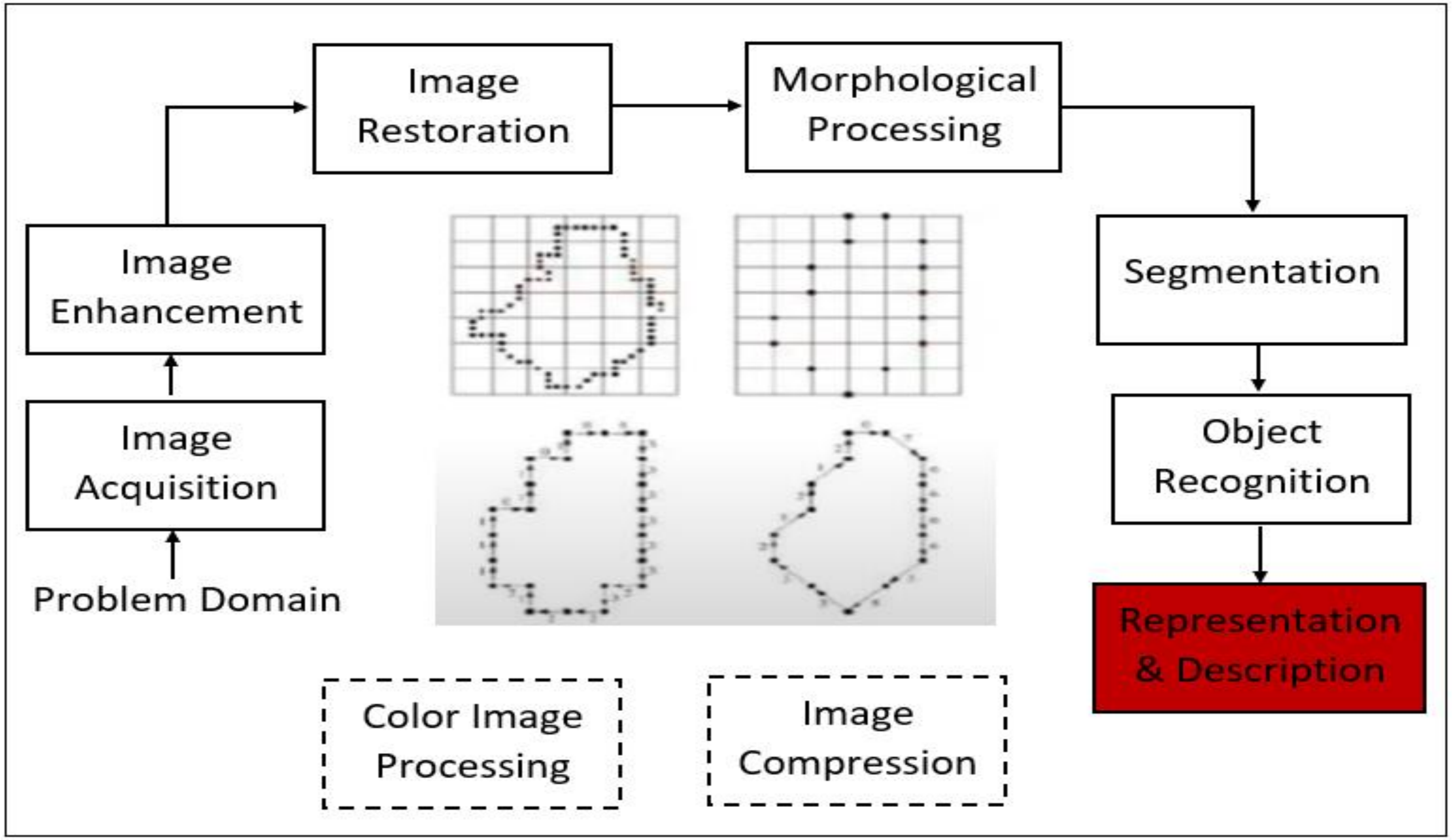
Here the computer tries to separate onjects from the image.

Phases of Image Processing



It is the process that assigns a label to an object based on its description.

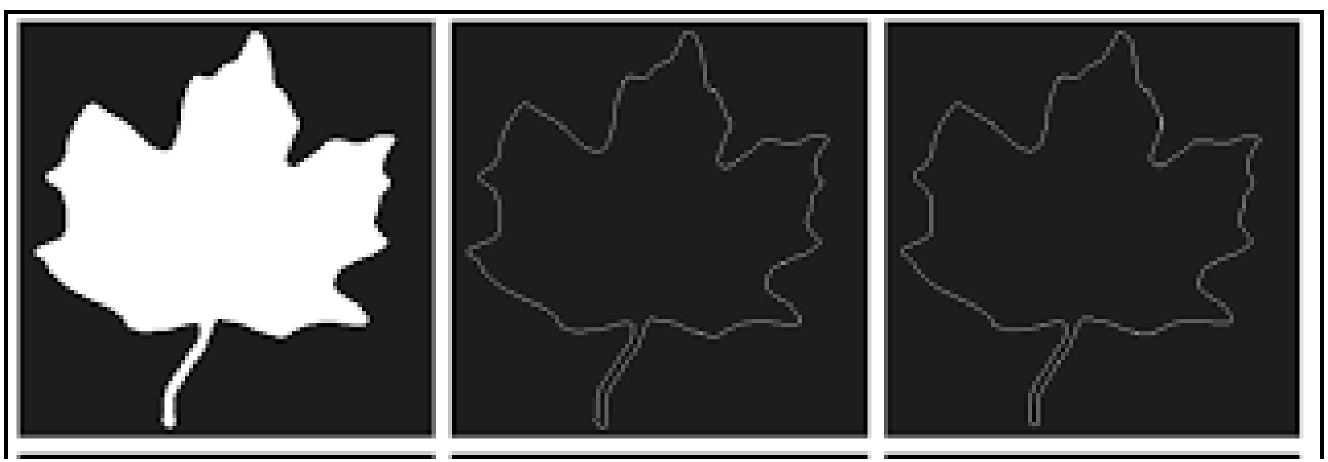
Phases of Image Processing



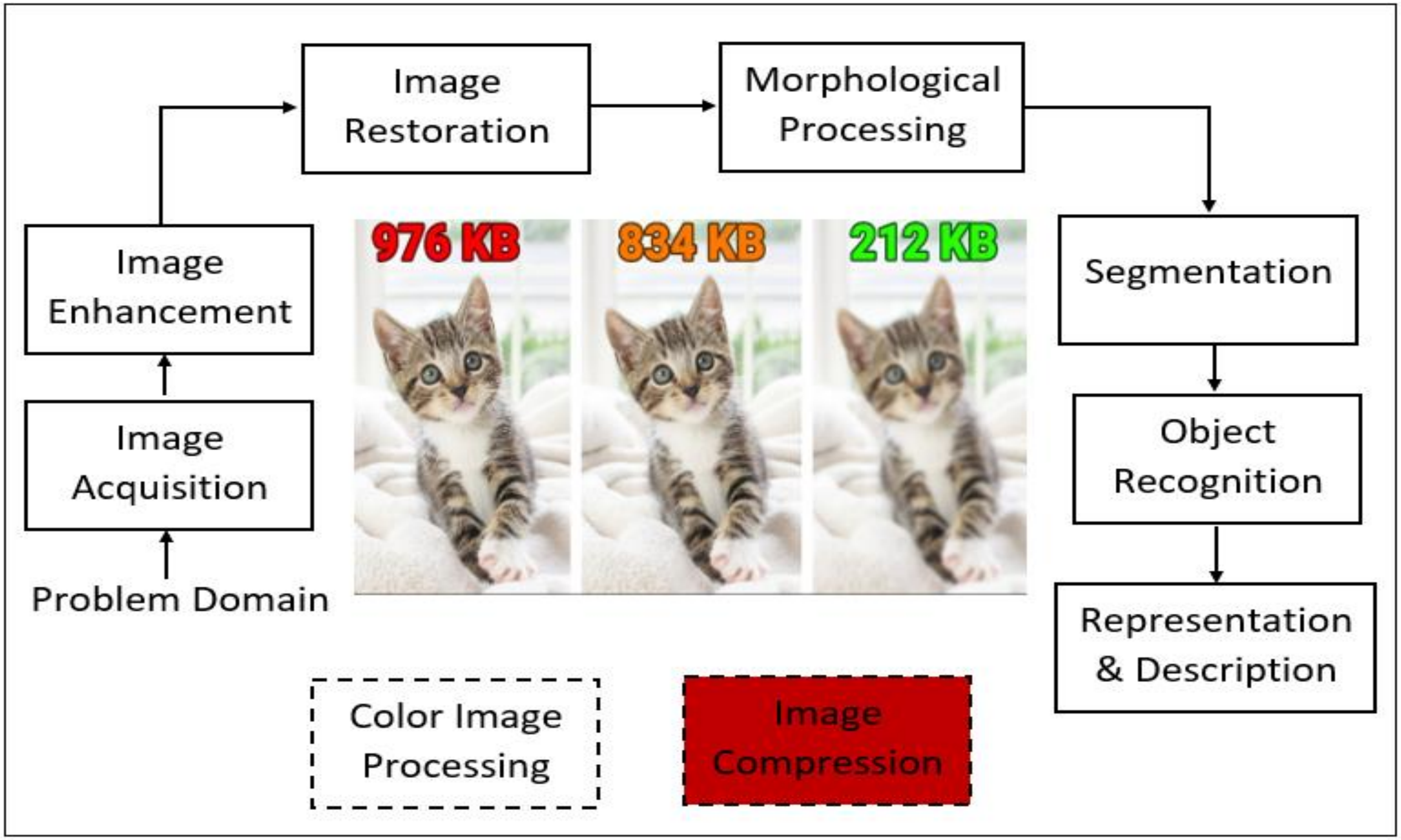
Representation deals with converting the data into a suitable form for computer processing

Description deals with extracting features.

Image Representation and Description



Phases of Image Processing



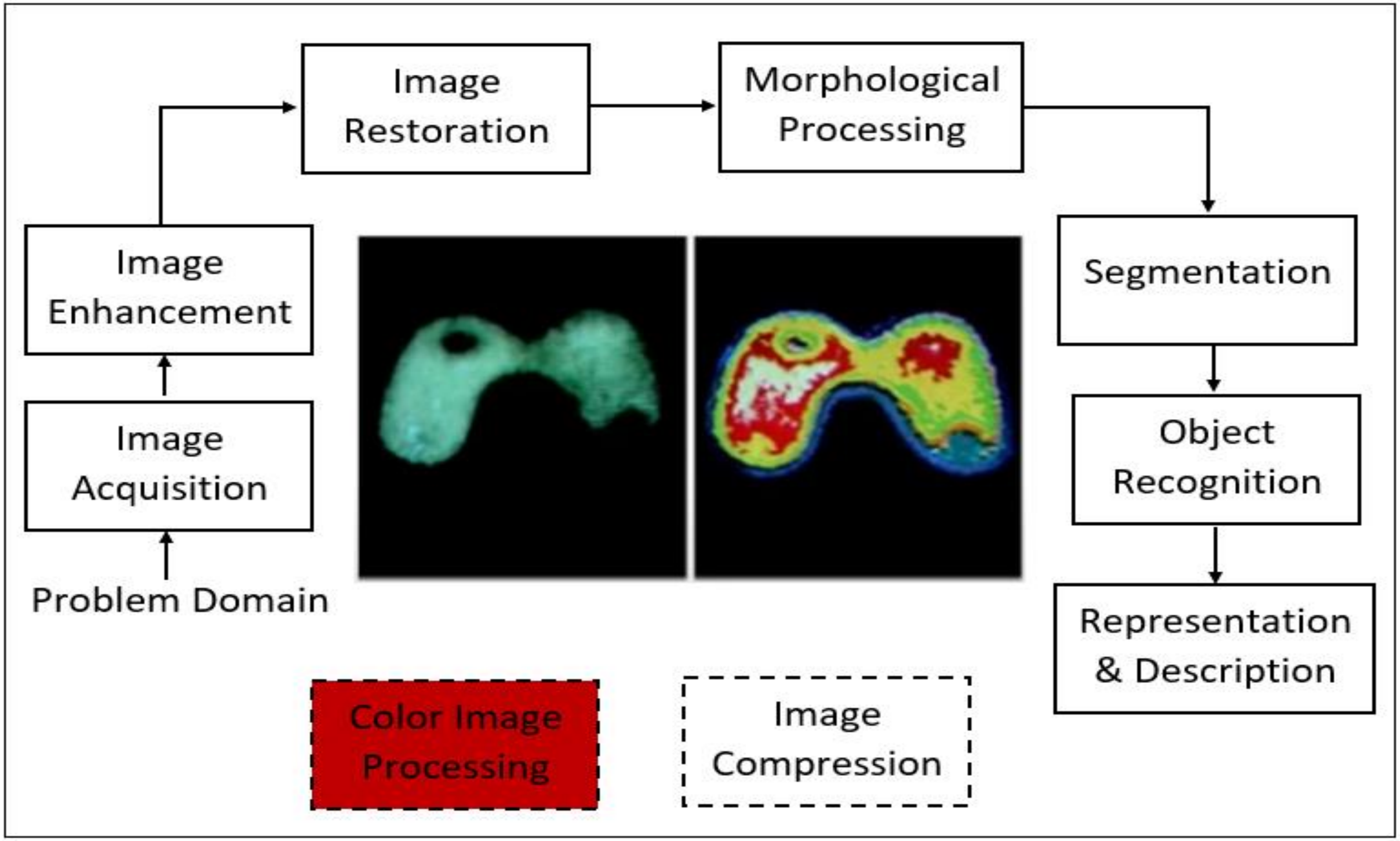
It deals with techniques for reducing the storage space required to save an image or the bandwidth required to transmit it.

Image Compression

- Color image of 600x800 pixels
  - Without compression
    - (600*800 pixels) * (24 bits/pixel) = 11.52M bits = 1.44M bytes
  - After JPEG compression (popularly used on web)
    - only 89K bytes
    - compression ratio ~ 16:1
- Movie
  - 720x480 per frame,
  - 30 frames/sec,
  - 24 bits/pixel
  - Raw video ~ 243M bits/sec
  - DVD ~ about 5M bits/sec
  - Compression ratio ~ 48:1

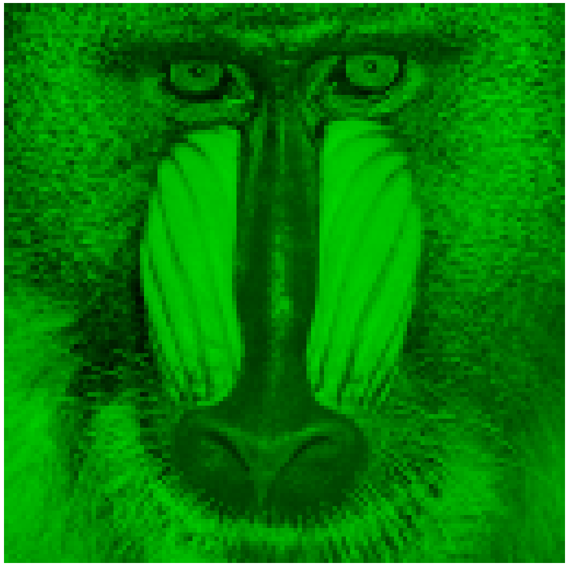
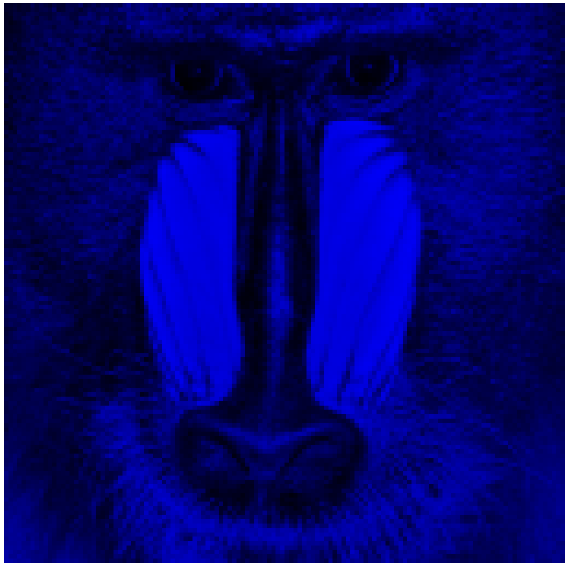
“Library of Congress” by M.Wu (600x800)
Based on slides by W. Trappe

Phases of Image Processing



It handles the image processing of coloured images either to RGB images.

Color Image


PART 2

- More on image acquisition

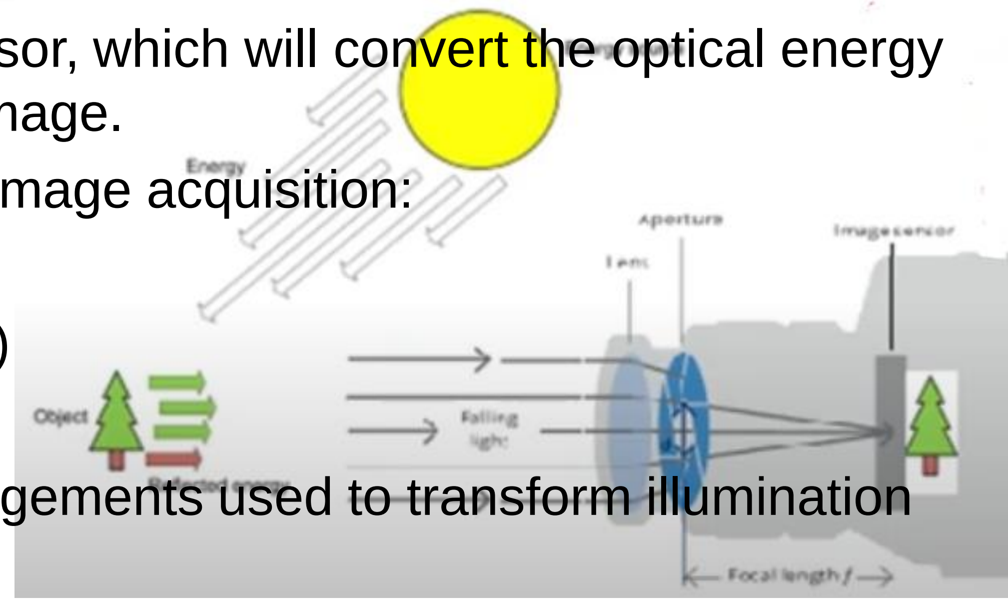
Image digitization → Sampling

→ Quantization

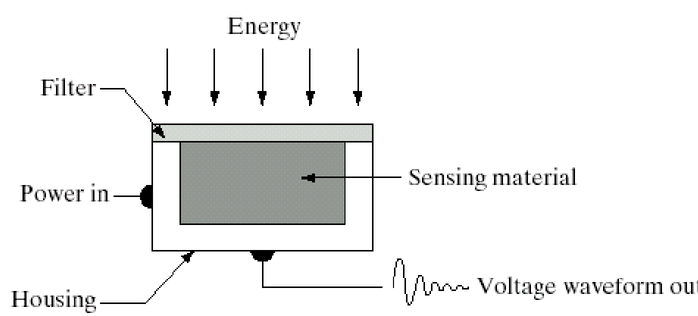
- Other image analysis (image enhancement, denoising, deblurring, etc.)
- Image histogram
- Morphological image processing

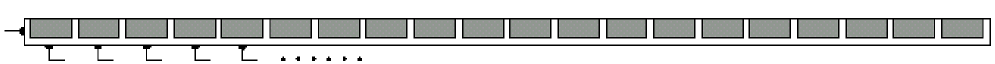
Mechanism for Digitizing

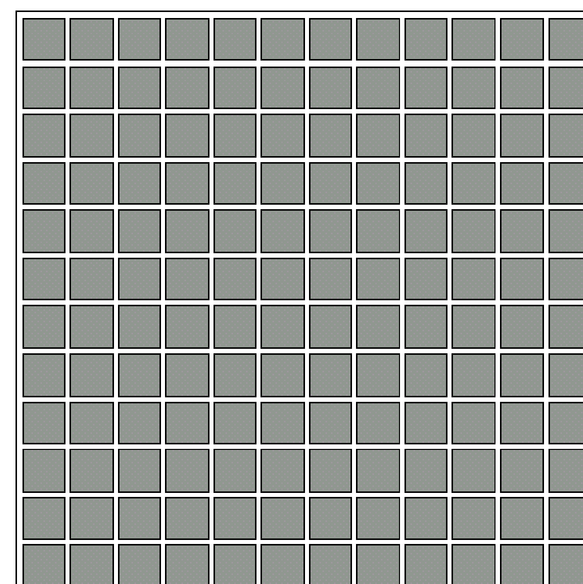
- Image sensing is done by a sensor, which will convert the optical energy into electrical energy or digital image.
- There are three components in image acquisition:
  - ➢ Illumination
  - ➢ Optical system (lens system)
  - ➢ Sensor system



- The three principal sensor arrangements used to transform illumination energy into digital images are:
  - ➢ Single sensor
  - ➢ Line sensor
  - ➢ Array sensor







Digital Image Acquisition

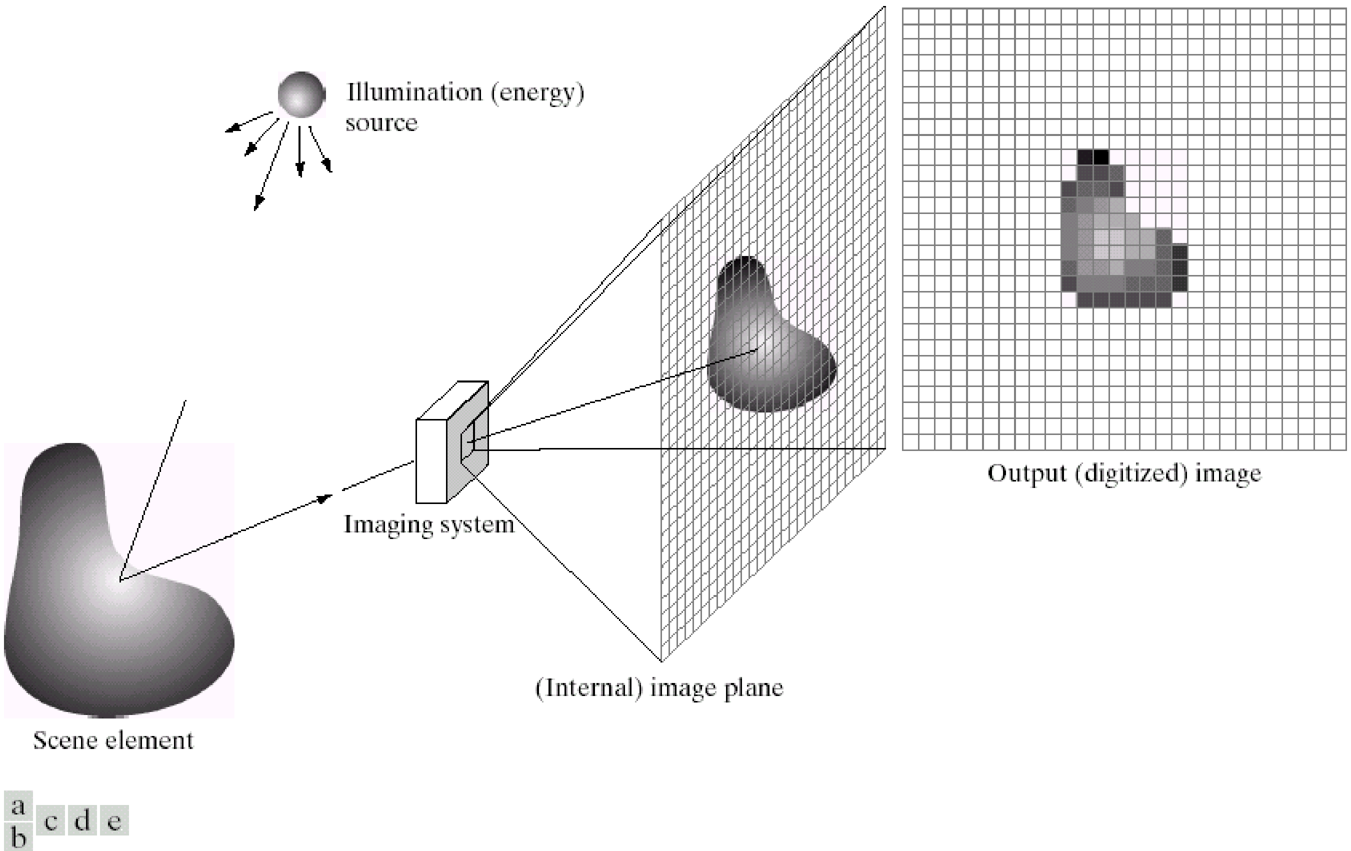
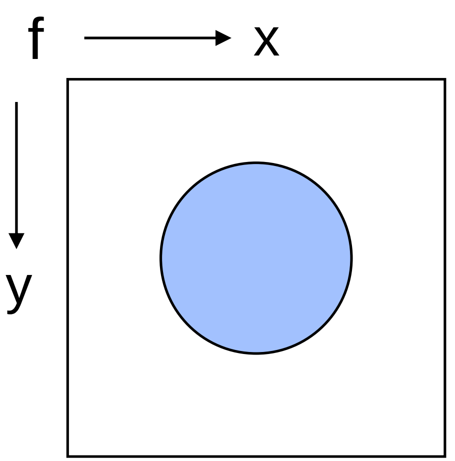


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Digitization

- Two stages in the digitization process:
  - **Spatial sampling**: Spatial domain location
  - **Quantization**: Gray level value

digital image
-> location/pixel
-> intensity



Continuous Image

$f(x,y)$

i \ j	1	2	3	4	5
1	100	100	100	100	100
2	100	0	0	0	100
3	100	0	0	0	100
4	100	0	0	0	100
5	100	100	100	100	100

5x5

Digital Image

$g(i,j) \in C$

Image Sampling and Quantization

- Image sampling refers to discretization of spatial coordinates
- Image quantization refers to discretization of gray level values or amplitude values.
- Given a continuous image f(x,y), digitizing the coordinate values is called sampling and digitizing the amplitude (intensity) values is called quantization.
- An image may be defined as a two-dimensional function, f(x,y), where x and y are *spatial* (plane) coordinates, and the amplitude of ‘f’ at any pair of coordinates (x,y) is called the *intensity* or *gray level* of the image at that point.

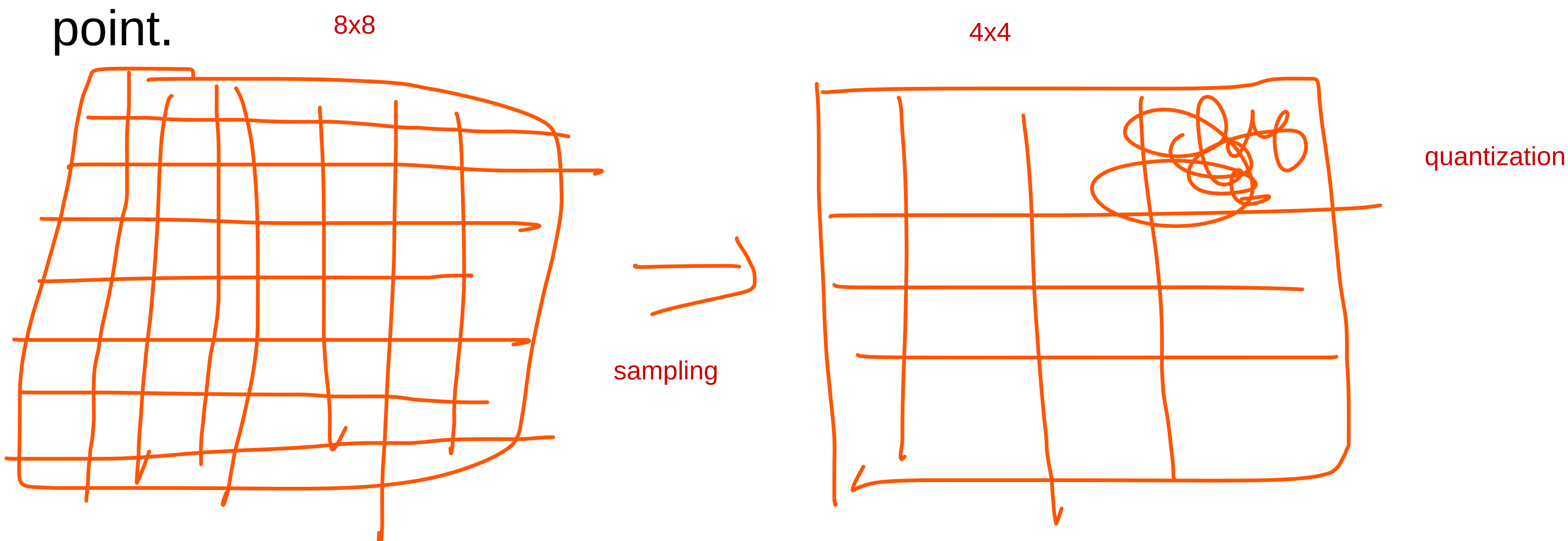


Image Sampling and Quantization

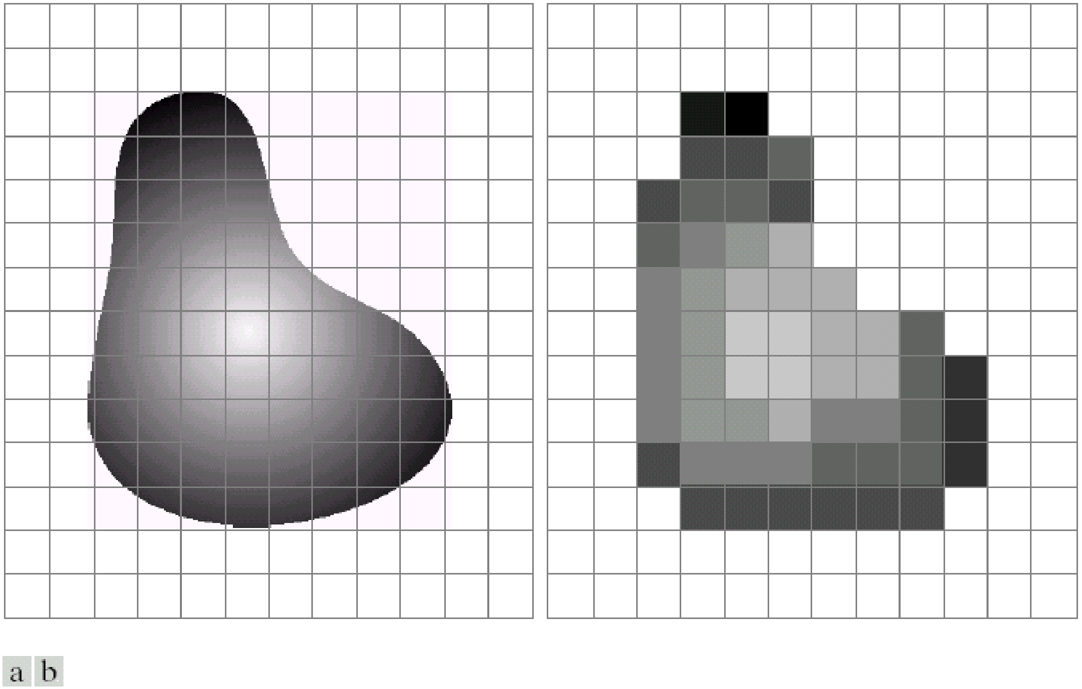
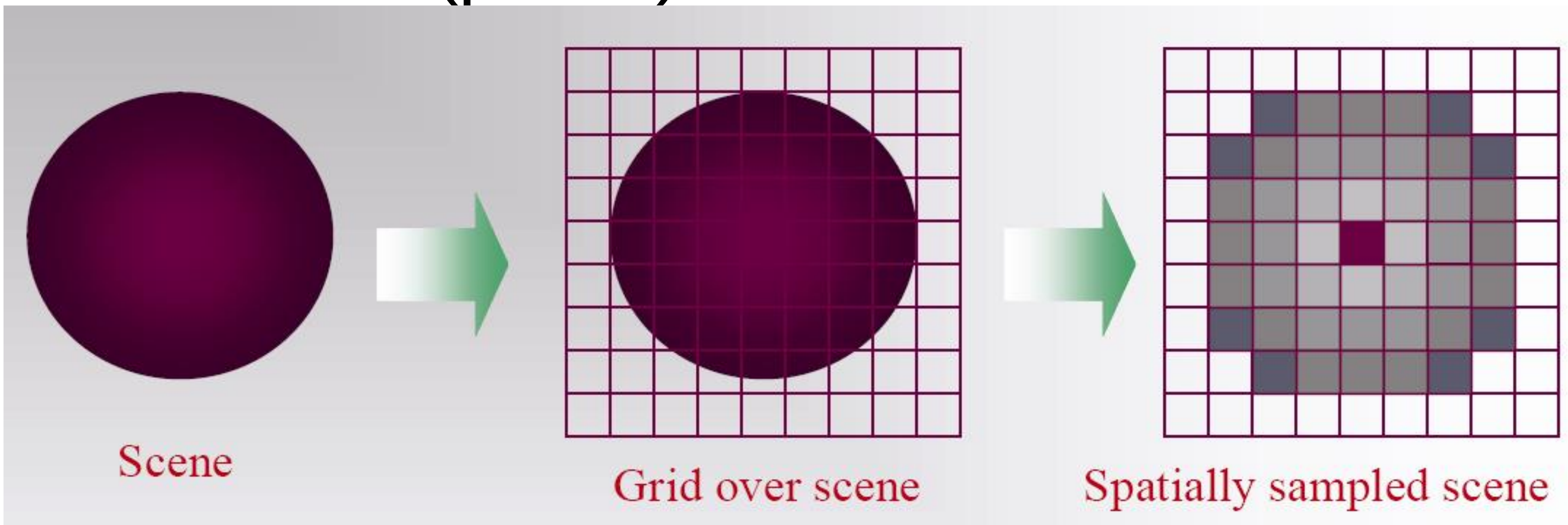


FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Spatial Sampling

- When a continuous scene is imaged on the sensor, the continuous image is divided into discrete elements - picture elements (pixels)



map the picture to the pixel

Effect of Sampling

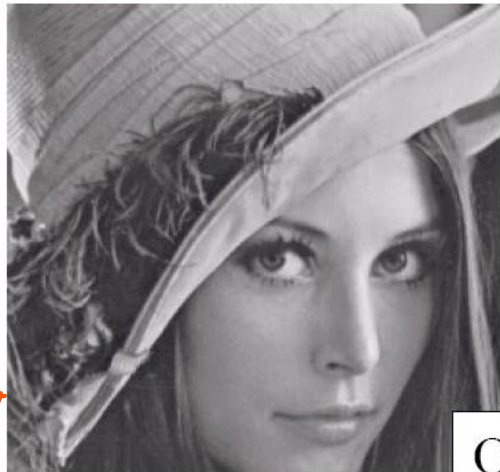
a b
c d

FIGURE 2.20 Typical effects of reducing spatial resolution. Images shown at: (a) 1250 dpi, (b) 300 dpi, (c) 150 dpi, and (d) 72 dpi. The thin black borders were added for clarity. They are not part of the data.

dpi = dots per inch
(top left image is 3692*2812 pixels & 1250dpi)
bottom right image is 213*162 pixels & 72dpi)

Spatial Sampling

256 × 256



Original

128 × 128

2 points

means combine 2 pixels

64 × 64

4 points

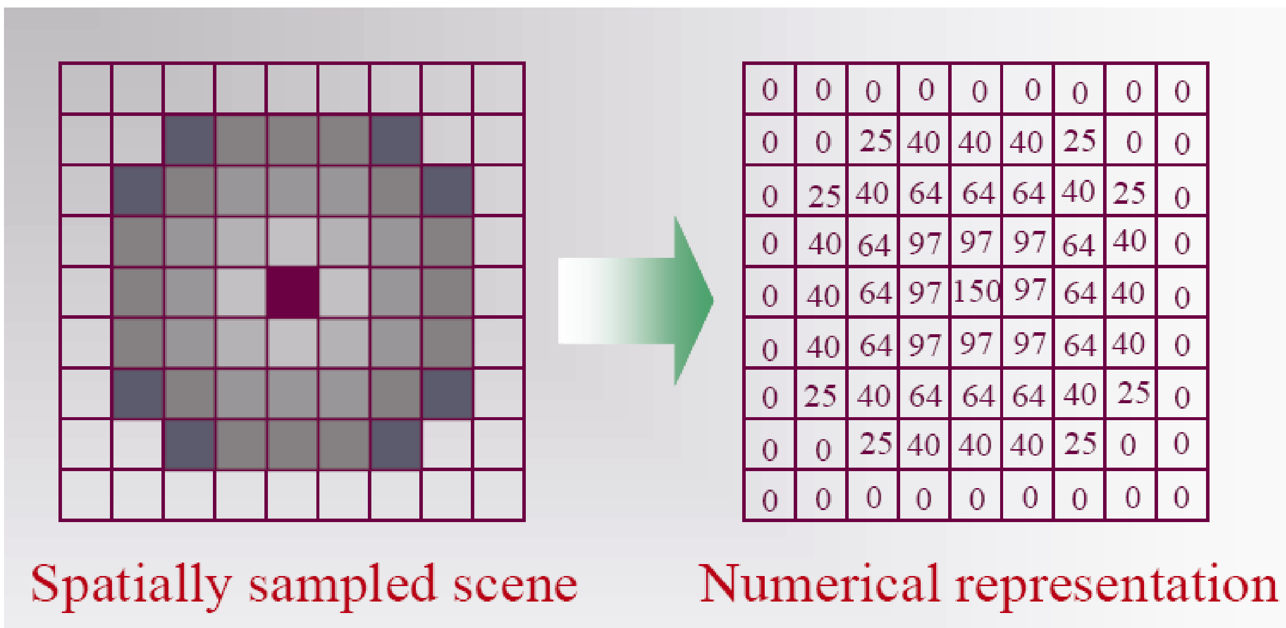
further combine another 2, hence 4 pixels combined

32 × 32

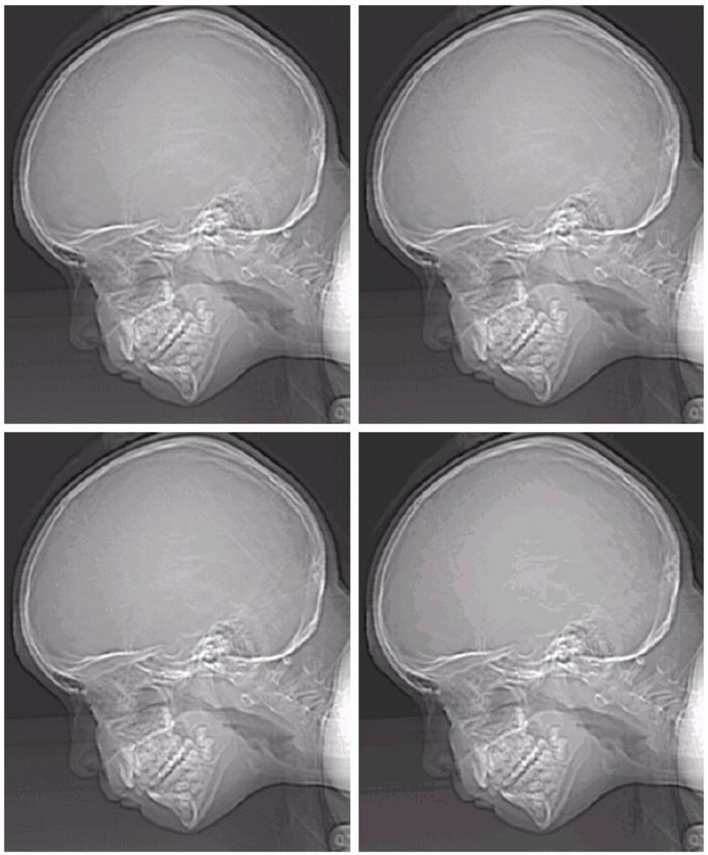
8 points

Quantization

- Choose number of gray levels (according to number of assigned bits)
- Divide continuous range of intensity values



Effect of Quantization

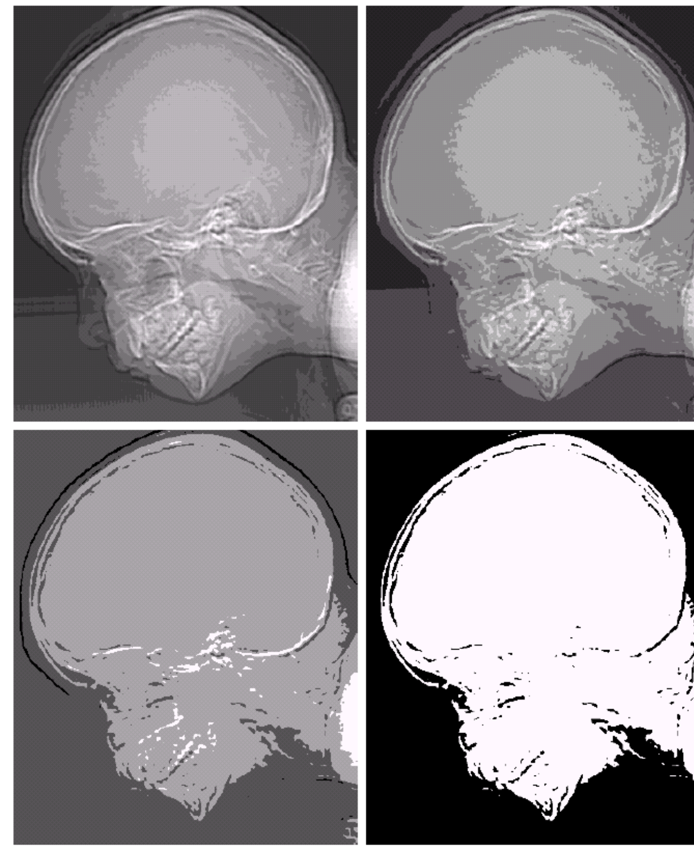


a b
c d

FIGURE 2.21
(a) 452 × 374, 256-level image. (b)–(d) Image displayed in 128, 64, and 32 gray levels, while keeping the spatial resolution constant.

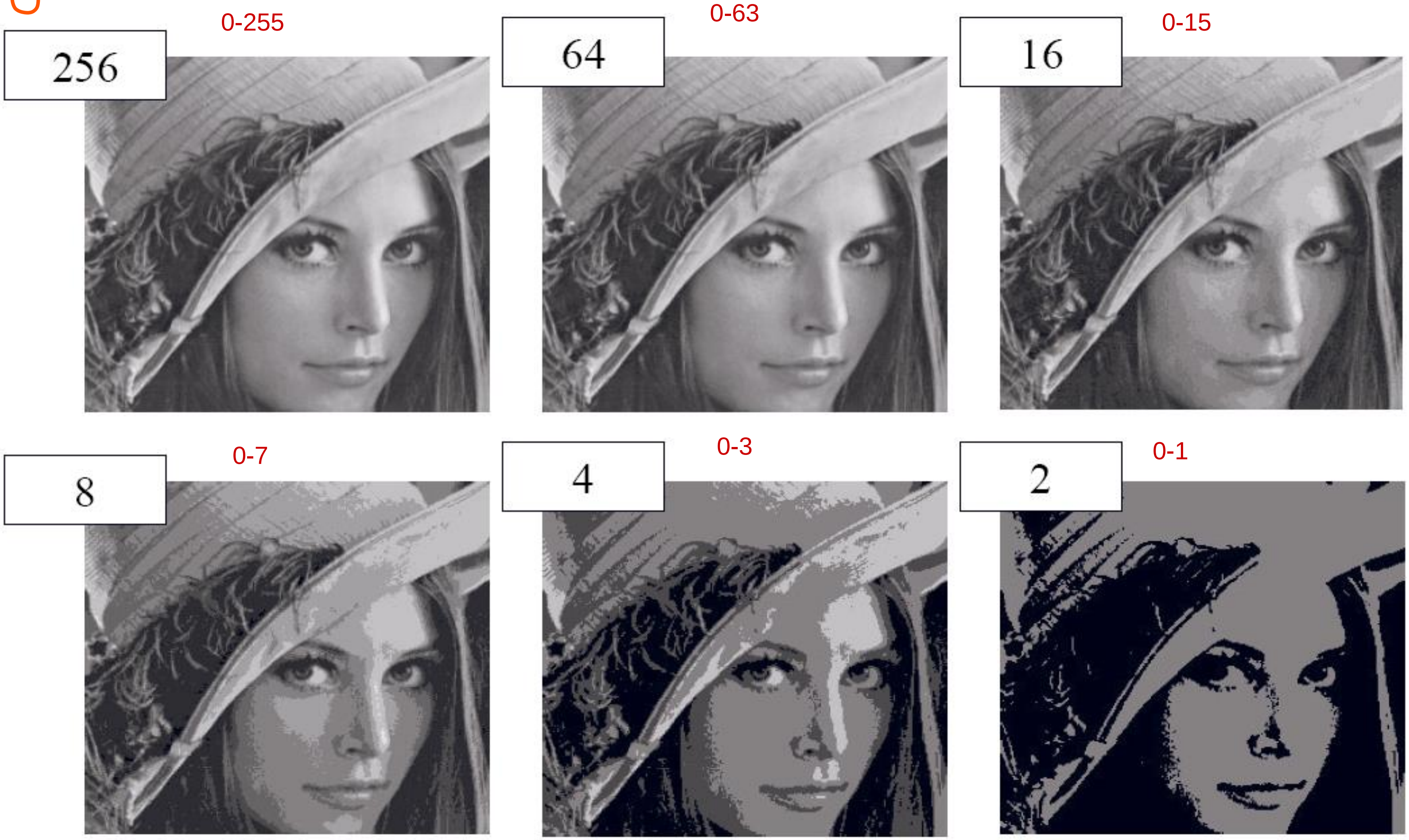
e f
g h

FIGURE 2.21
(Continued)
(e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)



Quantization

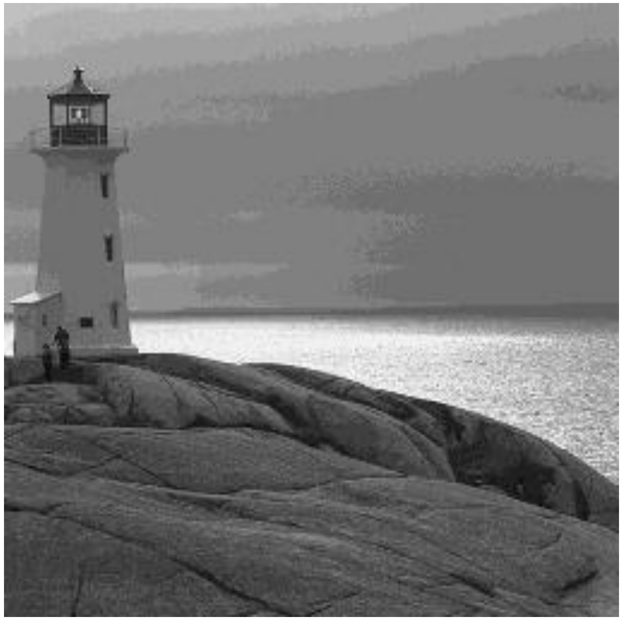
0 255



Quantization

- Low freq. areas are more sensitive to quantization

8 bits image

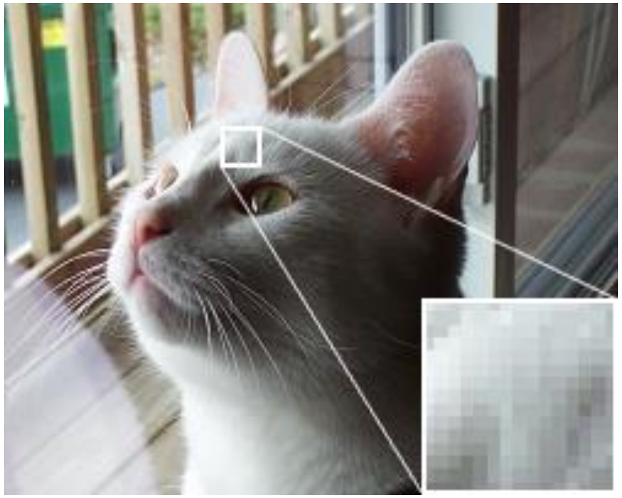


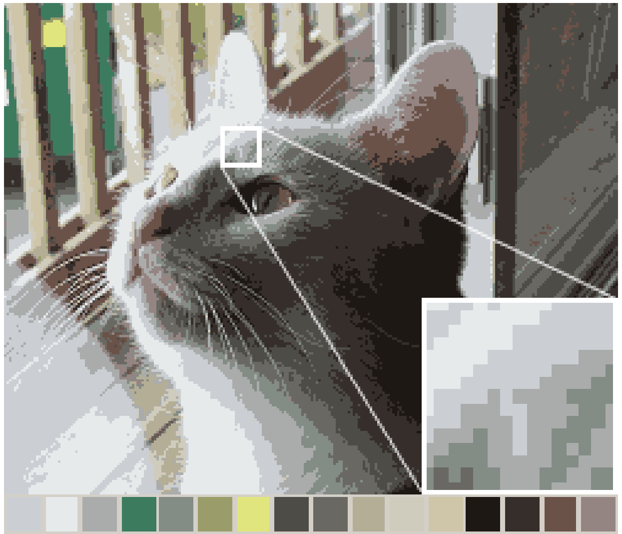
4 bits image

Color Quantization

- Common color resolution for high quality images is 256 levels for each Red, Greed, Blue channels, or $256^3 = 16777216$ colors.
- How can an image be displayed with fewer colors than it contains?
- Select a subset of colors (the colormap or pallet) and map the rest of the colors to them.

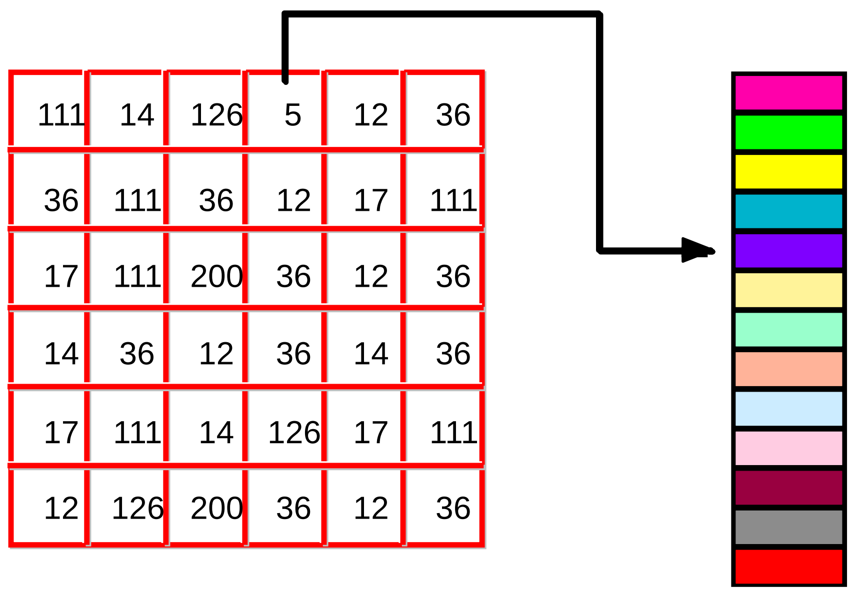
from: Daniel Cohen-Or





Color Quantization

- With 8 bits per pixel and color look up table we can display at most 256 distinct colors at a time.
- To do that we need to choose an appropriate set of representative colors and map the image into these colors



from: Daniel Cohen-Or

Color Quantization

2
colors

4
colors

16
colors

256
colors

from: Daniel Cohen-Or

Image Enhancement

- Image enhancement is the process of enhancing image so that the resultant image is more suitable than original for specific applications.

Image Enhancement

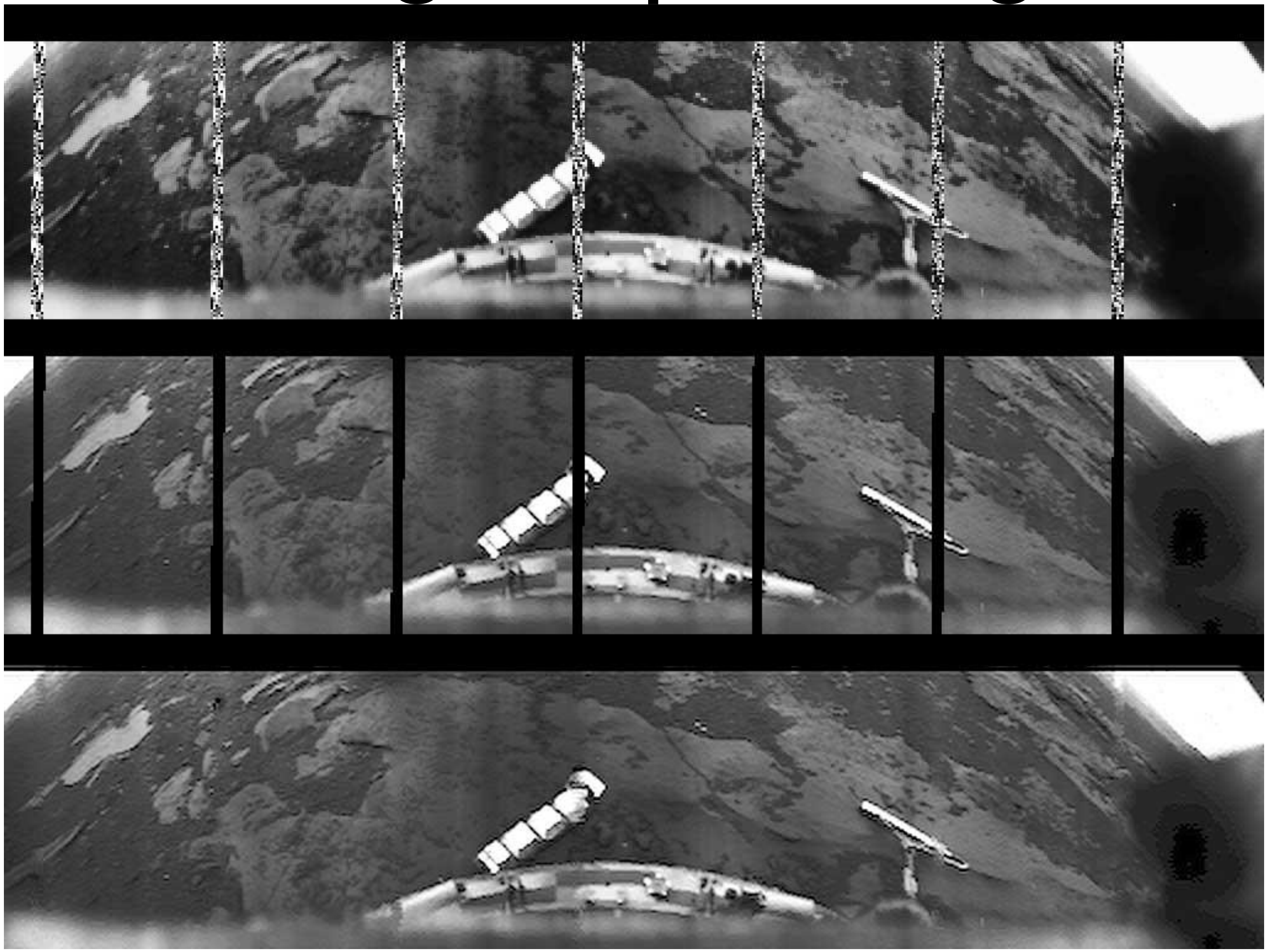
Image Denoising

Image Deblurring

Image Inpainting 1

Image Inpainting 2



Images of Venus taken by the Russian lander Ventra-10 in 1975

Image Histogram (Histogram Equalization)

- Histogram is the graphical representation of any data
- Histogram provide a global description of the appearance of an image. It is a spatial domain method.
- Histogram is the representation of relative frequency of occurrence of various grey levels of an image.
- Histogram equalization is used for image enhancement.
- Histogram can control the quality of image by normalizing the histogram values to a flat profile.

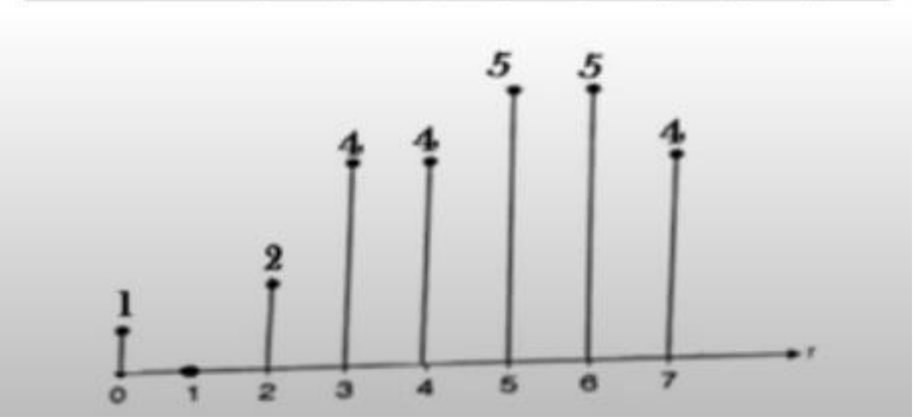
Image Histogram (Histogram Equalization)

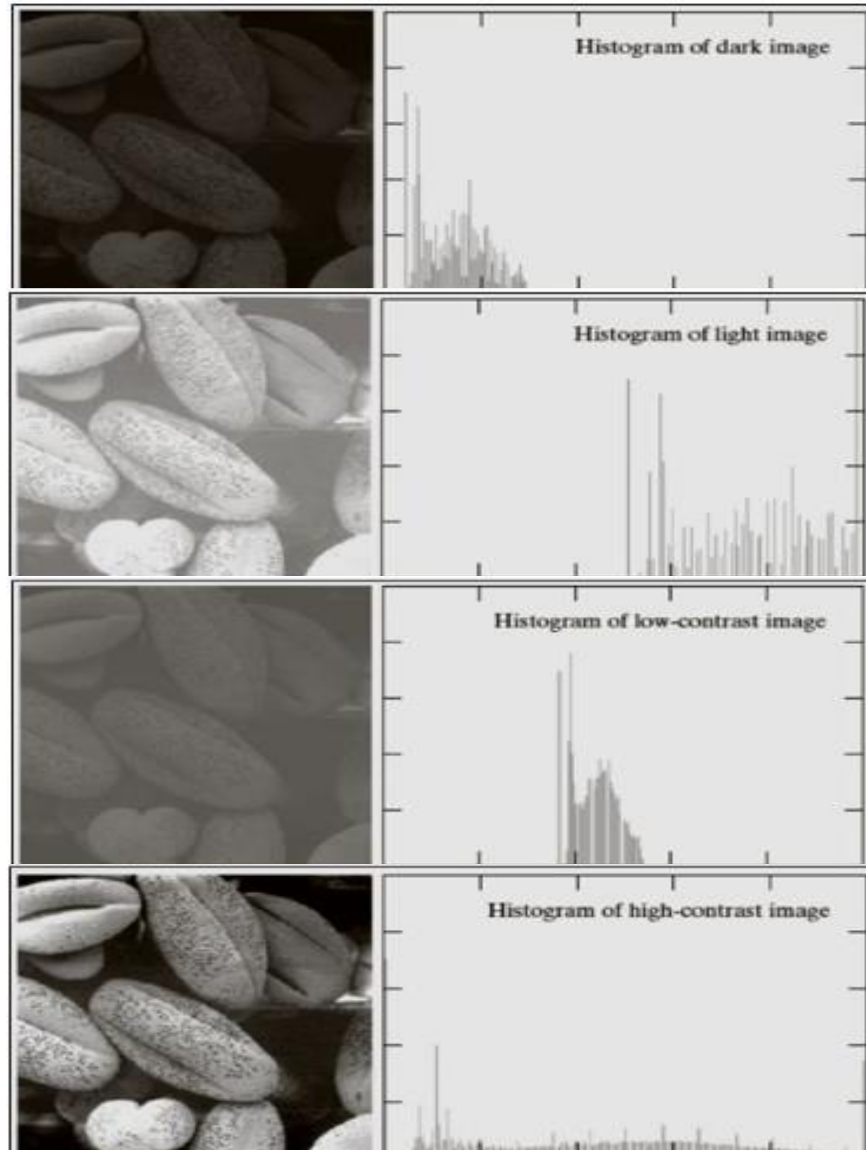
Image

Gray level

3	3	7	7	6
5	2	2	3	4
6	6	4	4	5
5	7	3	6	0
7	6	5	5	4

Gray levels	0	1	2	3	4	5	6	7
Frequency of occurance (no. of pixels)	1	0	2	4	4	5	5	4





Steps in Histogram Processing

Image

Gray level

3	3	7	7	6
5	2	2	3	4
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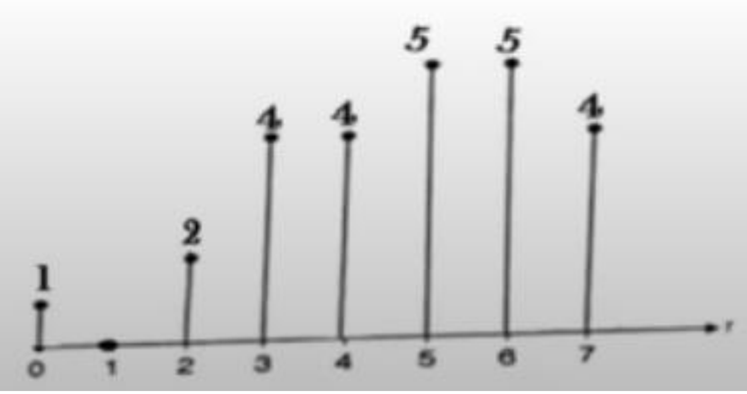

Step 1: Compute the frequency of occurrence and plot the original histogram (as shown beside)

8 bits representation - 1

why -1 it is in the formula (normalize)

Step 2: Perform histogram equalization

Grey level (Input pixel value)	Frequency, f_x	$PDF = \frac{f_x}{n}$	$CDF = \sum PDF$	$CDF \times 7$	Rounding off (New grey level)
0	1	0.04	0.04	0.28	0
1	0	0	0.04	0.28	0
2	2	0.08	0.12	0.84	1
3	4	0.16	0.28	1.96	2
4	4	0.16	0.44	3.08	3
5	5	0.2	0.64	4.48	4
6	5	0.2	0.84	5.88	6
7	4	0.16	1	7	7
	Total, $n = 25$				

ori	0	1	2	3	4	5	6	7
new	0	0	1	2	3	4	6	7

Steps in Histogram Processing

Image

Gray level

3	3	7	7	6
5	2	2	3	4
6	6	4	4	5
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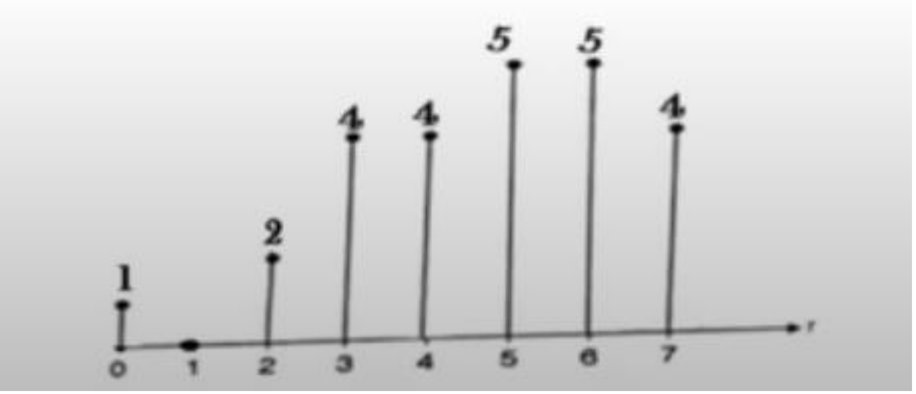

Step 2: Perform histogram equalization (From the previous table)

- PDF is obtained by dividing each frequency to the total
- CDF across the row is obtained by sum its corresponding PDF value and the previous CDF. For e.g., CDF at grey level 3 = PDF at grey level 3 + CDF at grey level 2 = 0.16+0.12 = 0.28
- Next, for CDF x 7, the no 7 is obtained by *L*-1, where *L* refers to 8 bits pixel. Hence *L*-1 = 8-1=7. By default, we use 7.
- Finally, round off the CDF x 7 to the corresponding integer.

Steps in Histogram Processing

Image

Gray level

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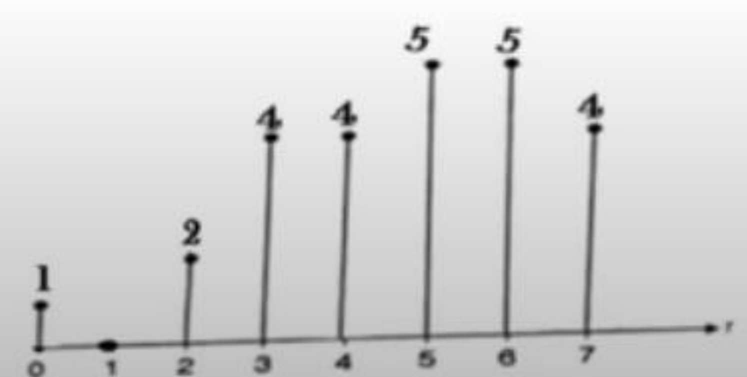
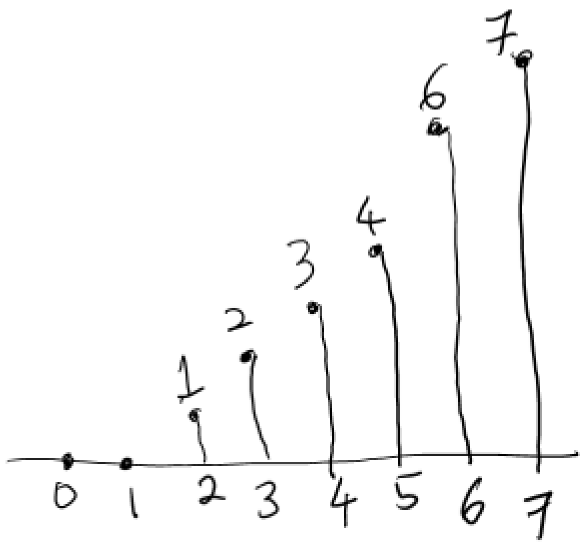


Step 3: New histogram table

Input	0	1	2	3	4	5	6	7
New	0	0	1	2	3	4	6	7

Step 4: Plot the graphical representation of the output image



Steps in Histogram Processing

Image

Gray level

3	3	7	7	6
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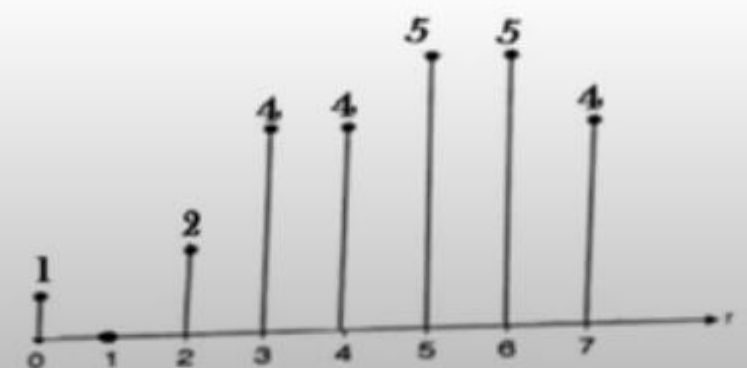


Step 4: Plot the graphical representation of the output image

Before histogram equalization:

3	3	7	7	6
5	2	2	3	4
6	6	4	4	5
5	7	3	6	0
7	6	5	5	4

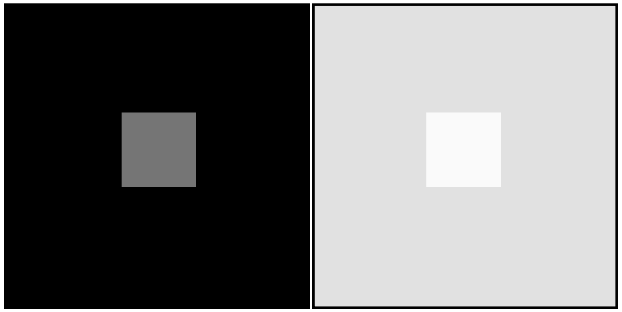
After histogram equalization:

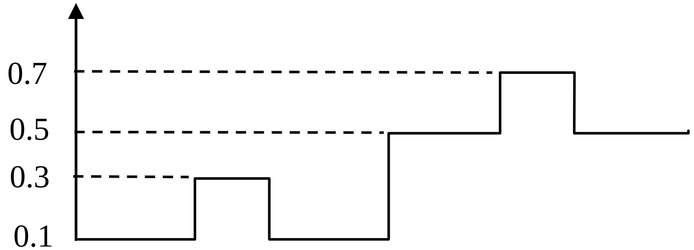
2	2	7	7	6
4	1	1	2	3
6	6	3	3	4
4	7	2	6	0
7	6	4	4	3

Image Contrast

- The **local** contrast at an image point denotes the (relative) difference between the intensity of the point and the intensity of its neighborhood:

$$C = \left| \frac{I_p - I_n}{I_n} \right|$$





$$C = \left| \frac{0.3 - 0.1}{0.1} \right| = 2$$

$$C = \left| \frac{0.7 - 0.5}{0.5} \right| = 0.4$$

- The contrast definition of the entire image is ambiguous
- In general it is said that the image contrast is high if the image gray-levels fill the entire range

Low contrast

High contrast

Adaptive Histogram

- In many cases histograms are needed for local areas in an image
- Examples:
  - Pattern detection
  - adaptive enhancement
  - adaptive thresholding
  - tracking

Histogram Usage

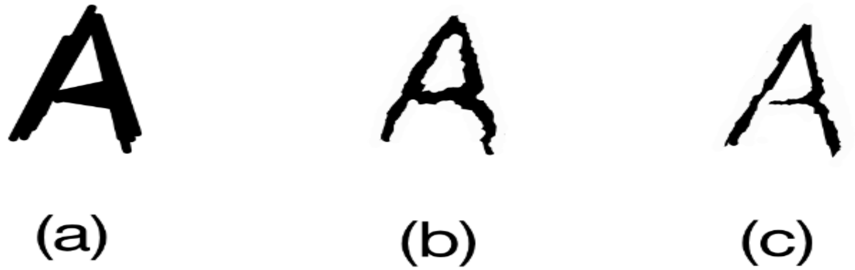
- Digitizing parameters
- Measuring image properties:
  - Average
  - Variance
  - Entropy
  - Contrast
  - Area (for a given gray-level range)
- Threshold selection
- Image distance
- Image Enhancement
  - Histogram equalization
  - Histogram stretching
  - Histogram matching

Morphological Image Processing

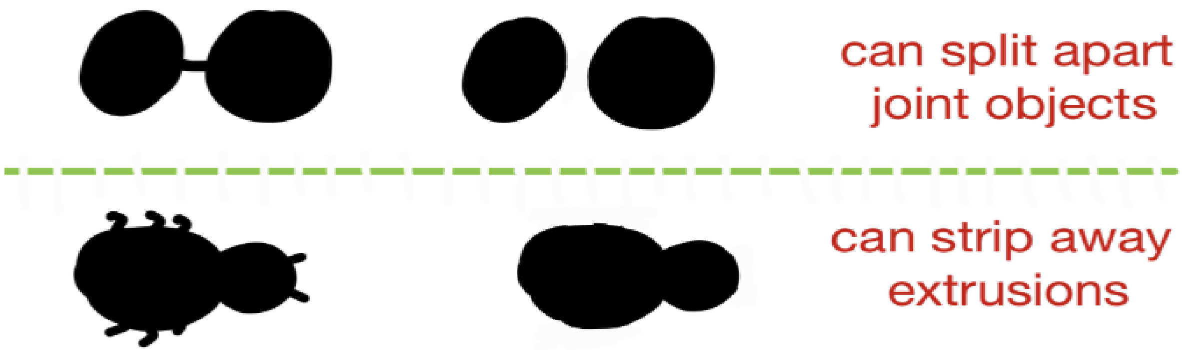
- Morphology is a comprehensive set of image processing operations that process image based on shape.
- Morphological operations apply a structuring element to an input image, creating an output image of the same size.
  - The value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors.

Morphological Image Processing

- Morphological operations
  - **Erosion**: shrinks the image pixels (remove the pixels on object boundaries.



  - Properties
    - ✓It can split apart joint objects
    - ✓It can strip away extrusions

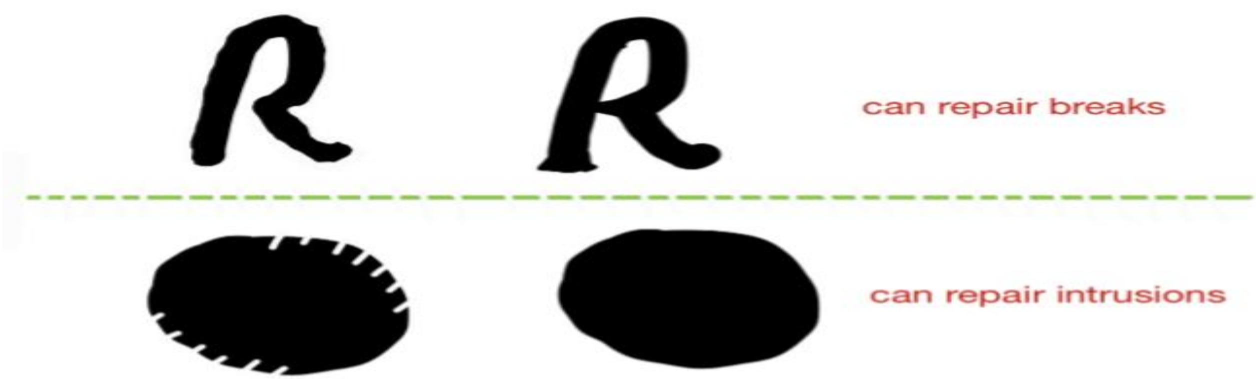


Morphological Image Processing

- Morphological operations
  - **Dilation**: expands the image pixels (add the pixels on object boundaries.

(a) (b) (c)

  - Properties
    - ✓It can repair breaks
    - ✓It can repair intrusions



Other Resources (Computation using R)

- Package “imager”: https://cran.r-project.org/web/packages/imager/imager.pdf
- Getting started with imager: https://cran.r-project.org/web/packages/imager/vignettes/gettingstarted.html
- Imager: an R package for image processing: https://dahtah.github.io/imager/imager.html
- Imager as image editor: https://dahtah.github.io/imager/gimptools.html
- Morphological operations in imager: https://dahtah.github.io/imager/morphology.html
- Pixsets: representing pixel sets in imager: https://cran.r-project.org/web/packages/imager/vignettes/pixsets.html
- Getting started with imagerExtra: https://cran.r-project.org/web/packages/imagerExtra/vignettes/gettingstarted.html

Appendix

```
library(imager)
file <- system.file('extdata/parrots.png',package='imager')
parrots <- load.image(file)
plot(parrots) #Parrots

rose <- load.image("Rose.png") #Load image
plot(rose) #Rose
save.image(rose,"Rose.jpeg") #save image

parrots.blurry <- isoblur(parrots,10) #Blurry parrots
parrots.xedges <- deriche(parrots,2,order=2,axis="x") #Edge detector along x-axis
parrots.yedges <- deriche(parrots,2,order=2,axis="y") #Edge detector along y-axis
gray.parrots <- grayscale(parrots) #Make grayscale
plot(gray.parrots)

#Denoising
birds <- load.image(system.file('extdata/Leonardo_Birds.jpg',package='imager'))
birds.noisy <- (birds + .5*rnorm(prod(dim(birds))))
layout(t(1:2))
plot(birds.noisy,main="Original")
isoblur(birds.noisy,5) %>% plot(main="Blurred")

plot(birds.noisy,main="Original")
blur_anisotropic(birds.noisy,ampl=1e3,sharp=.3) %>% plot(main="Blurred (anisotropic)")
```

Appendix

```
#Resize, rotate, ext.
thmb <- resize(parrots,round(width(parrots)/10),round(height(parrots)/10))
plot(thmb,main="Thumbnail") #Pixellated parrots

thmb <- resize(parrots,-10,-10)
imrotate(parrots,30) %>% plot(main="Rotating") #Rotate
imshift(parrots,40,20) %>% plot(main="Shifting") #Shift
imshift(parrots,100,100,boundary=2) %>% plot(main="Shifting (circular)") #Shift circular

#Histogram equalisations
plot(boats)
grayscale(boats) %>% hist(main="Luminance values in boats picture")
R(boats) %>% hist(main="Red channel values in boats picture")

library(ggplot2)
library(dplyr)
bdf <- as.data.frame(boats)
head(bdf,3)
bdf <- mutate(bdf,channel=factor(cc,labels=c('R','G','B')))
ggplot(bdf,aes(value,col=channel))+geom_histogram(bins=30)+facet_wrap(~ channel)
```

Appendix

```
#Normalizing
x <- rnorm(100)
layout(t(1:2))
hist(x,main="Histogram of x")
f <- ecdf(x)
hist(f(x),main="Histogram of ecdf(x)")

boats.g <- grayscale(boats)
f <- ecdf(boats.g)
plot(f,main="Empirical CDF of luminance values")
f(boats.g) %>% hist(main="Transformed luminance values")
f(boats.g) %>% str
f(boats.g) %>% as.cimg(dim=dim(boats.g)) %>% plot(main="With histogram equalisation")

#Morphological operations
im <- load.example("birds")
plot(im)

im.g <- grayscale(im)
plot(im.g)

layout(t(1:3))
threshold(im.g,"20%") %>% plot
threshold(im.g,"15%") %>% plot
threshold(im.g,"10%")
```