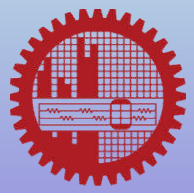
CSE6706:
Advanced Digital Image Processing

Dr. Md. Monirul Islam



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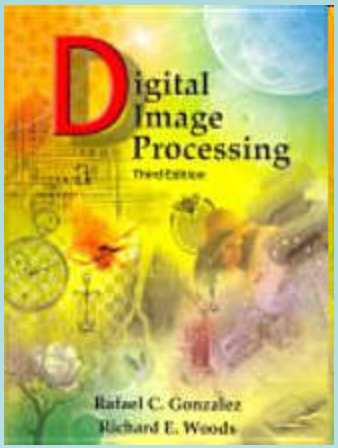
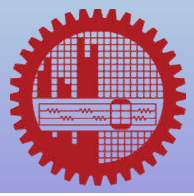
Reference Book

- Digital Image Processing, *3rd Edition*
  - Gonzalez and Woods





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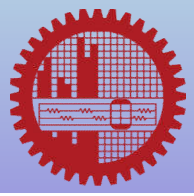
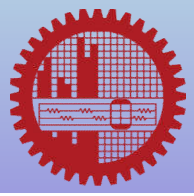
Grading

- Attendance : 15%
- Midterm 1 : 15%
- Midterm 2 : 15%
- Final Exam : 30%
- Project : 25%
  - Paper Presentation : 10%
  - Project Implementation : 15%



Presentation Outline

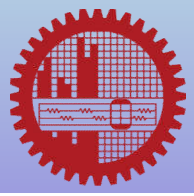
- Importance of *digital image processing*
- Major areas
- Image processing basics
- Selected areas – principles and issues



Origin of DIP

Crossing the Atlantic, 1921

From London to New York



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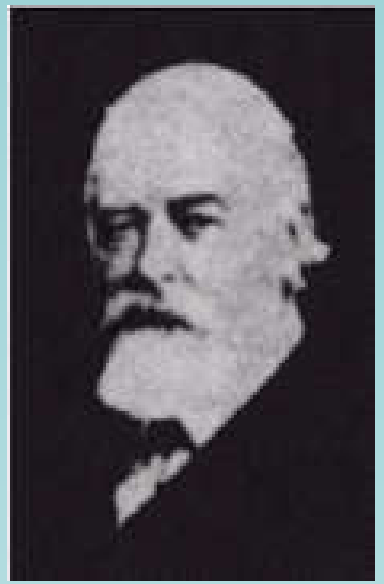
Origin of DIP



1922

1929

Crossing the Atlantic

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Origin of DIP: Scientific Research

***First picture** of the **moon**, 1964*
taken by** spacecraft **Ranger 7

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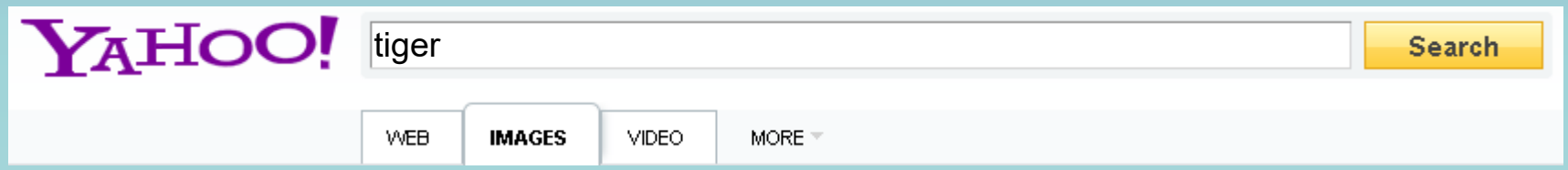
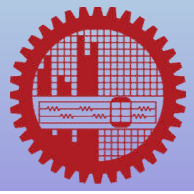
Why we need DIP





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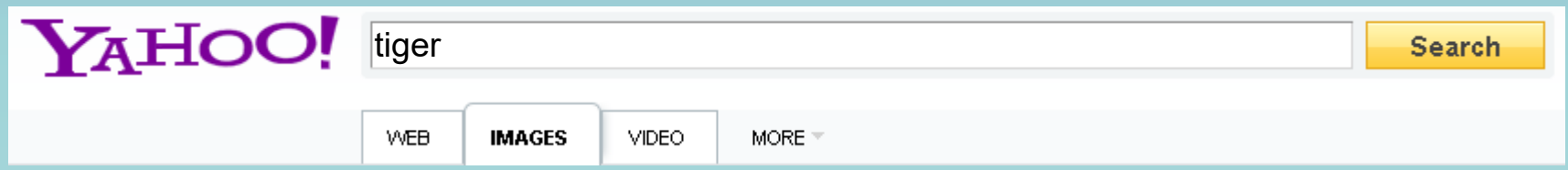

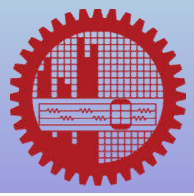

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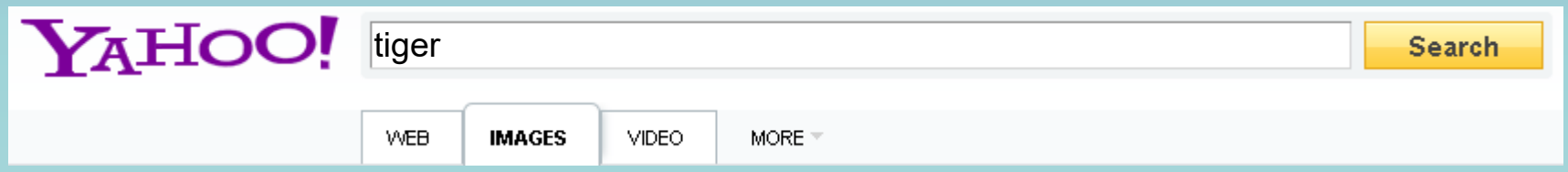

Tiger Woods makes his second ...

Tiger beetle

Tiger Lilly

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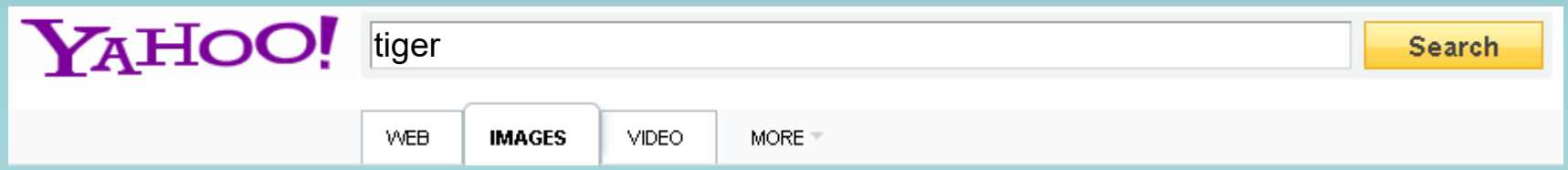
Why we need DIP



- uses only file name or text descriptions
- does not look at the image content

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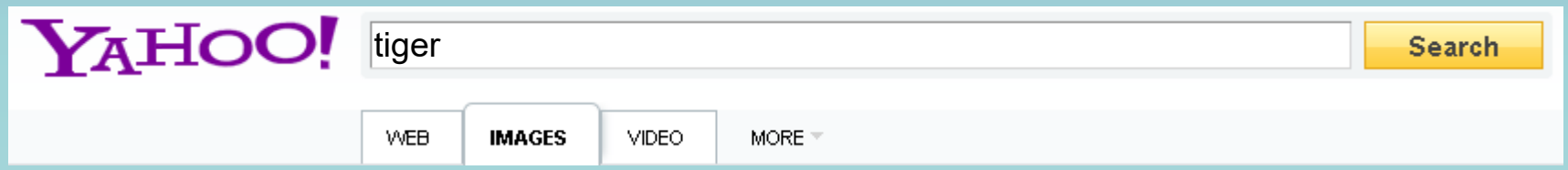
Why we need DIP



- Results might be different, if we could
  - use DIP to extract *image features*
  - let the machine learn the features and understand the images

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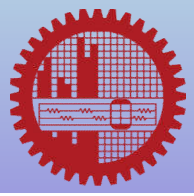
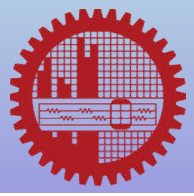
Why we need DIP

- DIP is not limited to image retrieval (IR)
- A large number of other areas:
  - Core area
  - Application area



DIP Research Area

- Core area
  - Image enhancement
  - Image de-noising
  - Image segmentation
  - Image & video retrieval
  - Image Security
    - watermarking and registration
  - Image compression



DIP Research Area

- Application area
  - Security and surveillance
    - Biometric application: face, iris, finger print, palm print recognition . . .
  - Medical imaging
    - automatic scanning and detection: X-ray, CT, MRI, PET, angiogram, ECG, echo, endoscopy, ….
  - Document Analysis/Classification/Preservation
    - Character recognition
  - Object and shape recognition
  - Intelligent transport system
  - Environmental monitoring and remote sensing
  - and, so on, . . .

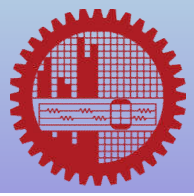
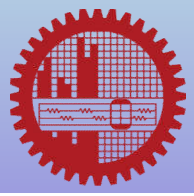


Image Processing Basics



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What is an Image/Digital Image

A sample benchmark image

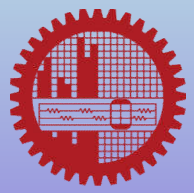
What is an Image/Digital Image

Let us start with a gray scale image

What is an Image/Digital Image

A gray scale image

A matrix
OR
2 D function



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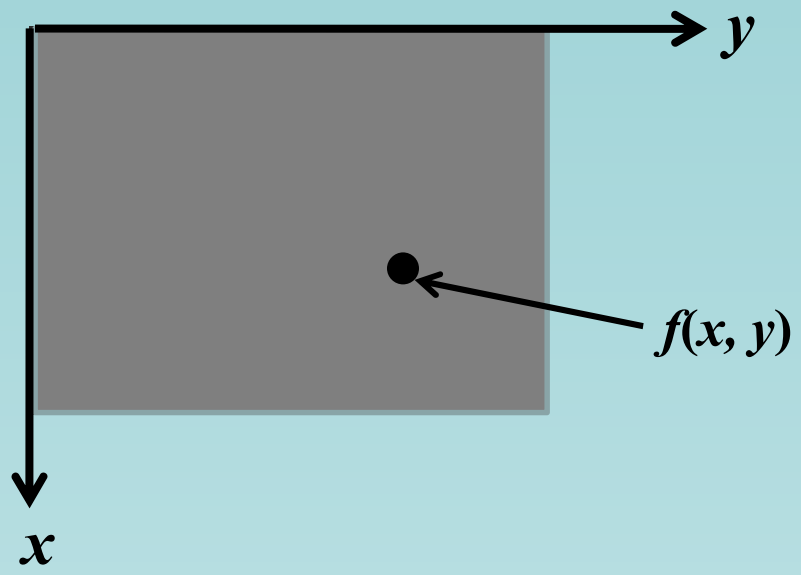
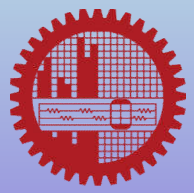
What is an Image/Digital Image

A gray scale image

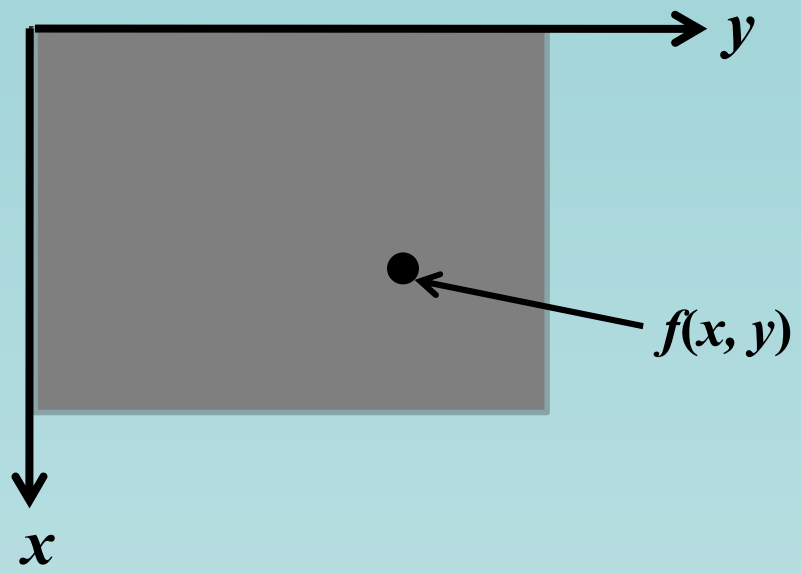


- 2 attributes:
  - A location (x, y): picture element, pixel, pel, etc
  - A value $f(x, y)$ at pixel (x, y): gray scale value

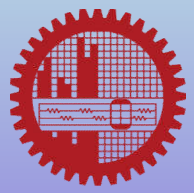


What is an Image/Digital Image

A gray scale image

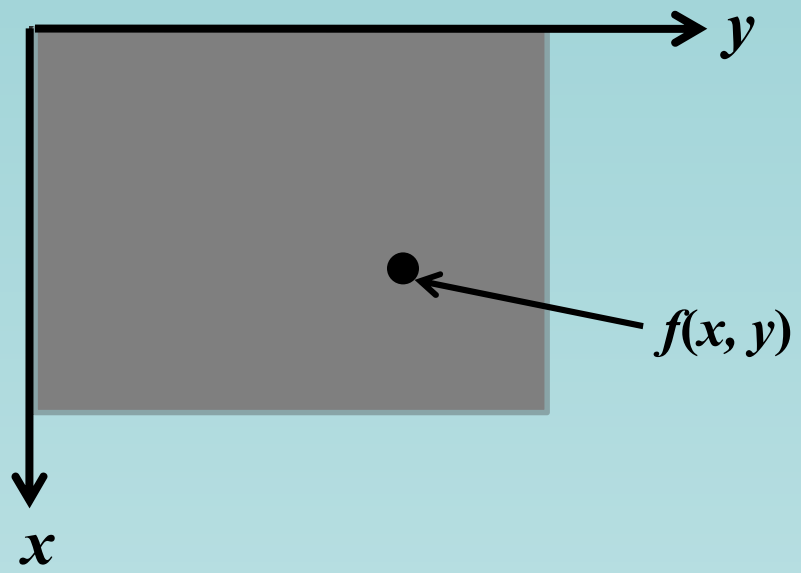


– $f(x, y)$ can take any value from 0.0 (black) to 1.0 (white)

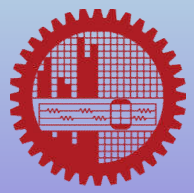


What is an Image/Digital Image

A gray scale image

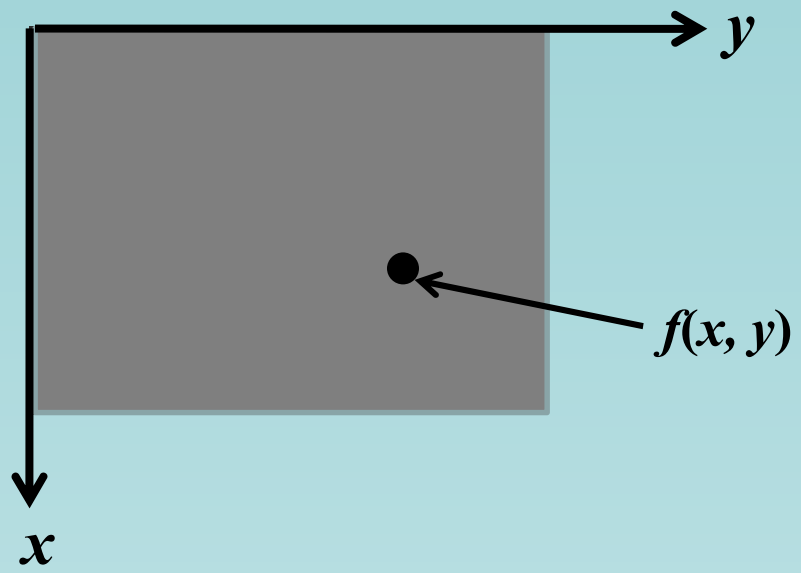


– Similarly: x and y can take any real numbers

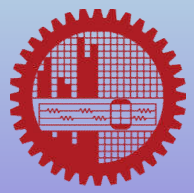


What is a Digital Image

A gray scale image



– In a digital image, $f(x, y)$ can take only discrete values



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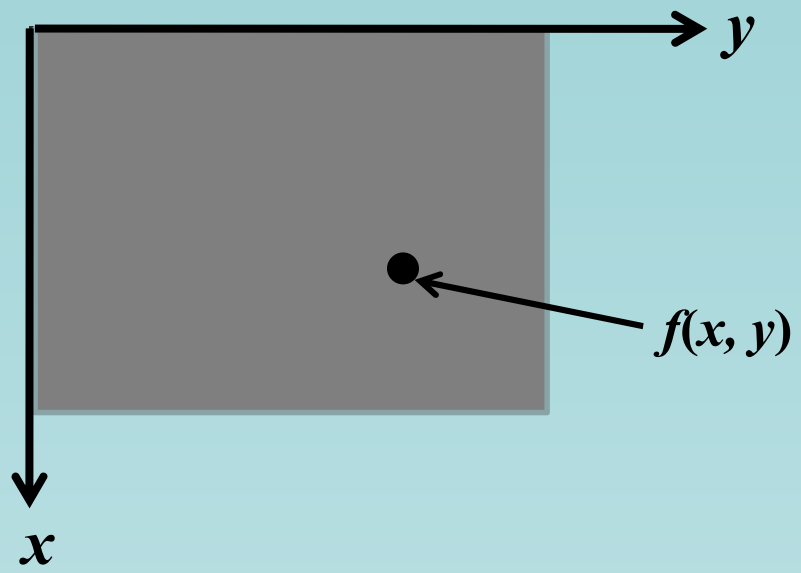
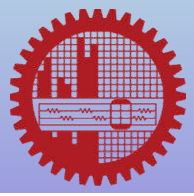
What is a Digital Image

A gray scale image

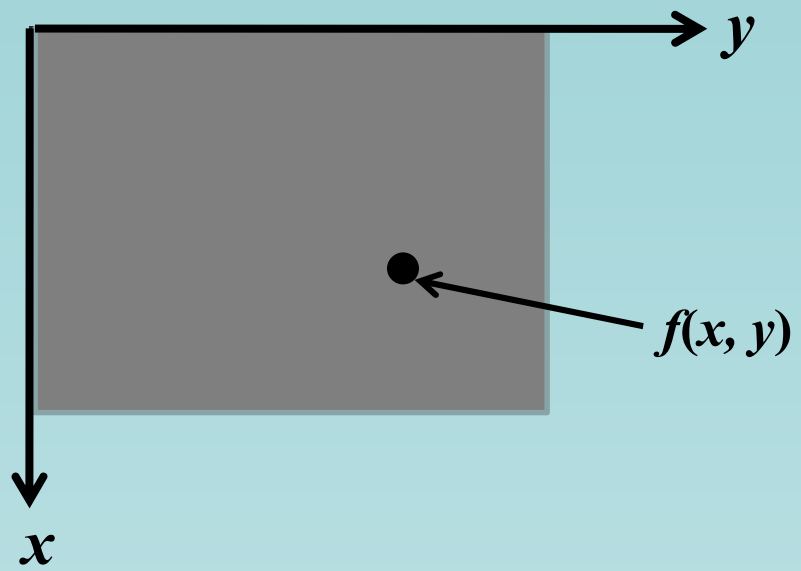


– Similarly: pixels' locations (x, y) are also discrete



What is a Digital Image

A gray scale image



- Digital image means
  - pixels' locations (x, y) are discrete
  - gray level values $f(x,y)$ are also discrete

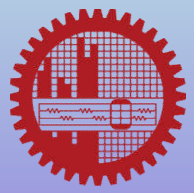
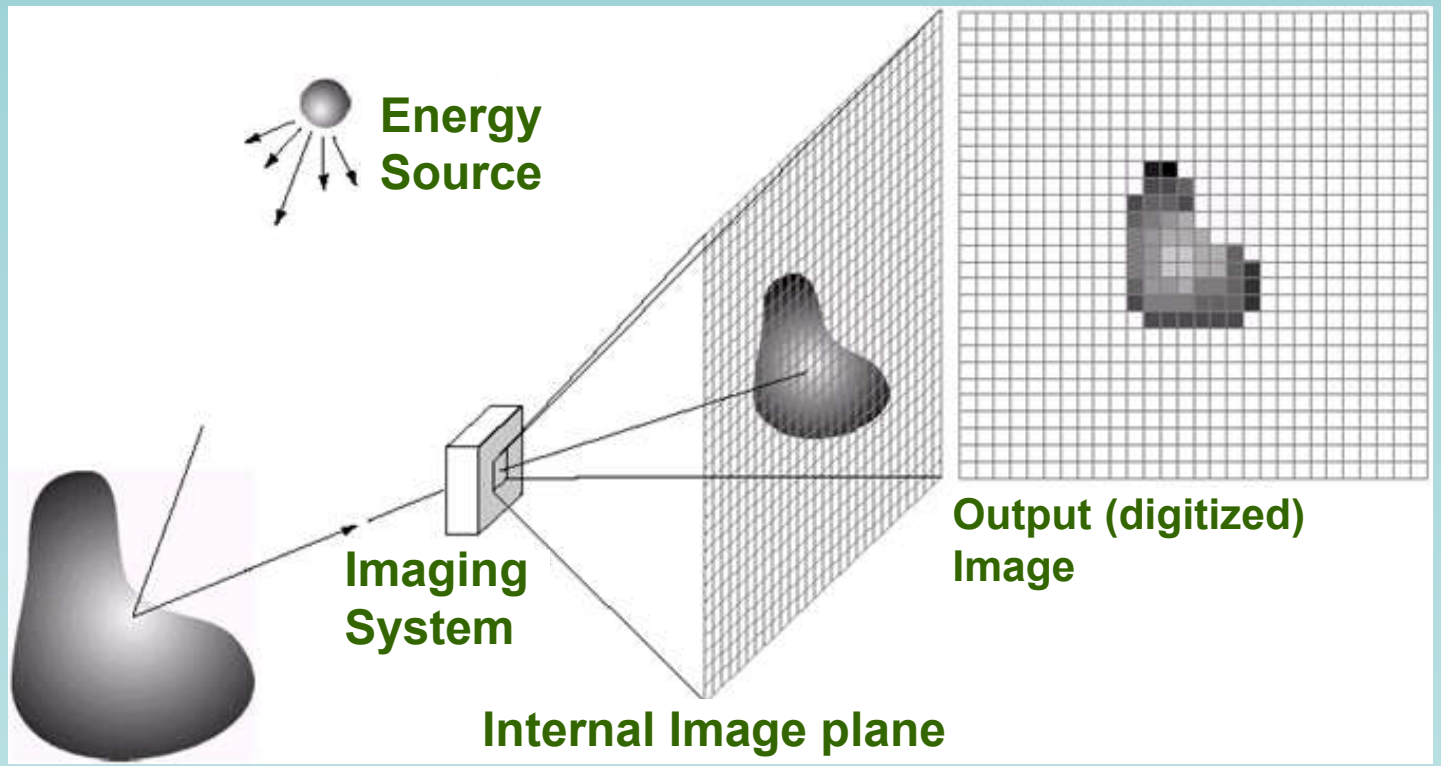
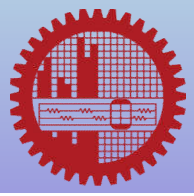


Image Acquisition and Digitization





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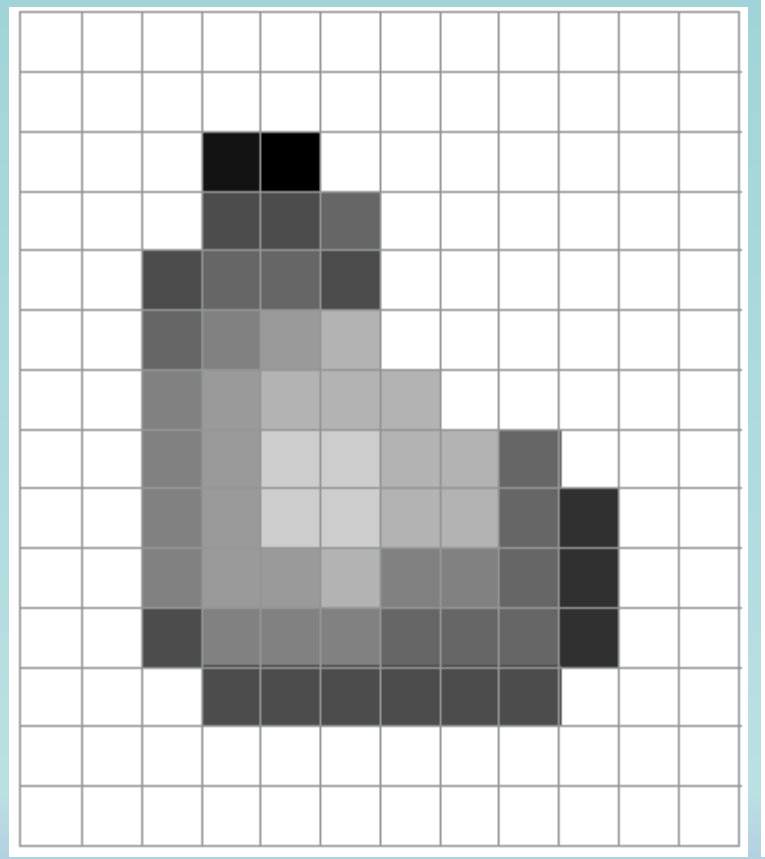
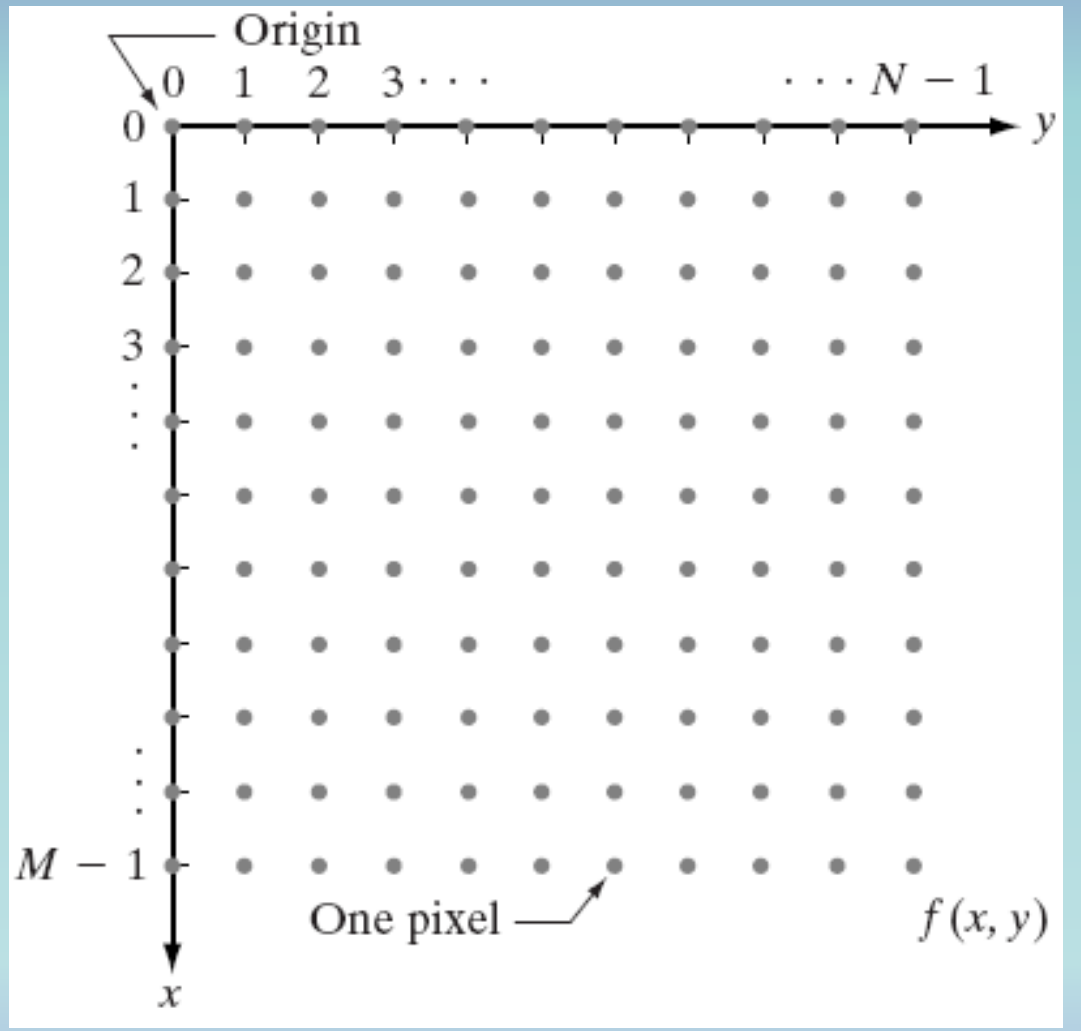
Representation of Digital Image





Matrix Representation

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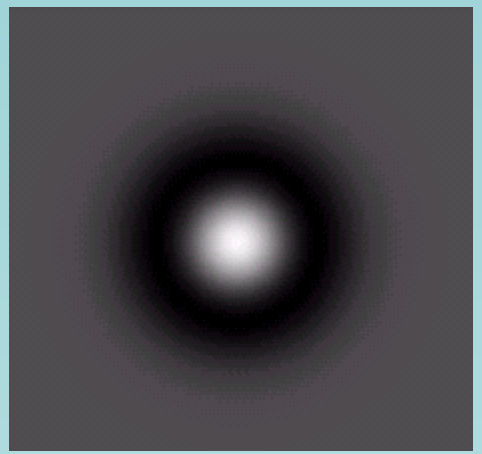
Digital Image from Matrix

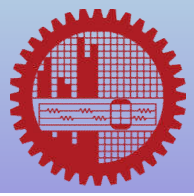
0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0



A matrix

An imaige

Any matrix can be visualized as an image



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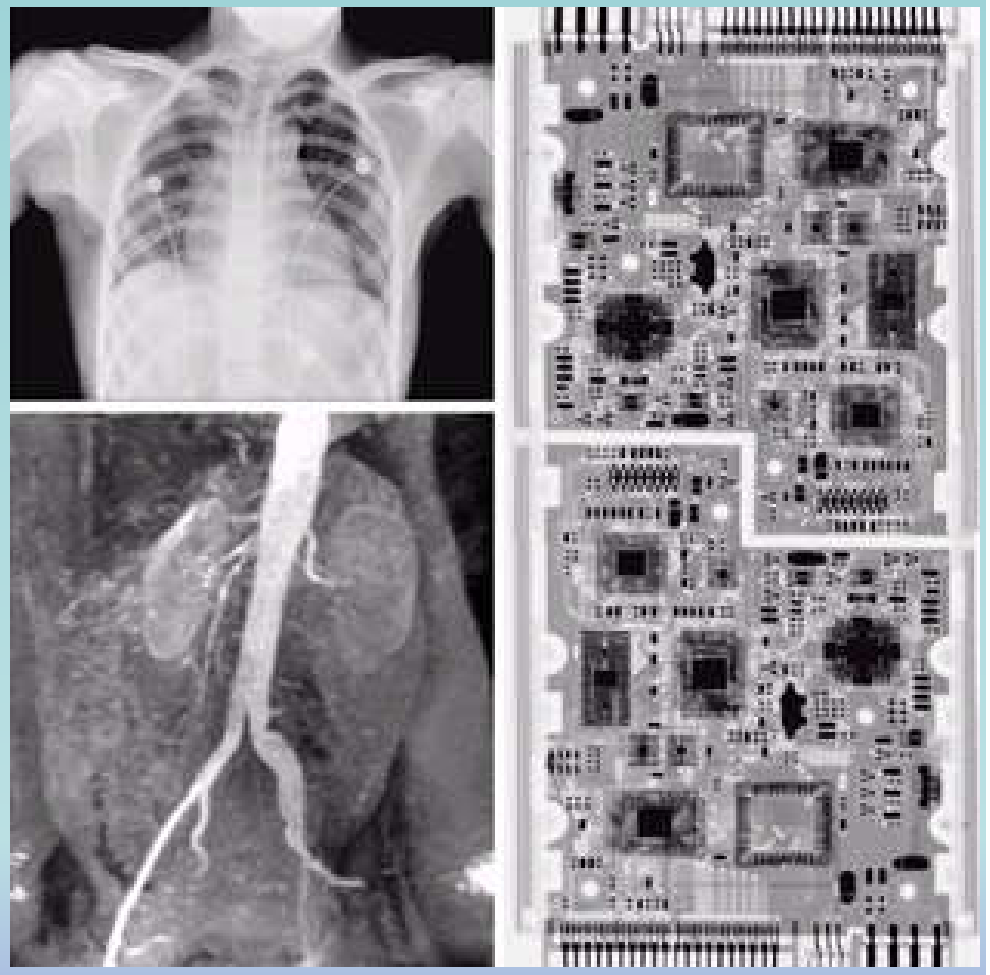
Images from Non-Visible EM Band: X-Ray Imaging

- Too many uses
  - Medical diagnostic
  - Security
  - Factory inspection, etc
- Digitization:
  - Scanning
  - Direct method
    - guiding x-ray to an x-ray-sensor



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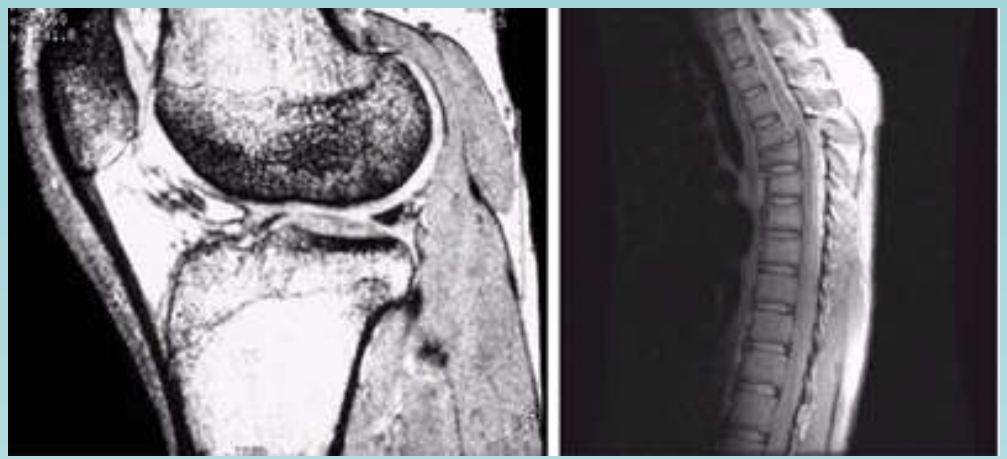
Images from Non-Visible EM Band: Imaging in Radio Band

- MRI
  - Patient is placed in a strong magnetic place
  - Radio wave passes through body



Images from Non-Visible EM Band:
Ultrasound

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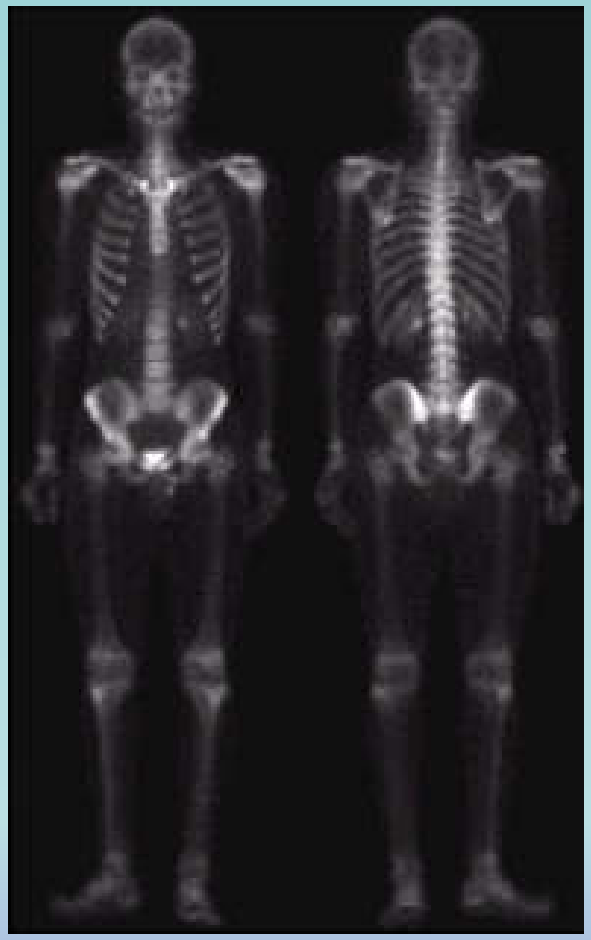
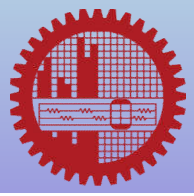
Images from Non-Visible EM Band: Gamma Ray Imaging

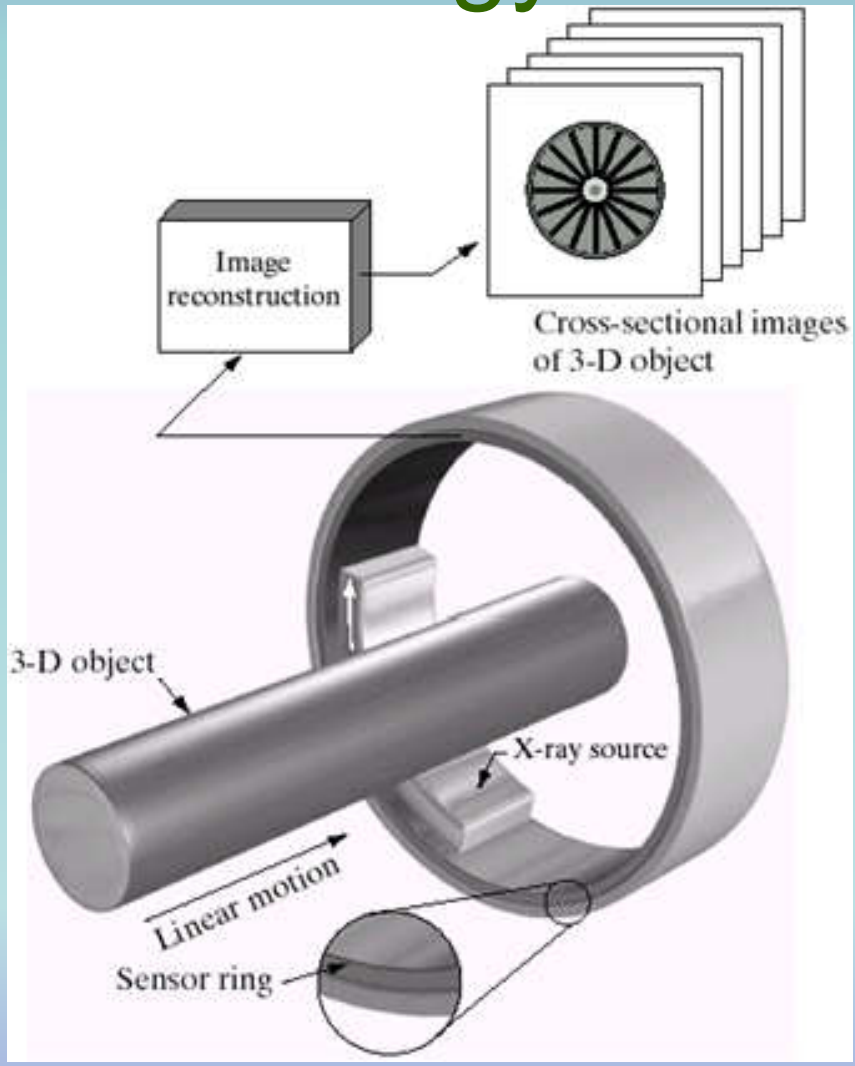
- Main difference:
  - Inject radio-active element into body
  - Radiations collected by gamma ray detectors





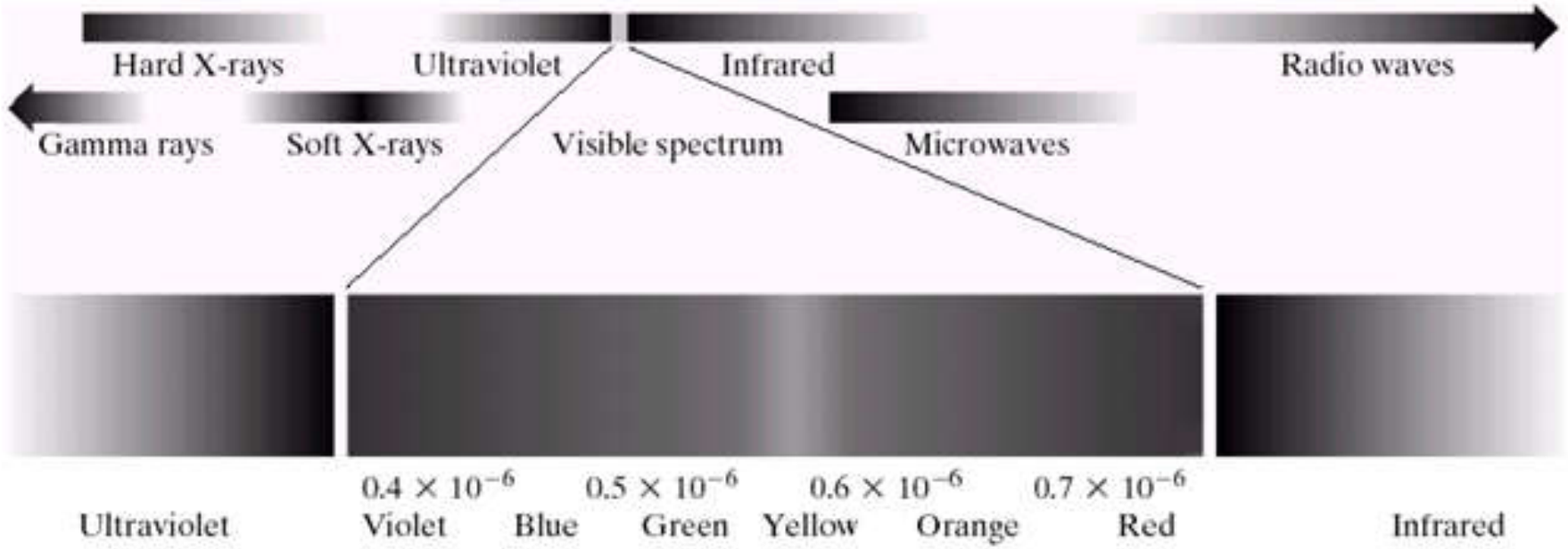
Images from Reconstruction: CT, CAT, PET Technology

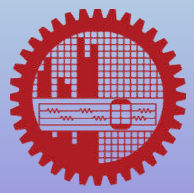
- These have similar arrangements
- CAT, CT:
  - Uses external X-ray source
- PET:
  - injected radioactive element works as an energy source



Images from Reconstruction: Illumination Source

- Each energy band can produce images





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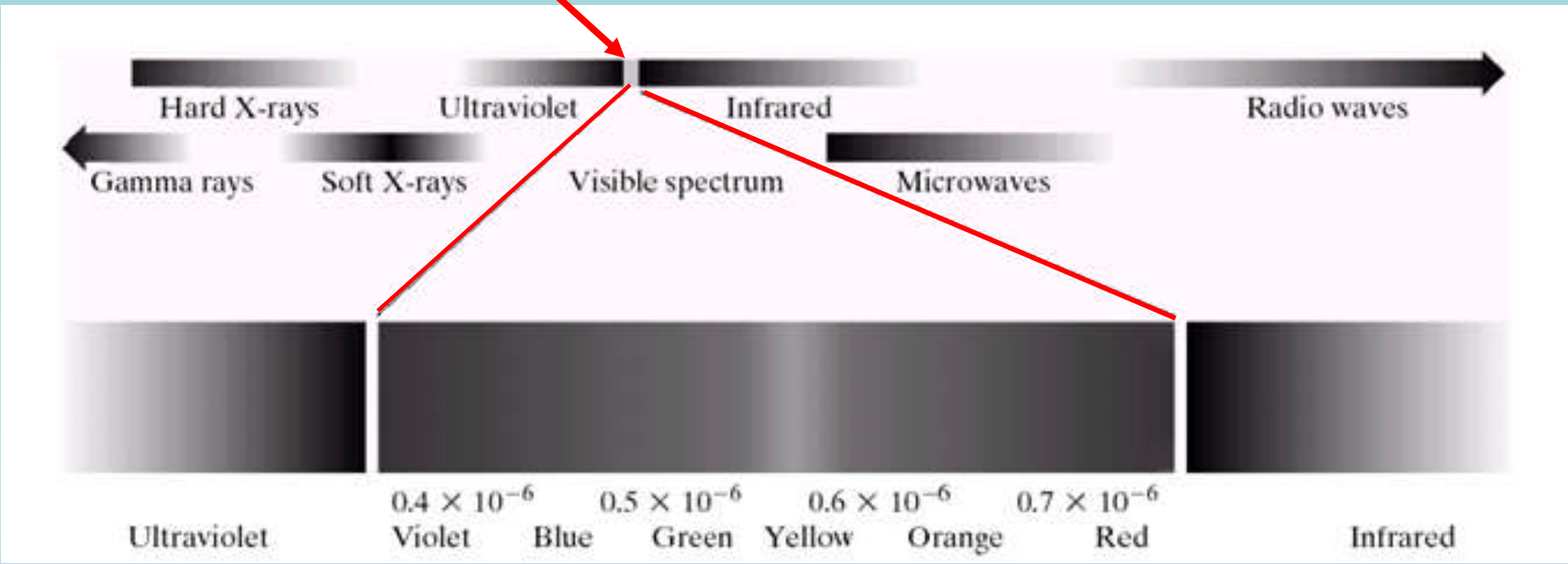
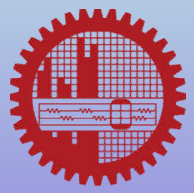
Images from Reconstruction: Illumination Source

- Each energy band can produce images
- Human *can see* only in the visible spectrum





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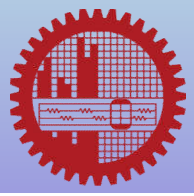
Digital Image Processing

– processing of *digital images* using *digital devices* (*computers*)



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Scope of DIP

– Is it DIP?

Find avg. gray value

0.67

Scope of DIP

- 3 levels of DIP
  - Low level
    - Input/Output: both are images
    - Example: Enhancement, sharpening, blurring, de-noising
  - Mid level:
    - Input: image
    - Output: object, regions
    - Example: Image segmentation
  - High level:
    - Input: image
    - Output: class labels
    - Example: Recognition, classification, etc

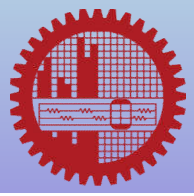

Image Enhancement

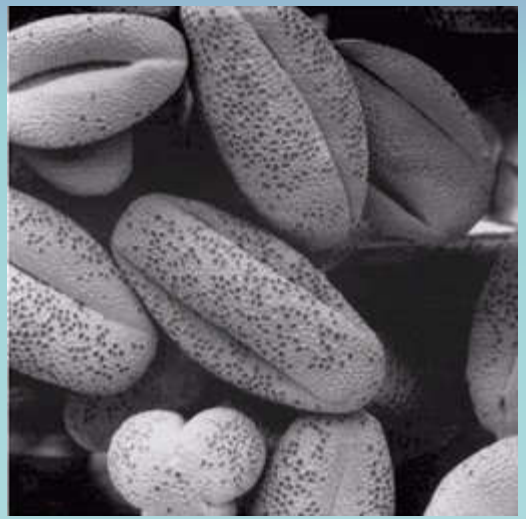

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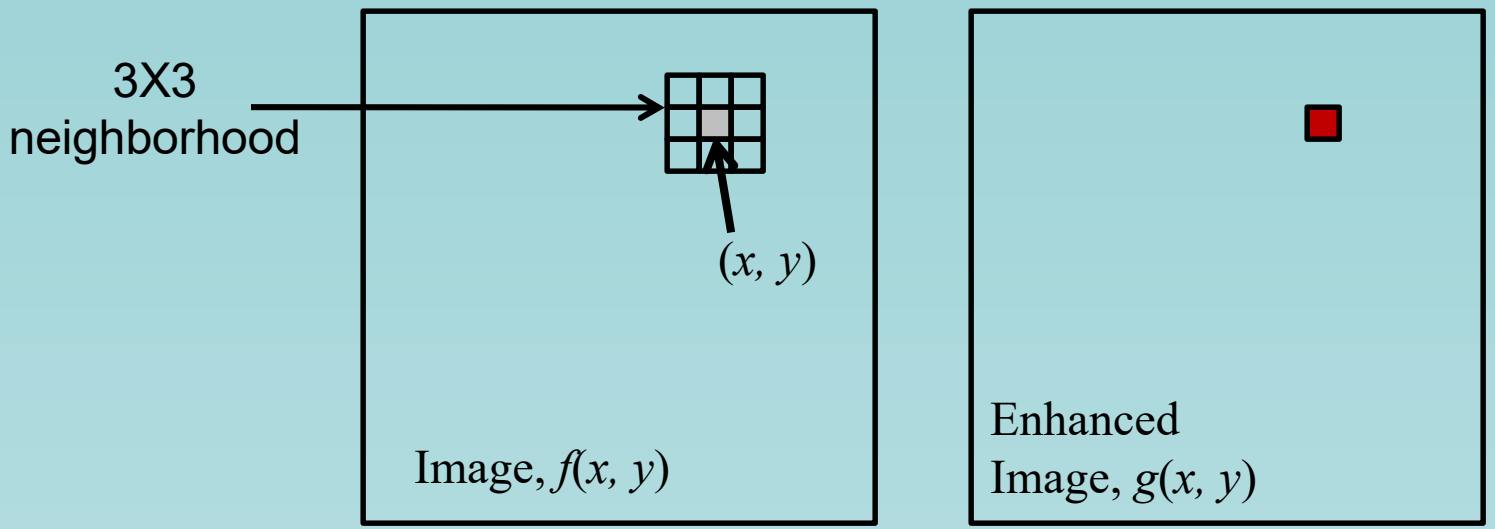
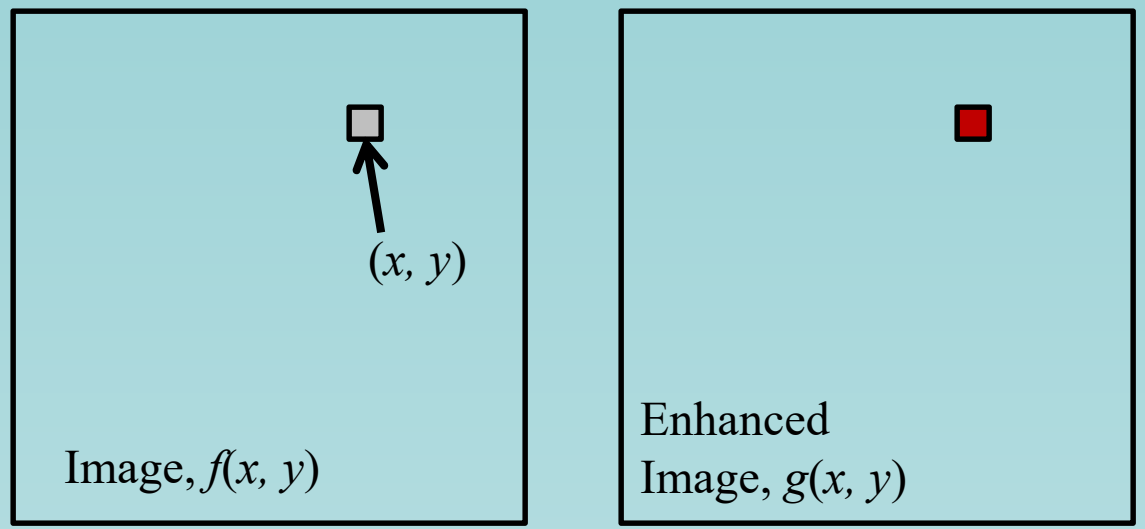
Image Enhancement



$$g(x,y) = T\left[f(x,y)\right]$$

Image Enhancement



$r = f(x, y)$ $s = g(x, y)$

– Neighborhood can be as small as 1X1 sub-image

$$s = T(r)$$

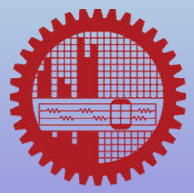


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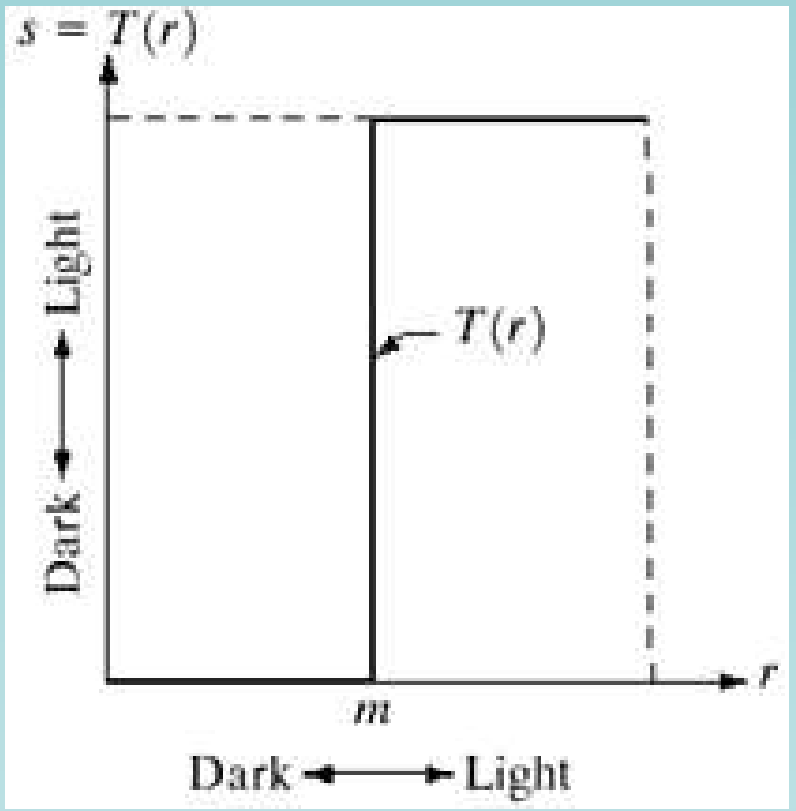
Image Enhancement: Thresholding



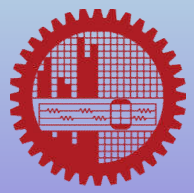


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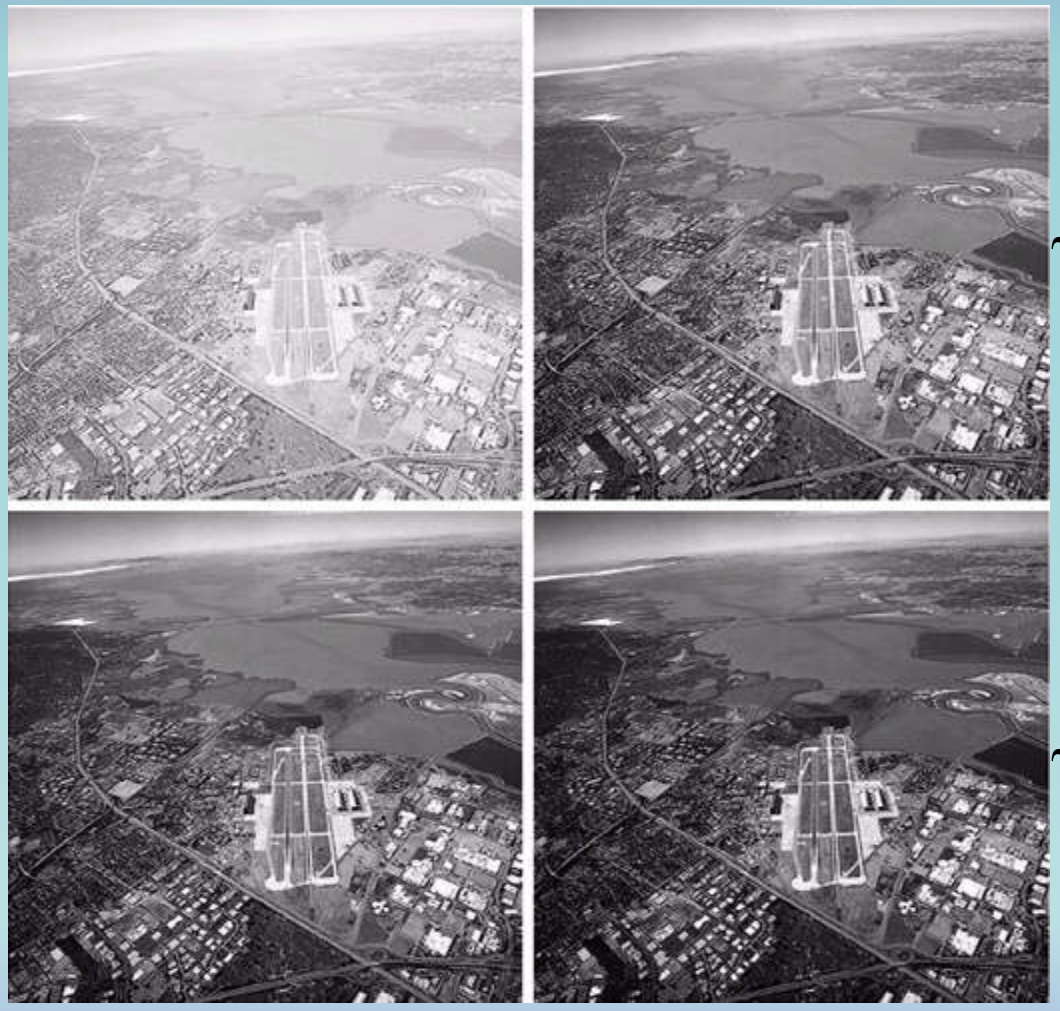
Image Enhancement

Power Law Transform:

$$s = cr^{\gamma}$$



γ= 3

γ= 4

γ= 5

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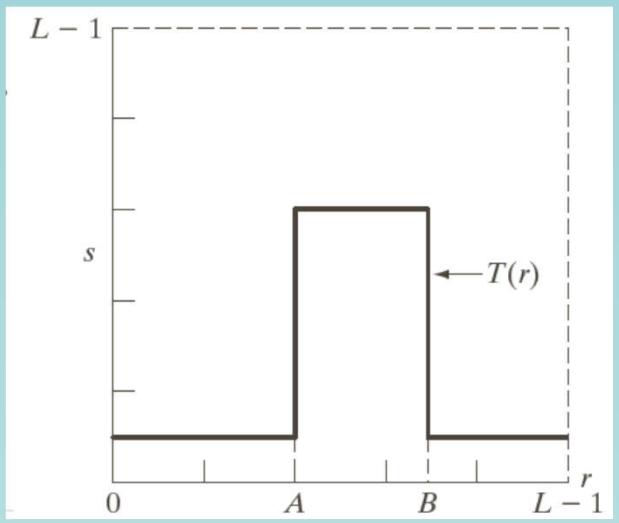
Image Enhancement Application: Segment out Region of Interest

Original Image



Transformation function

Enhanced image

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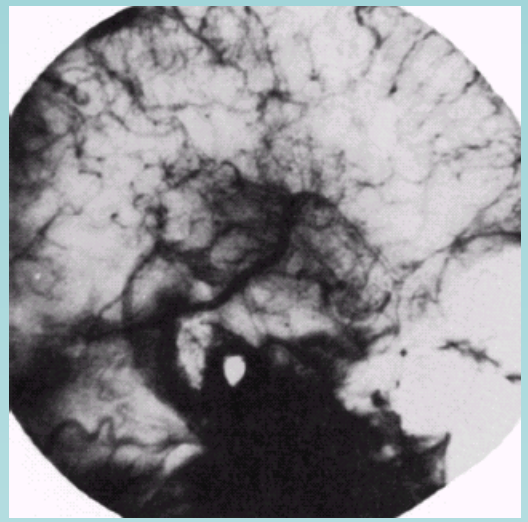
Image Enhancement Application: Medical Diagnostic

- *Mask mode radiography*
  - The first picture is used as mask
  - Contrast medium injected into blood stream



Area under investigation

also used as mask image

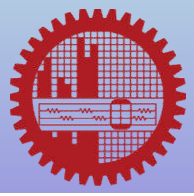
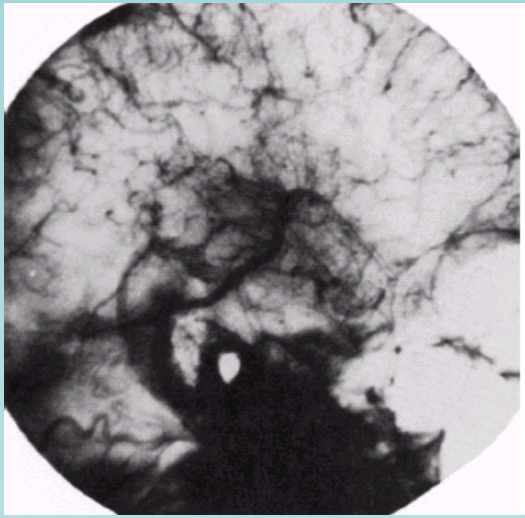
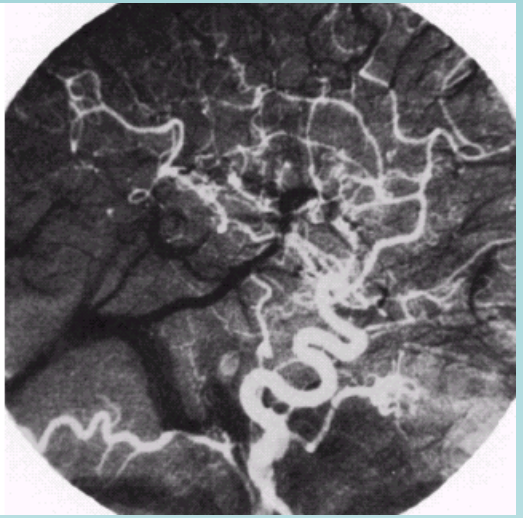


Image Enhancement Application: Medical Diagnostic

- contrast medium goes through blood vessels
- The mask is subtracted from each subsequent photograph

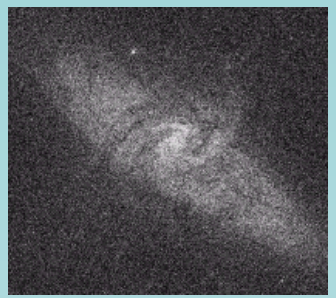


mask image



A single diff. image. Along with other shots, it appears as a video

Image Enhancement Application: Space Research



Noisy image

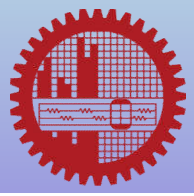


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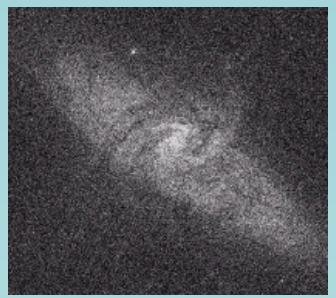
Image Enhancement Application: Space Research



Noisy image

$$\bar{g}(x,y) = \frac{1}{K}\sum_{i=1}^{K} g_i(x,y)$$

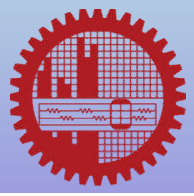


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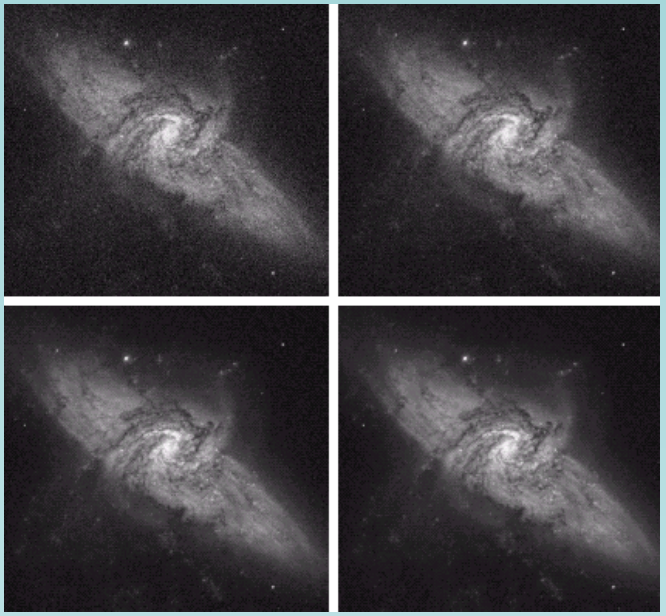
Image Enhancement Application: Space Research

Enhanced by averaging

From 8 images



From 16 images

From 64 images

From128 images

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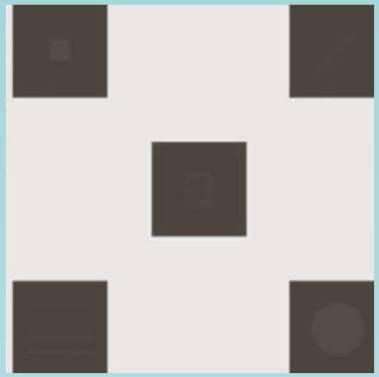
Image Enhancement Application: Steganography



A plain image

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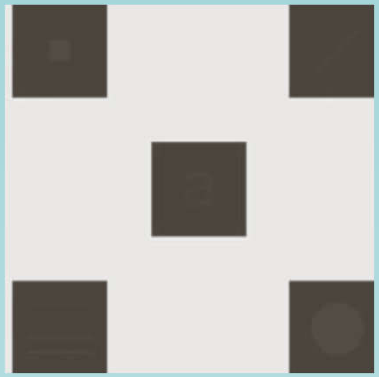
Image Enhancement Application: Steganography



A plain image

Message decrypted using histogram equalization

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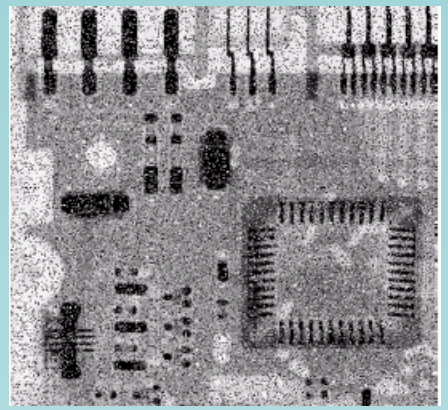
Image Enhancement Application : De-noising



Noisy image

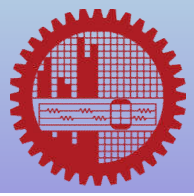


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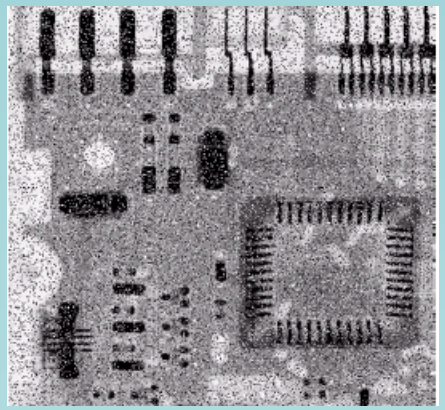
Image Enhancement Application : De-noising



Noisy image

- Replace each pixel's value by the median of its neighbors

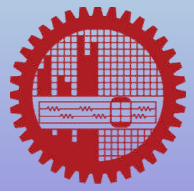


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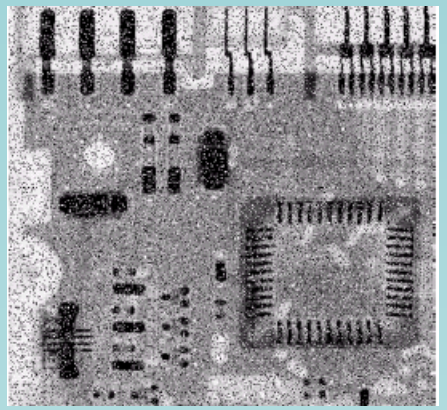
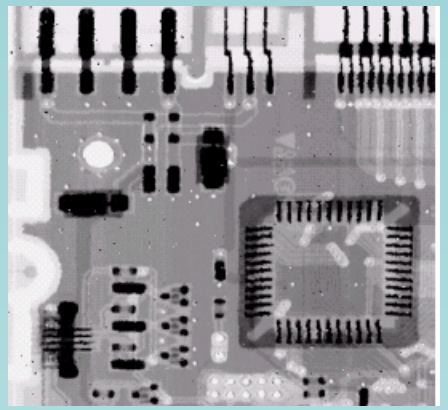
Image Enhancement Application : De-noising



Noisy image



Noise reduction
by median filter

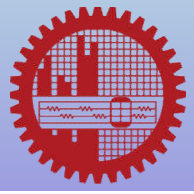


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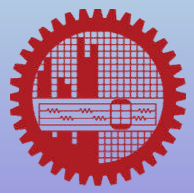
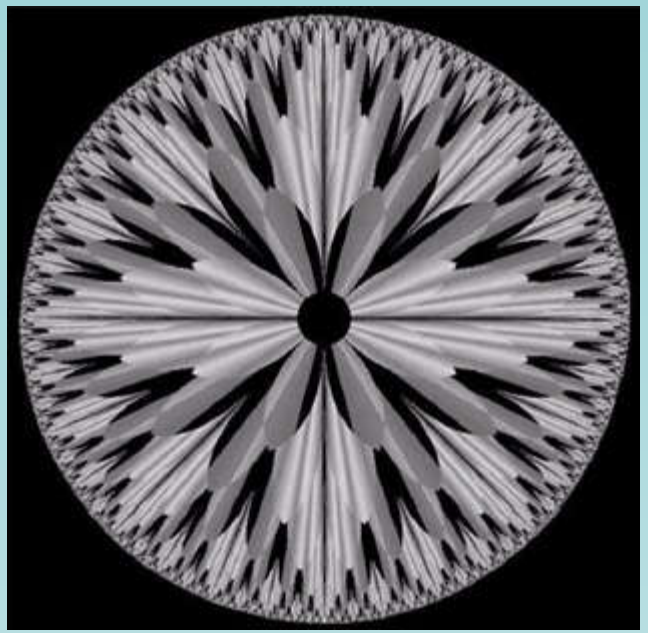
Image Compression

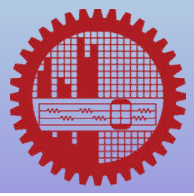
- Objectives: minimize
  - *Coding redundancy*
  - *Spatial and temporal redundancy*
  - *Irrelevant information*



Compression using Bit-Plane Slicing



Example Image



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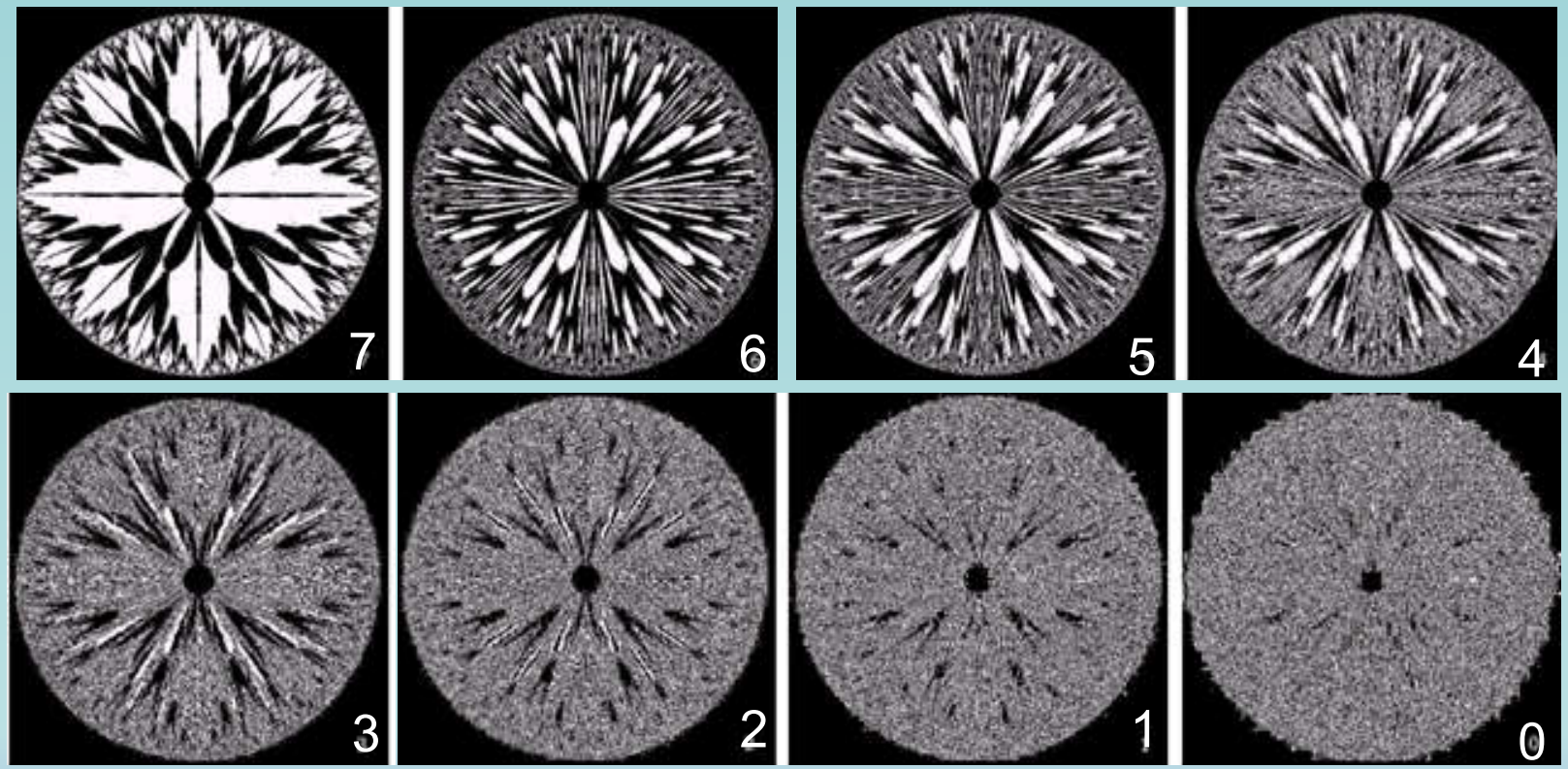
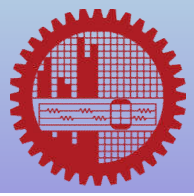
Compression using Bit-Plane Slicing

Contribution of individual bits





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Compression using Bit-Plane Slicing

Contribution of individual bits

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Compression using Bit-Plane Slicing

Reconstructed Images from fewer bits

Using bit 6 and 7 Using bit 5, 6 and 7 Using bit 4, 5, 6 and 7

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Compression using Bit-Plane Slicing

Reconstructed Images from fewer bits

Using bit 6 and 7 | Using bit 5, 6 and 7 | Using bit 4, 5, 6 and 7

- Most 4 significant bits are enough

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Compression using Bit-Plane Slicing

Image Reconstruction from fewer bits

Be careful

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Compression using Bit-Plane Slicing

Reconstructed Image from fewer bits

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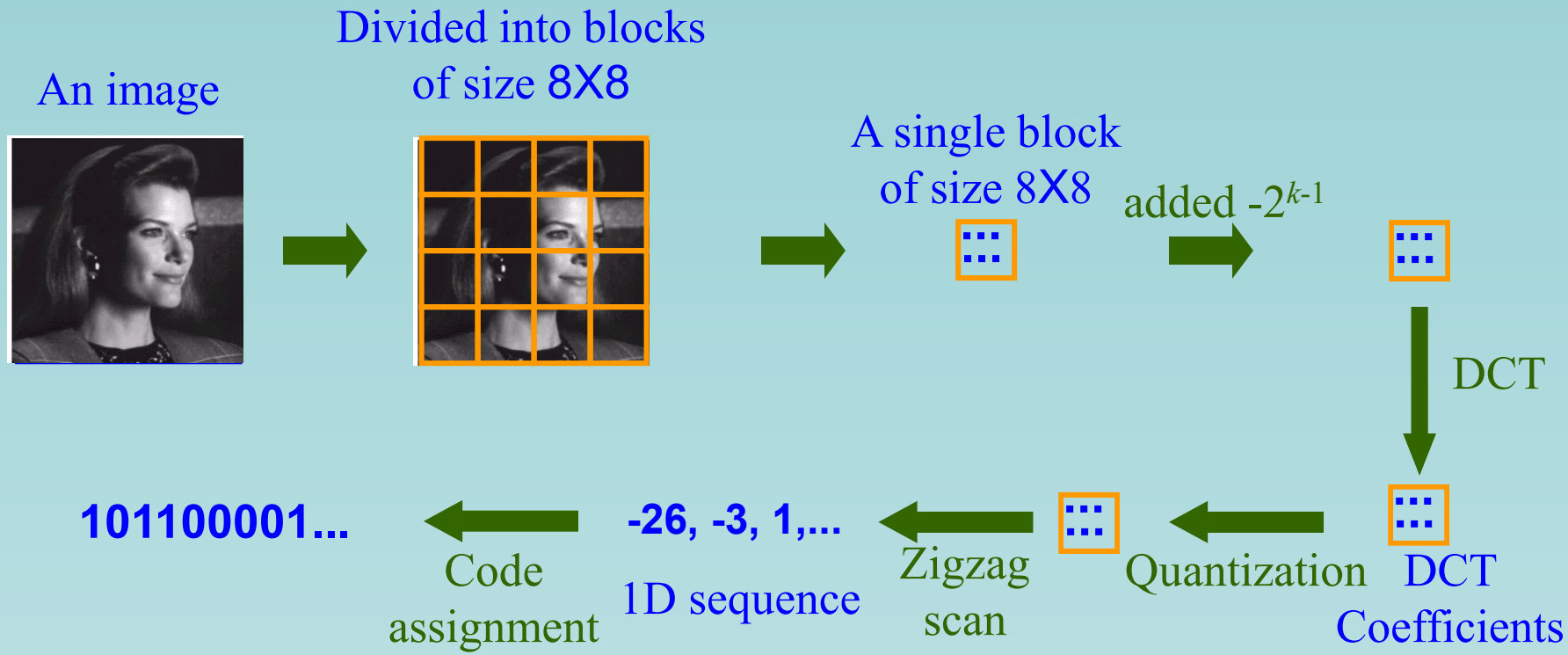
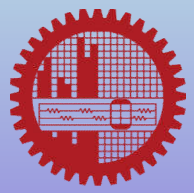
JPEG Compression





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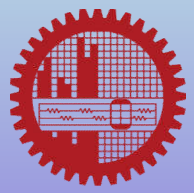
JPEG Compression

$$\hat{T}(u,v) = \text{round}\left[\frac{T(u,v)}{Z(u,v)}\right]$$

A typical **Z** matrix

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99



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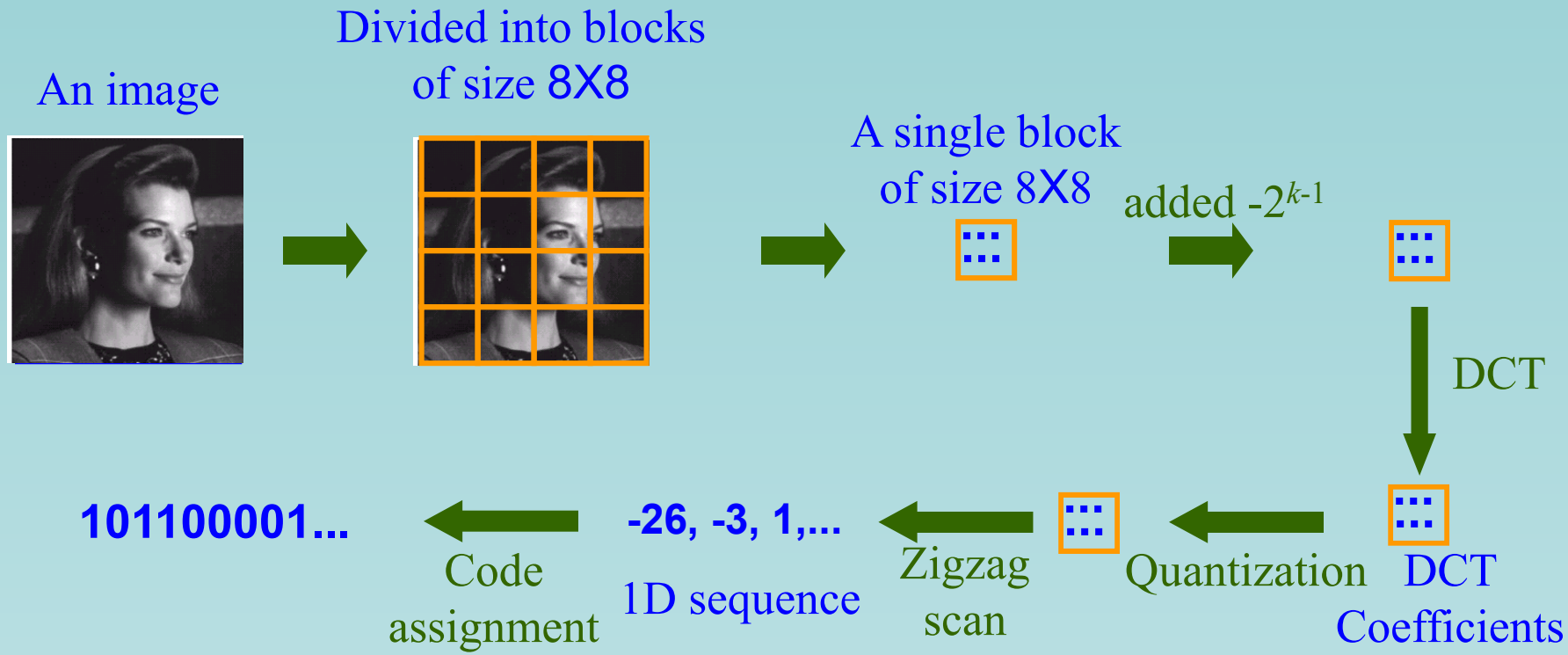
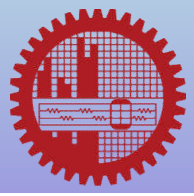
JPEG Compression





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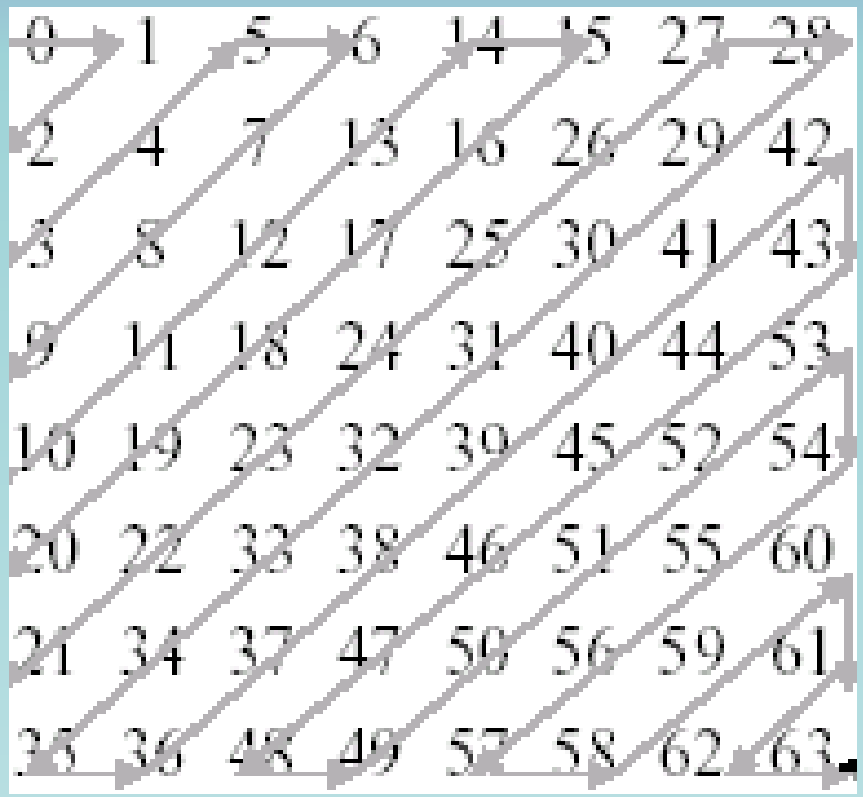
JPEG Compression

−26	−3	−6	2	2	0	0	0
1	−2	−4	0	0	0	0	0
−3	1	5	−1	−1	0	0	0
−4	1	2	−1	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Quantized Coefficients values of the first block



Zigzag scan sequence

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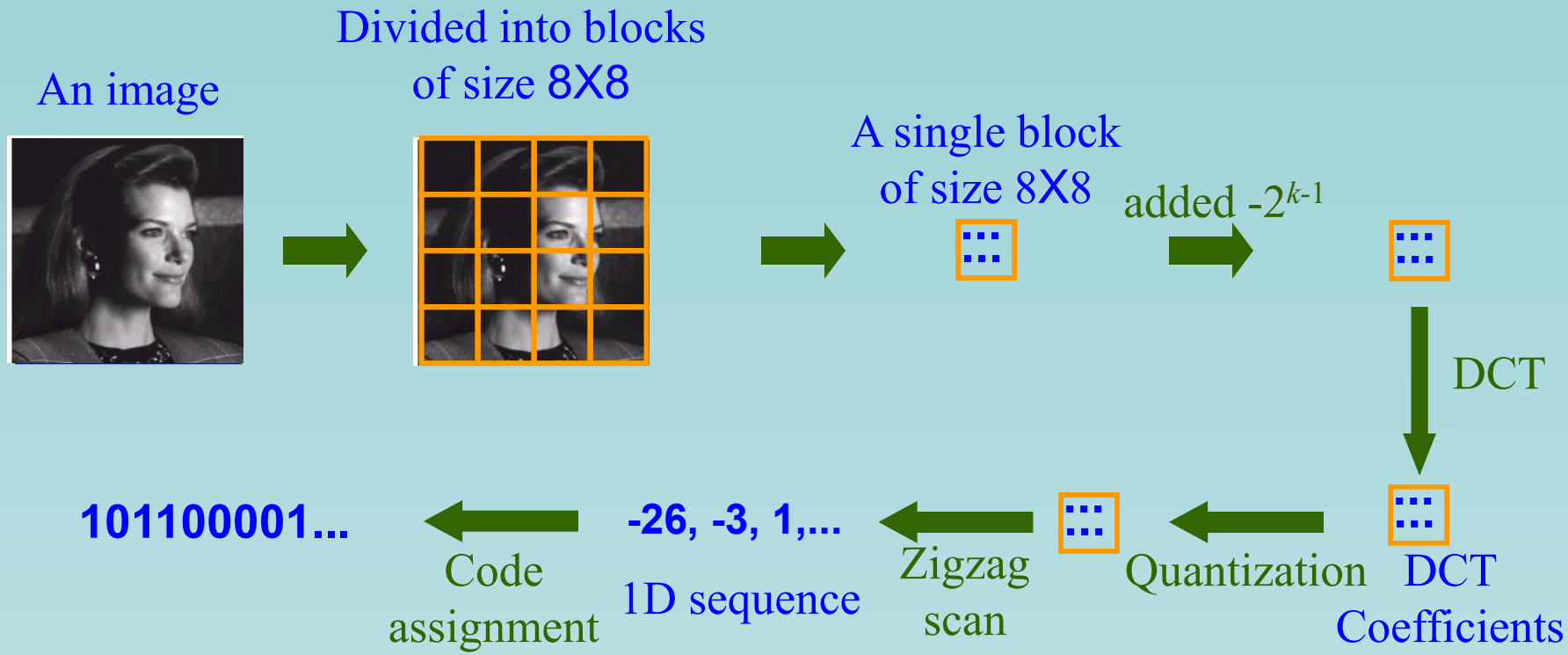
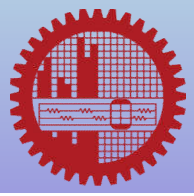
JPEG Compression





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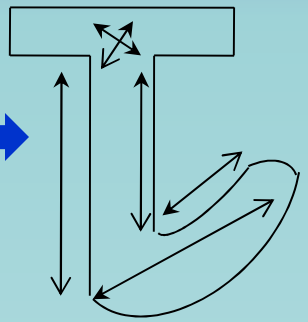
Recognition: LPR, OCR

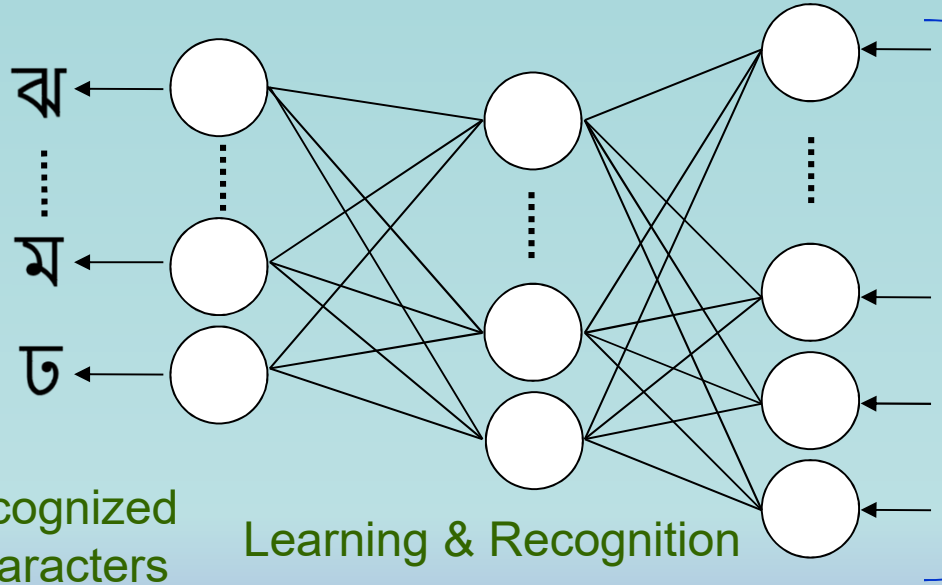
Vehicle Image

LP Area Extraction

Separate Lines and Characters

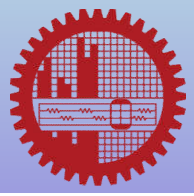


Feature Extraction



Recognized Characters

Learning & Recognition



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Recognition: LPR, OCR

- Issues
  - Variable illumination
  - Slanted/distorted image
  - Hazardous conditions
    - Fog, rain, darkness
  - Overlaps between lines and characters

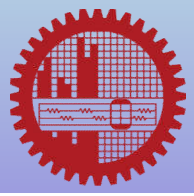
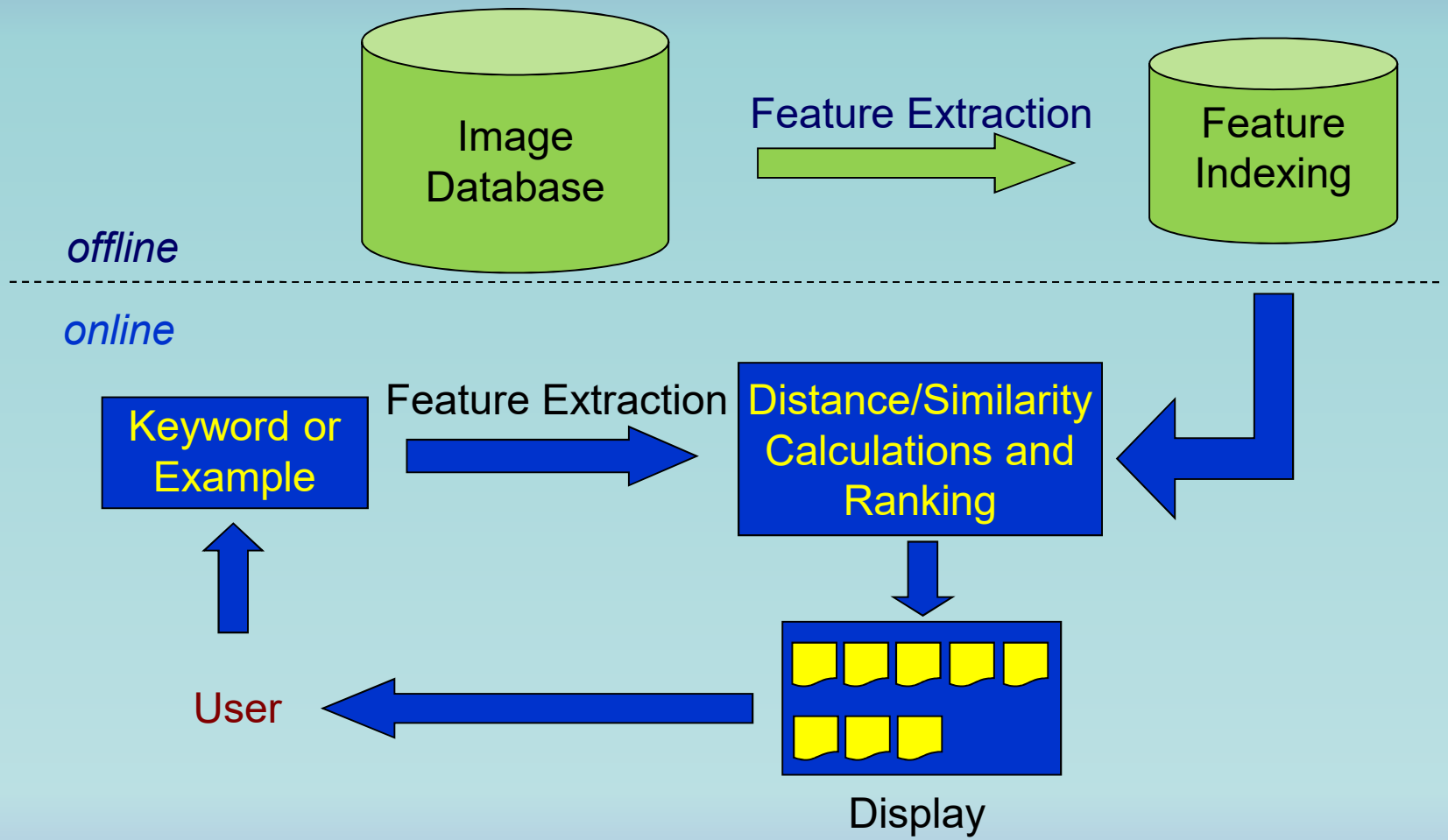
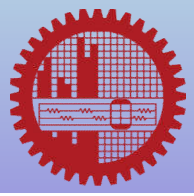


Image Retrieval





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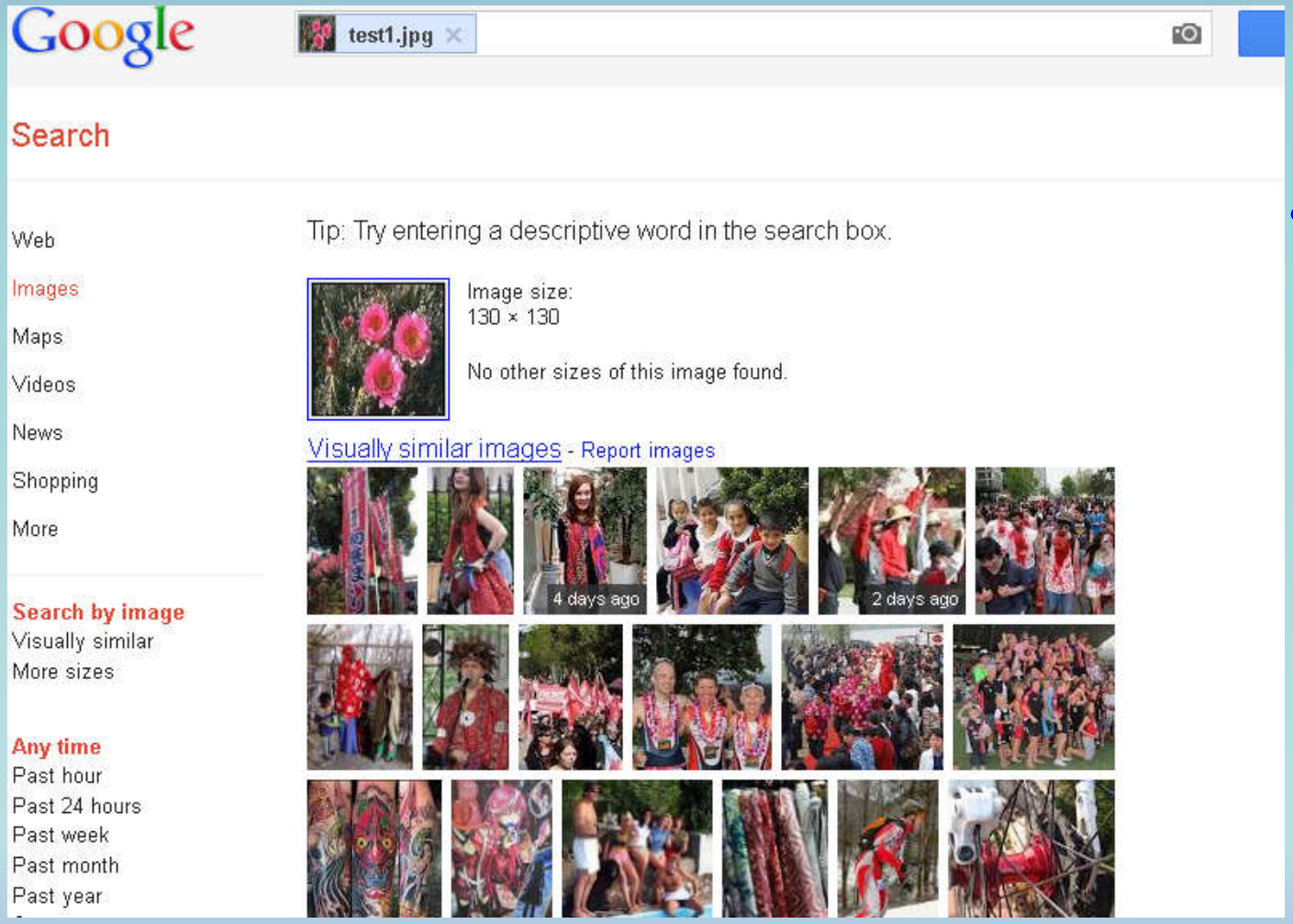
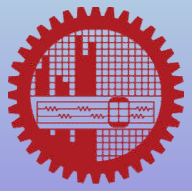
CBIR: Content Based Image Retrieval



- Issues
  - semantic gap
  - subjectivity



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(Traditional) SBIR: Semantic Based Image Retrieval

Retrieved by **Google** images using keyword 'cat', 'horse' and 'tiger'

Textual description in web: *The official line is that **cats** carry ...*

Textual description in web: *... famous and enigmatic White **Horse** is the oldest chalk-cut hill ...*

Textual description in web: ***Tiger** Woods, who is considered one ...*

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(Traditional) SBIR: Semantic Based Image Retrieval

Mirpur.jpg

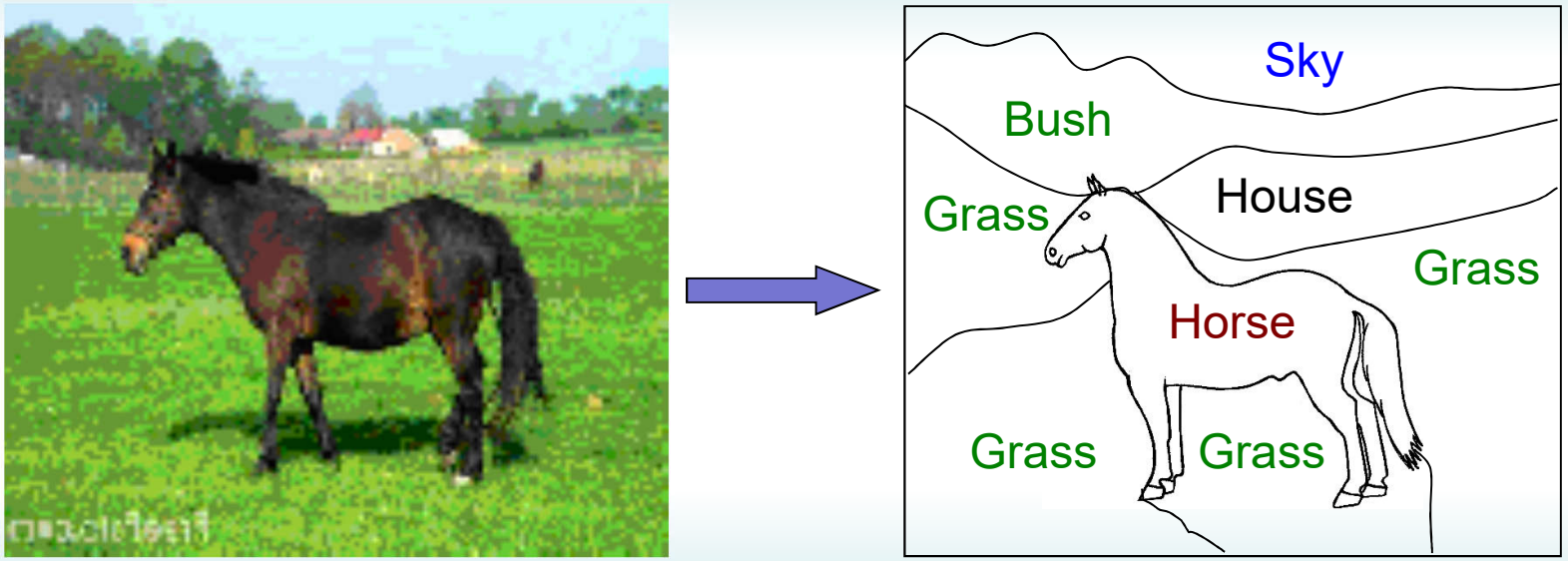
Safari park.jpg

Sundarban.jpg

- Human annotation is
  - tedious
  - misleading
  - subjective

Recent Trend in SBIR

Translation from image document to text document



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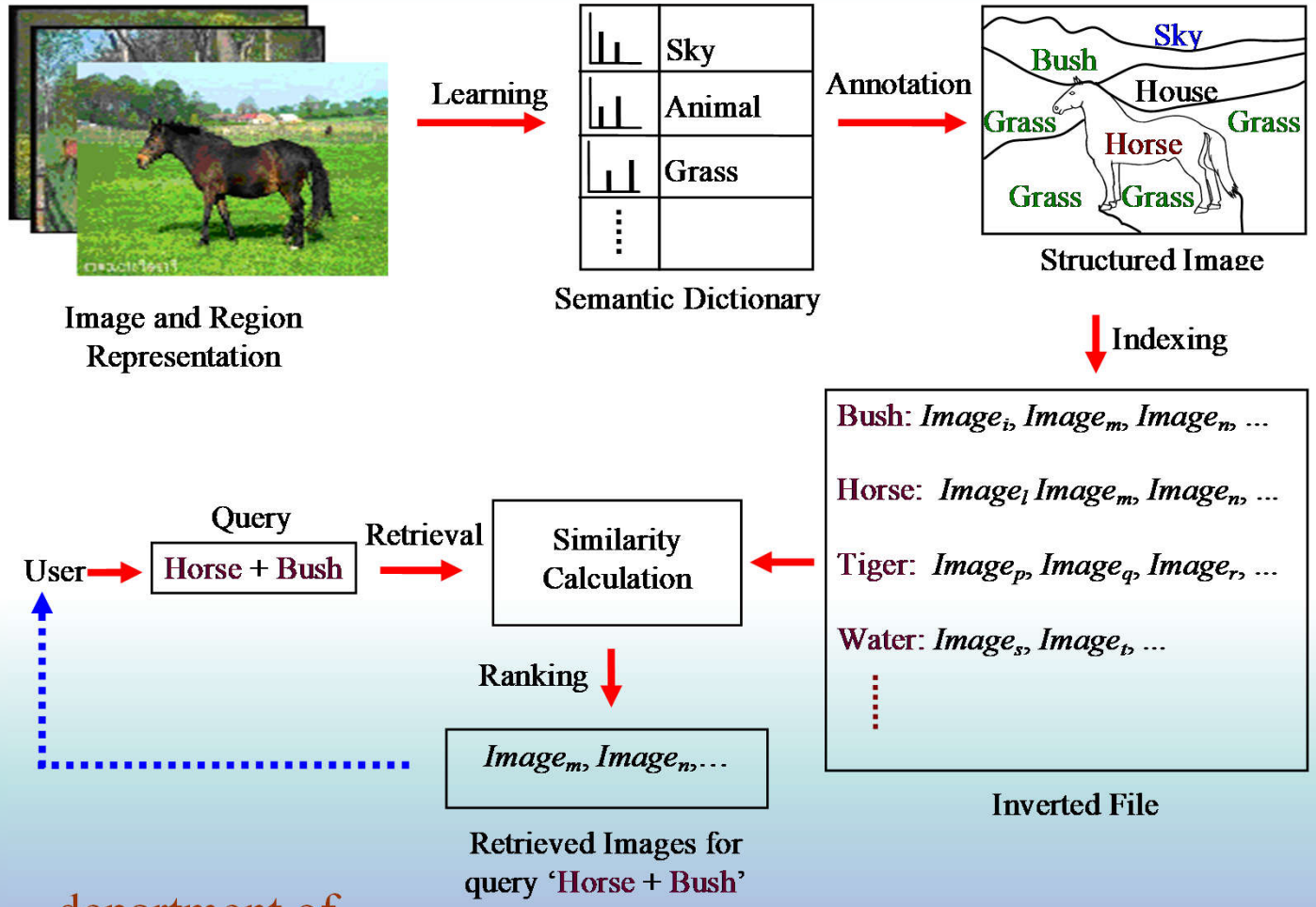
Recent Trend in SBIR



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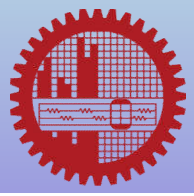
Issues in SBIR

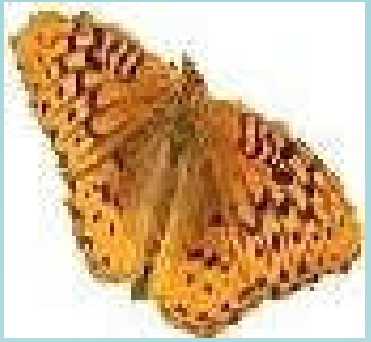
- Challenges:
  - Accurate image segmentation
  - Feature extraction for irregular shape
  - Inadequate number of regions (terms) per image (document)



Issues in SBIR

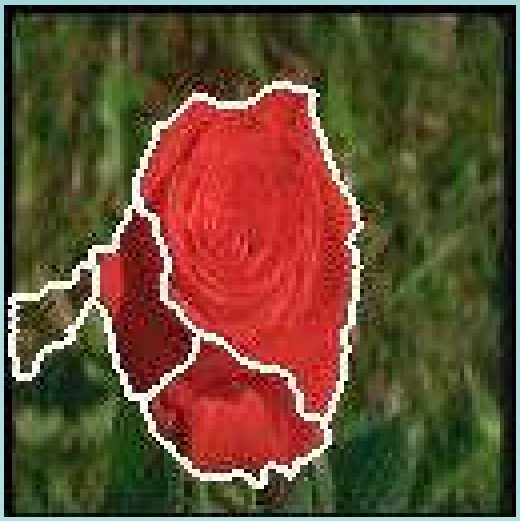
- Irregular shape



Issues in SBIR

- Inadequate number of regions to use ***tf-idf*** principle



An image with 3 flower regions

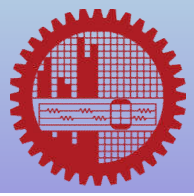


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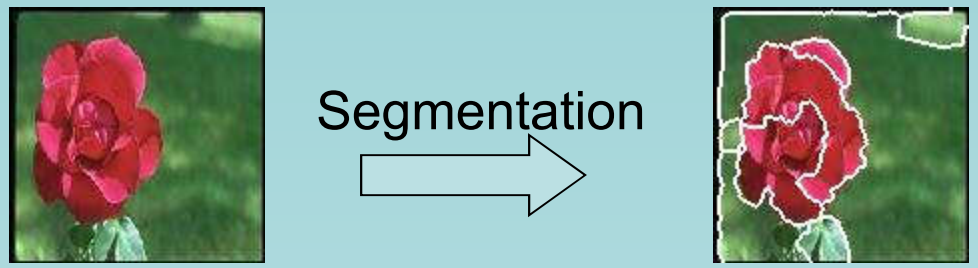
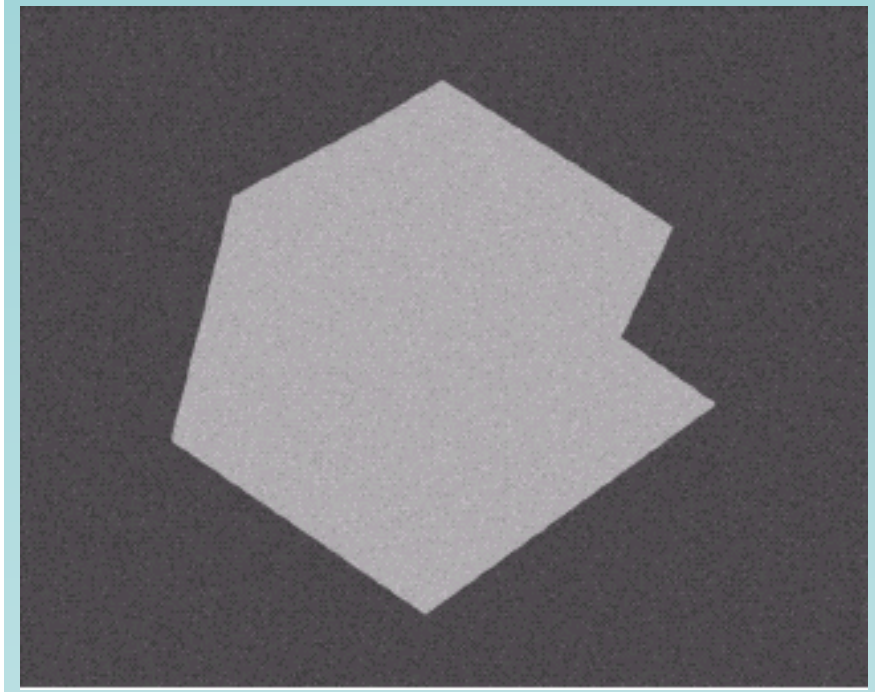
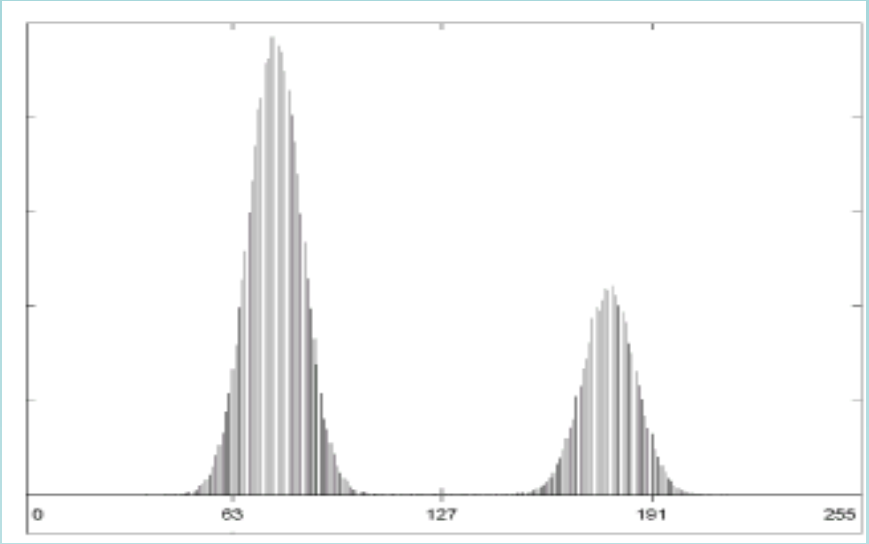
Image Segmentation



- Objective:
  - separate semantically meaningful regions (objects)

Image Segmentation:
Thresholding – A Simple Approach





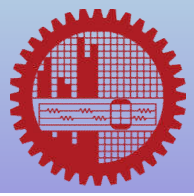


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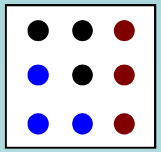
Image Segmentation:
NCut – A Graph Based Approach



Let a color image

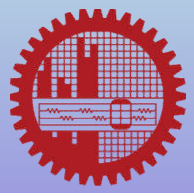


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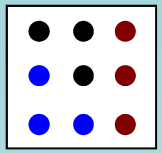
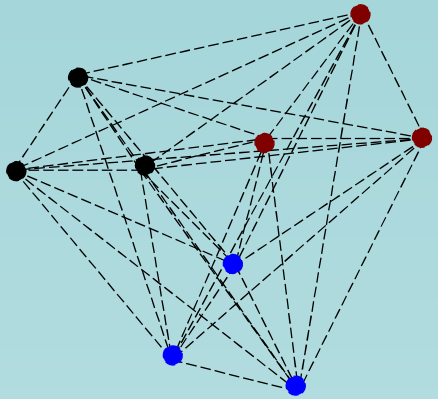
Image Segmentation:
NCut – A Graph Based Approach



A color image



Graph Representation

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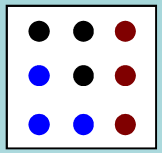
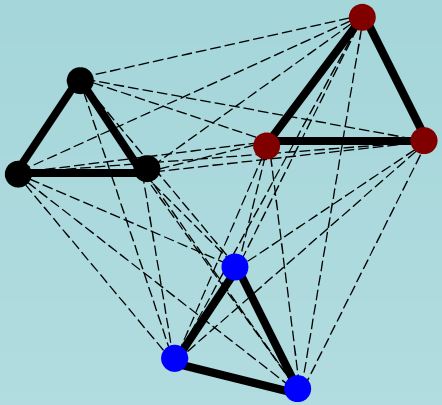
Image Segmentation:
NCut – A Graph Based Approach





— Strong relation between pixels
···· Weak relation between pixels

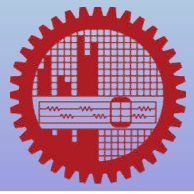


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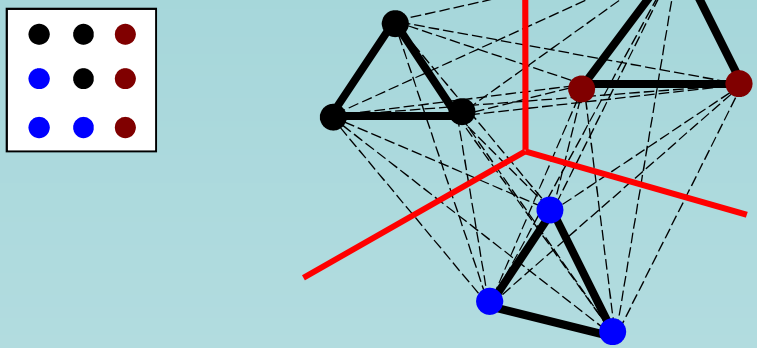
Image Segmentation:
NCut – A Graph Based Approach



Strong relation between pixels
Weak relation between pixels
Partition boundary

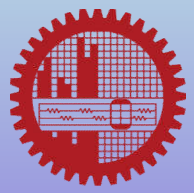


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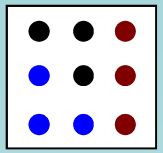
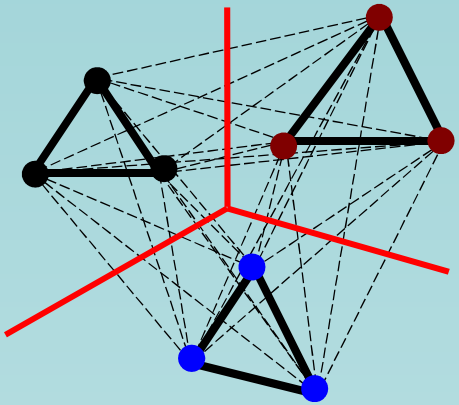
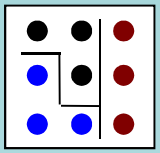
Image Segmentation:
NCut – A Graph Based Approach







Segmentation

— Strong relation between pixels
···· Weak relation between pixels
— Partition boundary

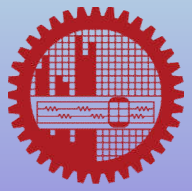


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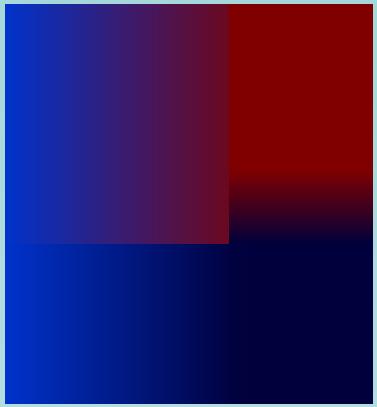
Image Segmentation:
JSEG – A Widely Used Algorithm



An image

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Image Segmentation:
JSEG – A Widely Used Algorithm

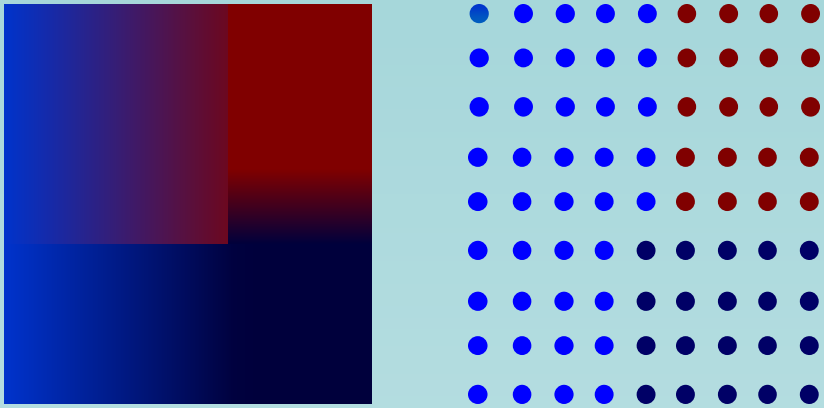

image with class maps

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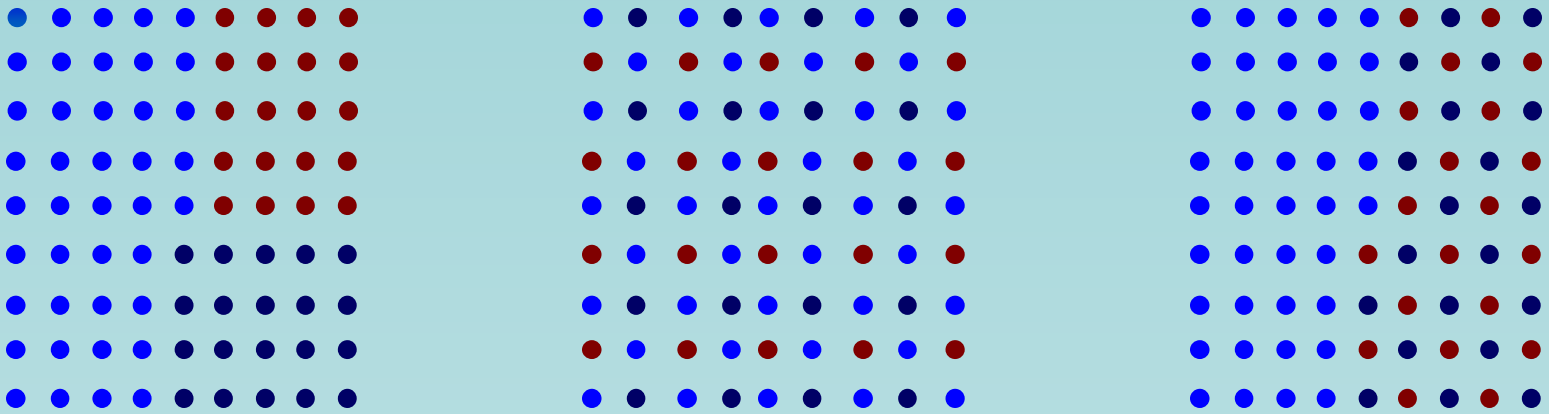
Image Segmentation:
JSEG – A Widely Used Algorithm



Class maps of 3 different images

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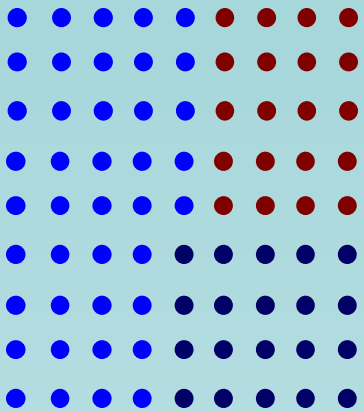
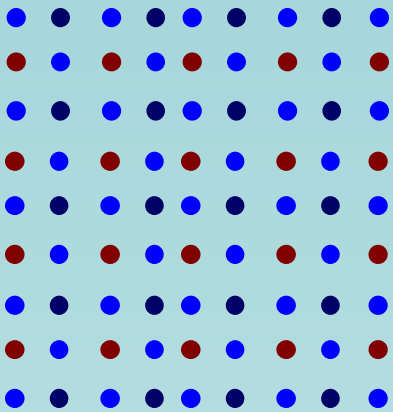
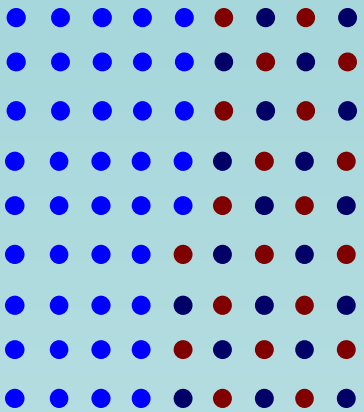
Image Segmentation: JSEG Approach



J=1.720



J=0.0



J=0.855

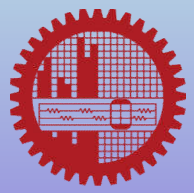


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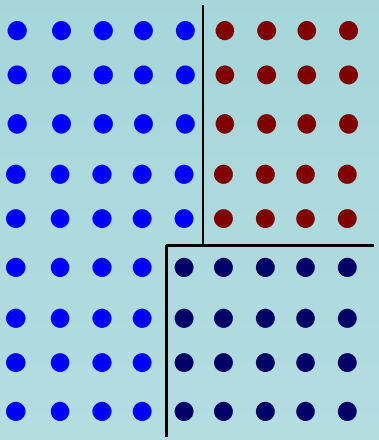
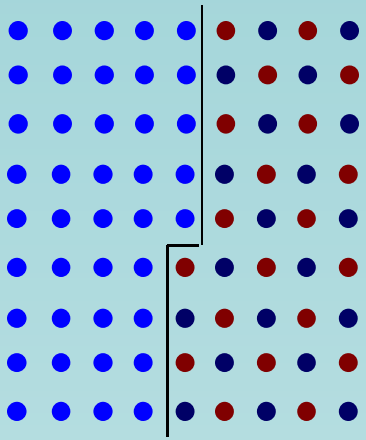
Image Segmentation: JSEG Approach



$J_0 = J_0 = J_0 = 0$

$J_{avg} = 0$



$J_0 = 0$, $J_{00} = 0.011$

$J_{avg} = 0.05$

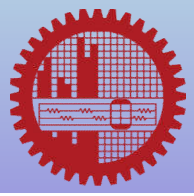


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Image Segmentation: JSEG Output

original image

segmented image

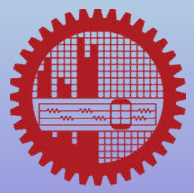

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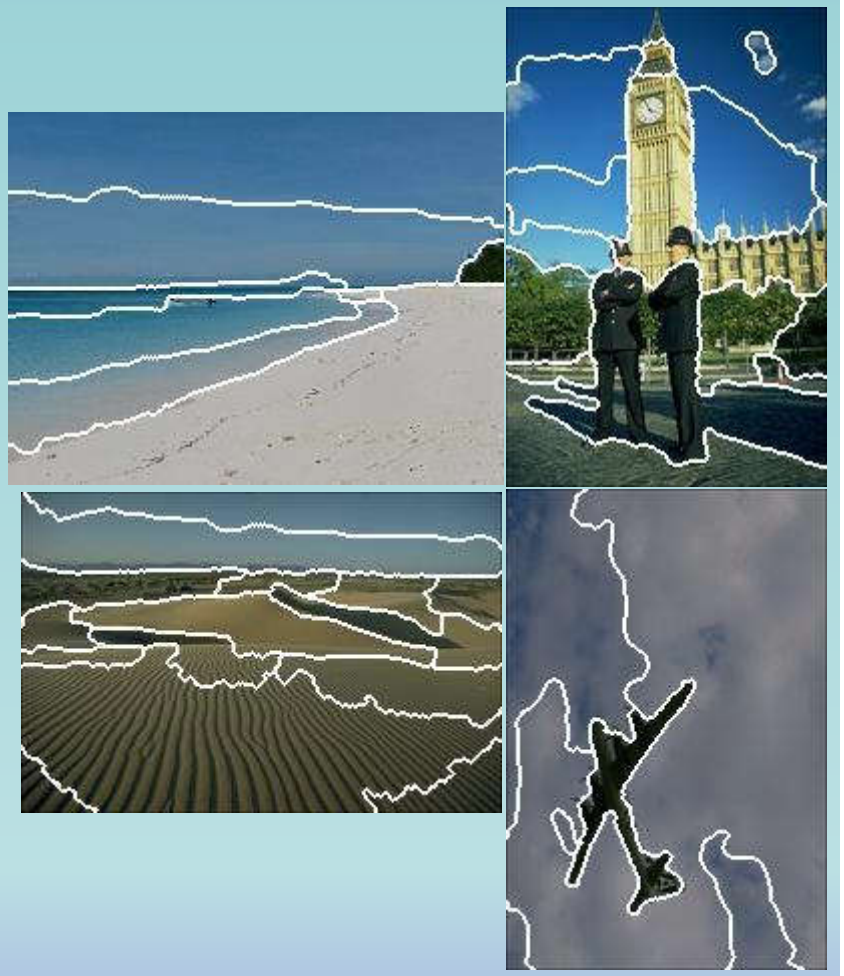
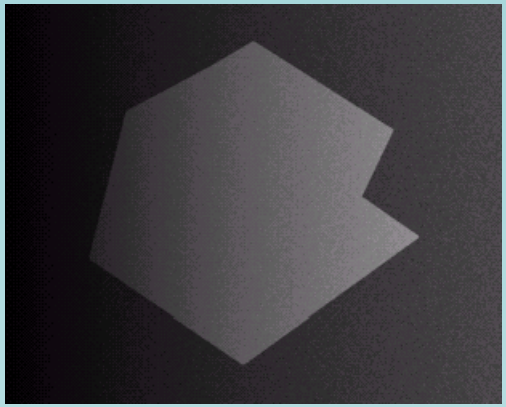
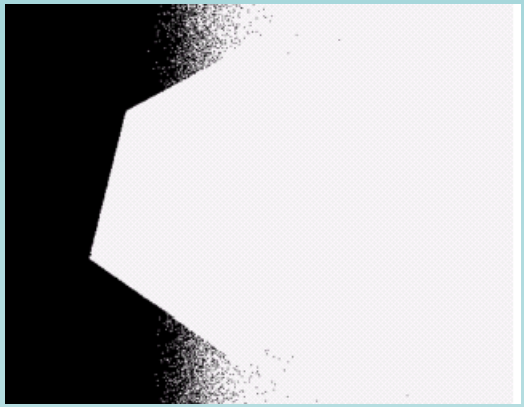
Image Segmentation

- Issues in all segmentation algorithms:
  - over/under segmentation
  - overlapping segments
  - variable illumination

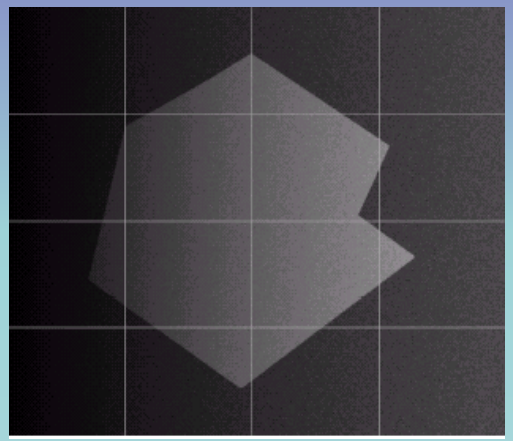


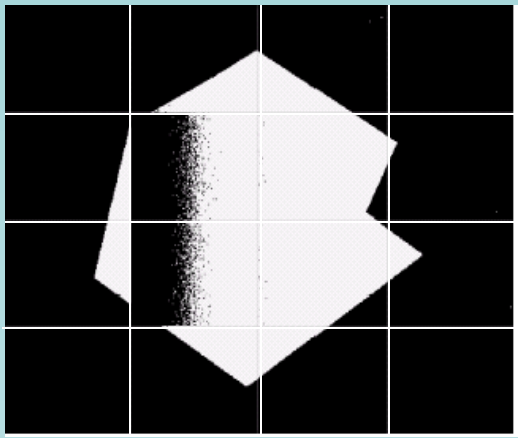
Segmentation Issues: Variable Illumination

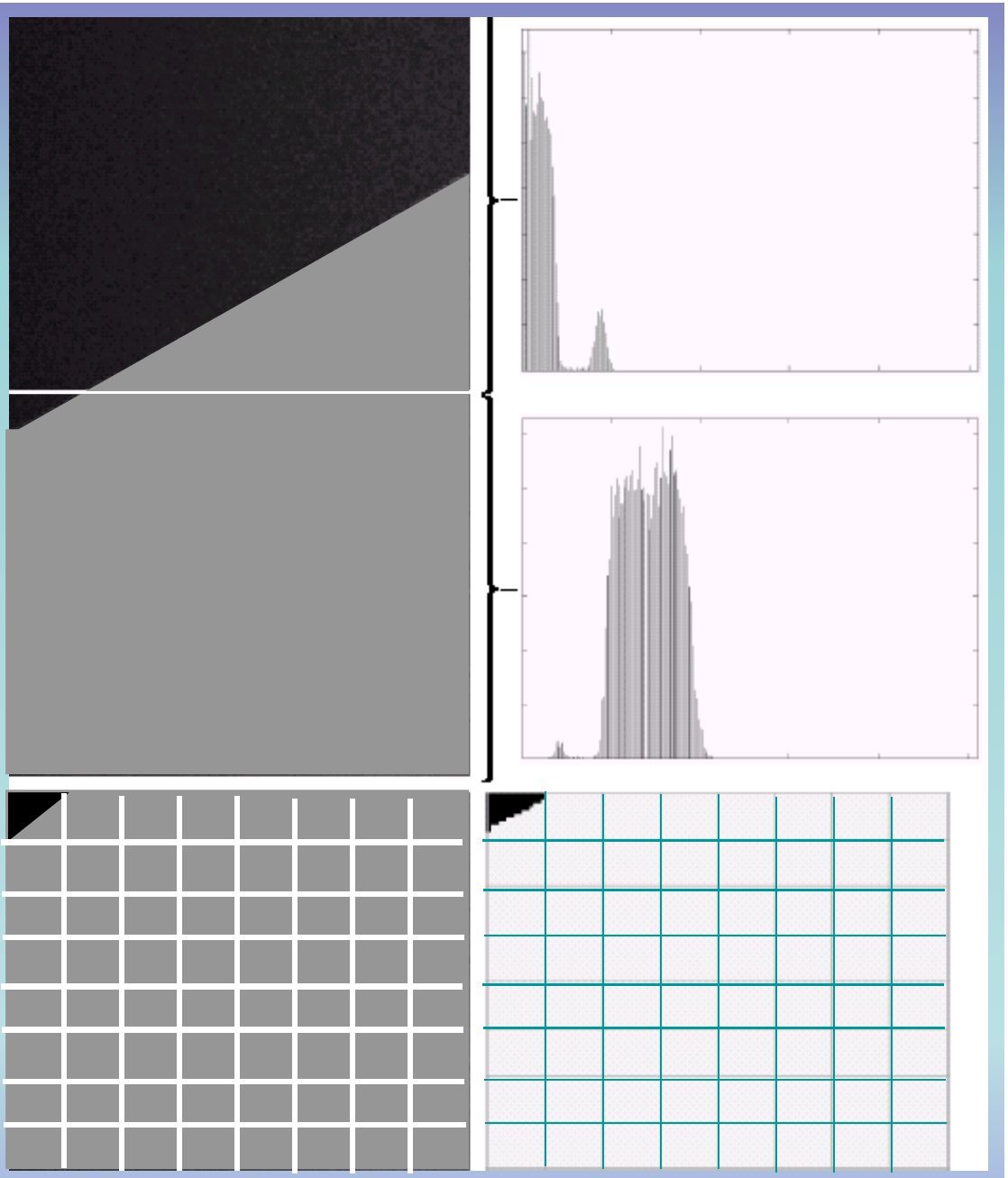




Variable Illumination in Gray Scale Images







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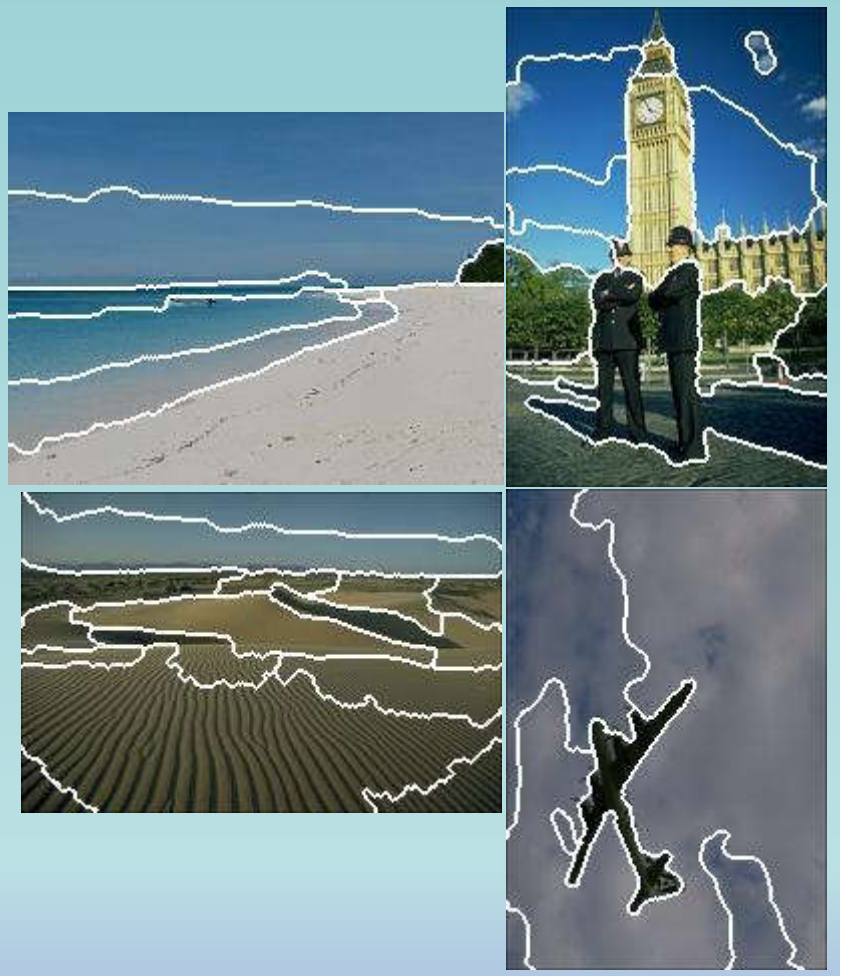
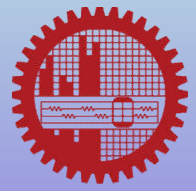
Segmentation Issues in Color Images





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Improving using Visible Color Difference

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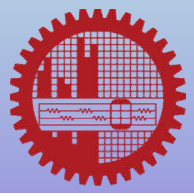
Work on License Plate Detection

- Issues
  - Variable illumination
  - Slanted/distorted image
  - Hazardous conditions
    - Fog, rain, darkness
  - Overlaps between lines and characters



Work on License Plate Detection

- Hazardous Conditions

Courtesy: Samiul Azam

- **Hazardous weather** (rain, fog)
- **Low contrast** (indoor, night, blur)
- **Background objects** (other objects in background)
- **Tilted view of license plate** (horizontally tilted LP)

Rain

Indoor

Complex Background

Tilted

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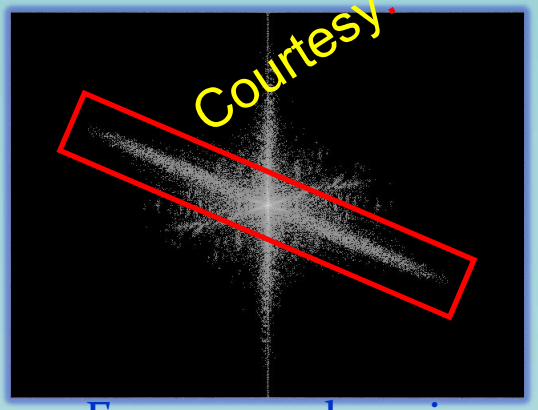
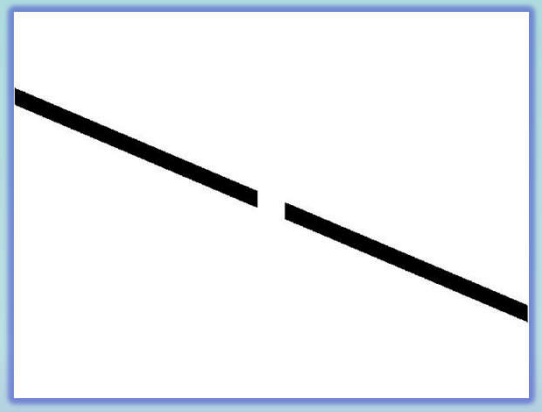
Rain Effect Removal

Consider rain streaks as periodic noise

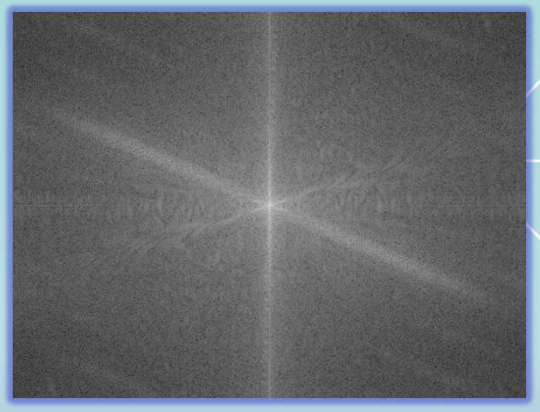


Courtesy: Samiul Azam

Frequency domain



Rain mask



Frequency domain

Rain removed image

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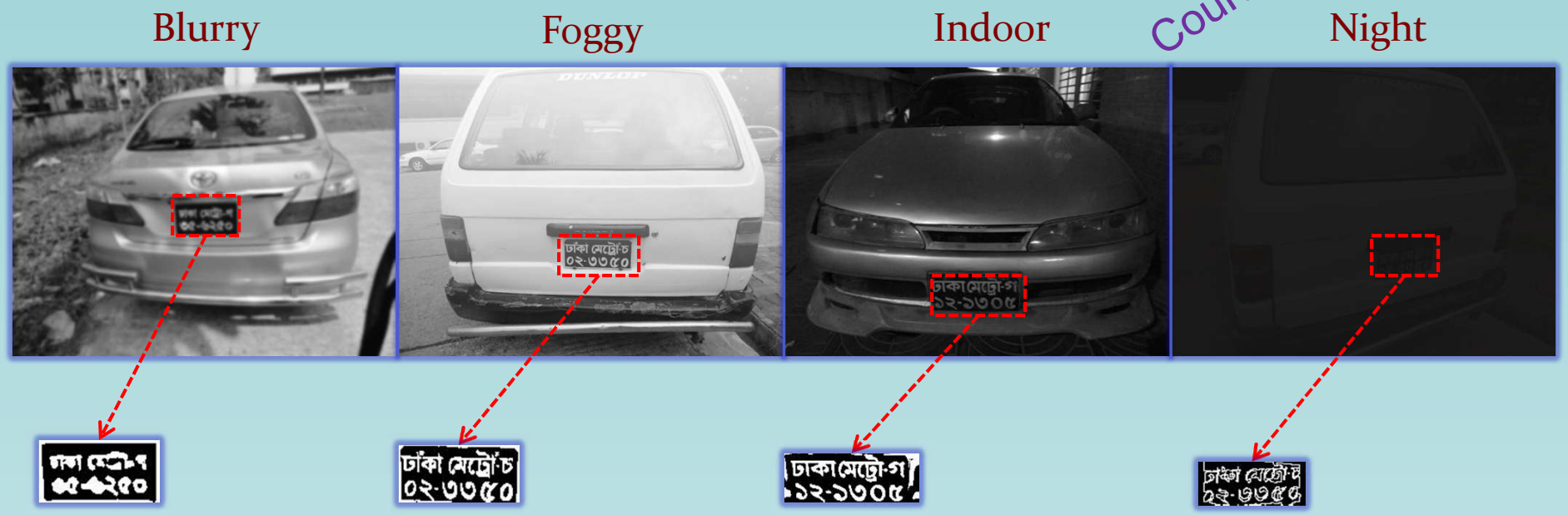
LPD in Hazardous Weather Conditions

- Experiment on indoor, day, night, blurry and foggy Images

Courtesy: Samiul Azam



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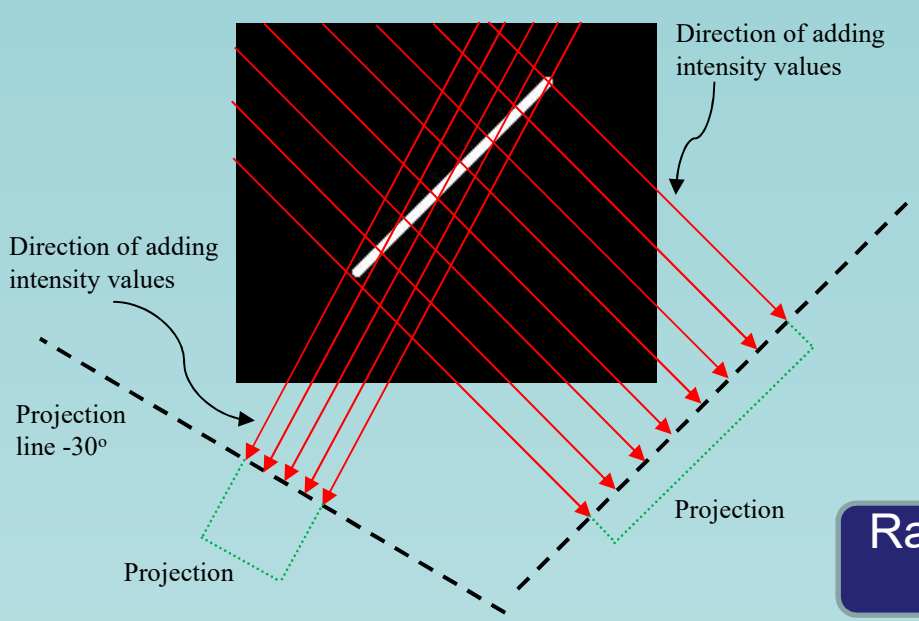
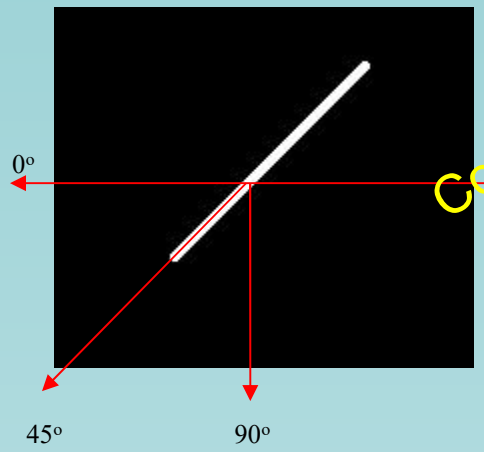
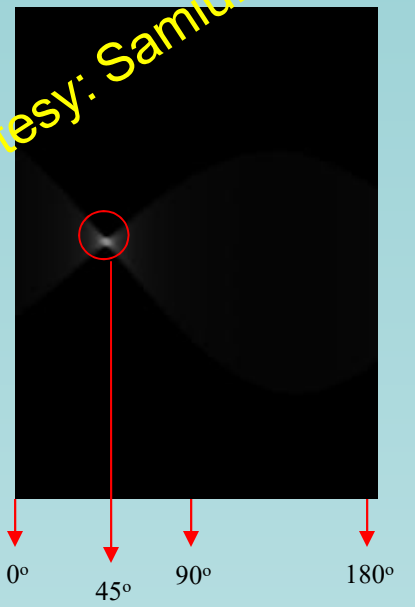
Tilt Angle Correction in LPD





Radon transformation of an image



Courtesy: Samiul Azam

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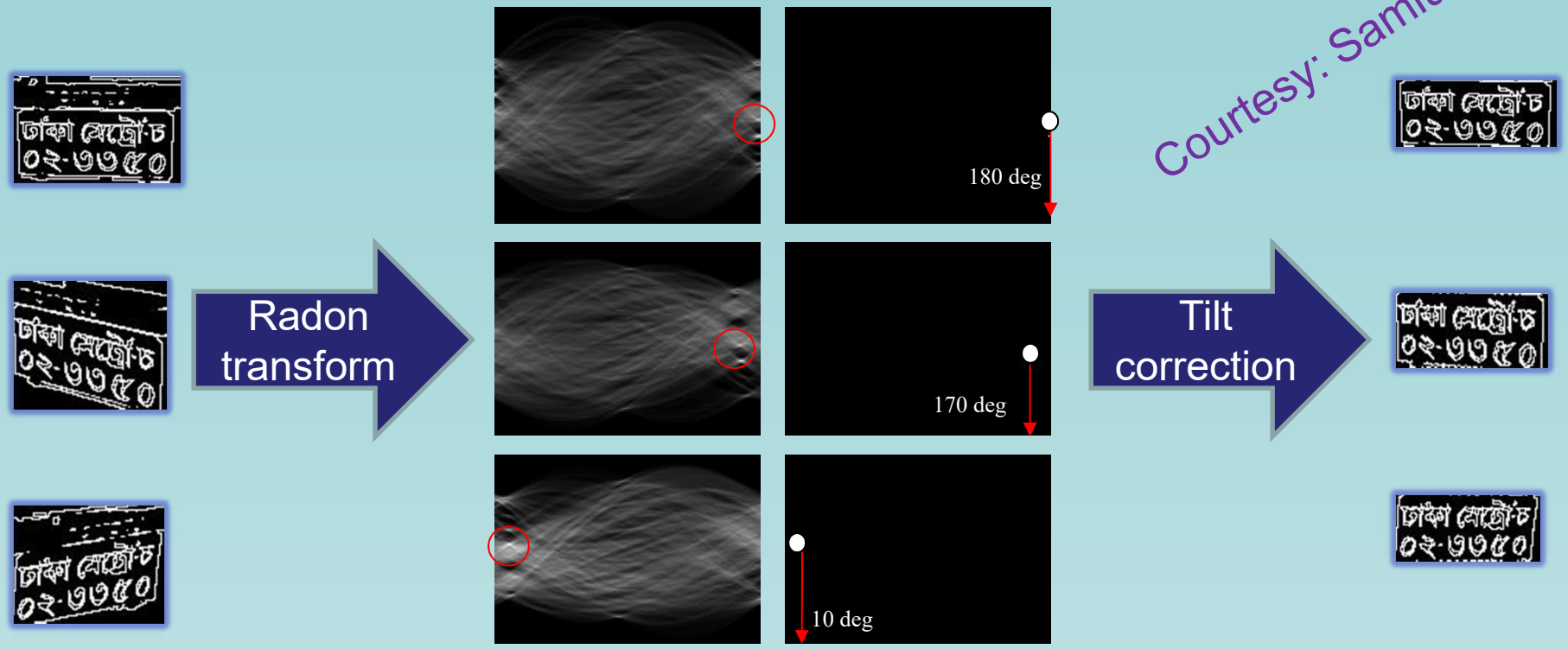
Tilt Angle Correction in LPD



Courtesy: Samiul Azam

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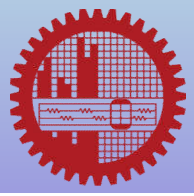
Thank you



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