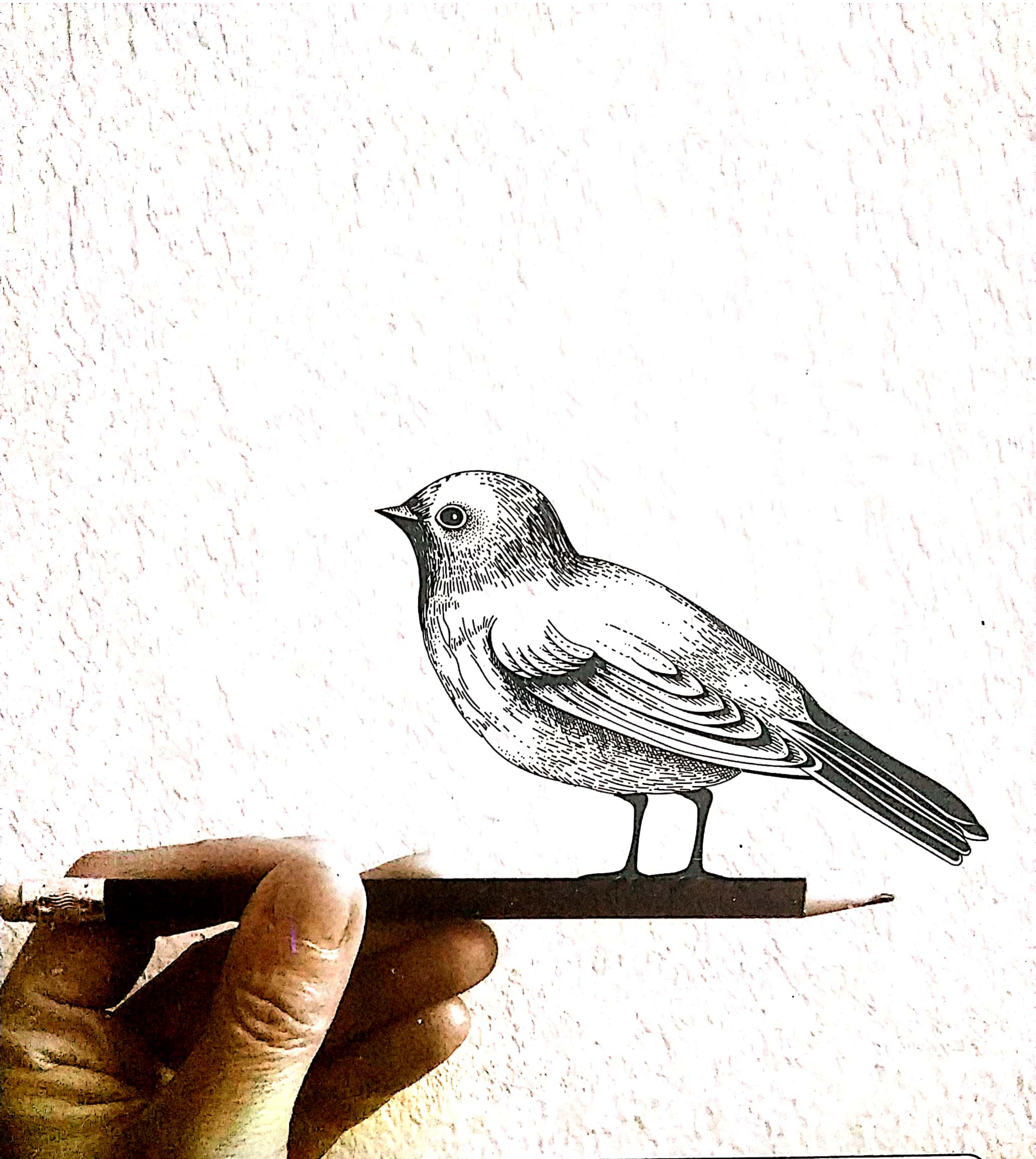


Bashundhara
Exercise Book
Write Your Future

Digital Image Processing (CSE-4245)
SMS
Naima Islam Nodi

Ref. Book :

1. Digital Image Processing by Rafael C. Gonzales
4th/3rd edition

2. Digital Image Processing using MATLAB,
Gonzales (2nd edition)

3. Image Processing using Python, web reference.

Objectives :

1. Explain how digital image are represented & manipulated in a computers.

2. Mathematical description of image processing techniques & algorithms.

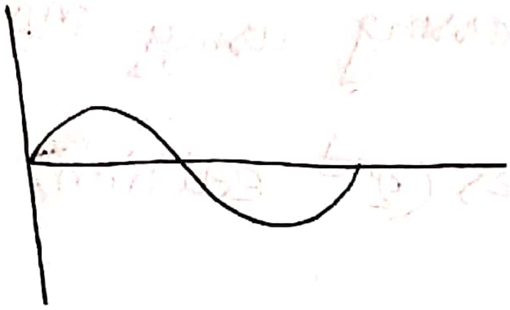
Digital image

└→ 2D signal

↓

$f(x, y)$ → Spatial co-ordinate
intensity

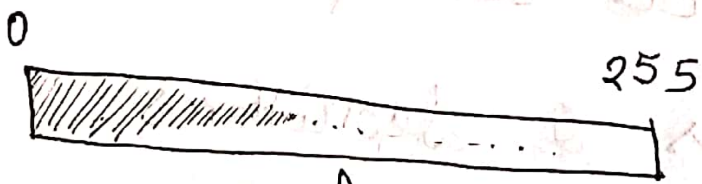
AC current
Sound wave



pixel → picture element

1 bit → 0, 1 } Representation

Gray Scale Image:



8-bit

Color image: → RGB

Different Intensity value

Source of Image:

Digital camera | Computer Vision
X-Ray | AI
Painting | ML

* Image Processing:

Image enhancement

Image filtering → Special Domain filtering
→ Frequency " "

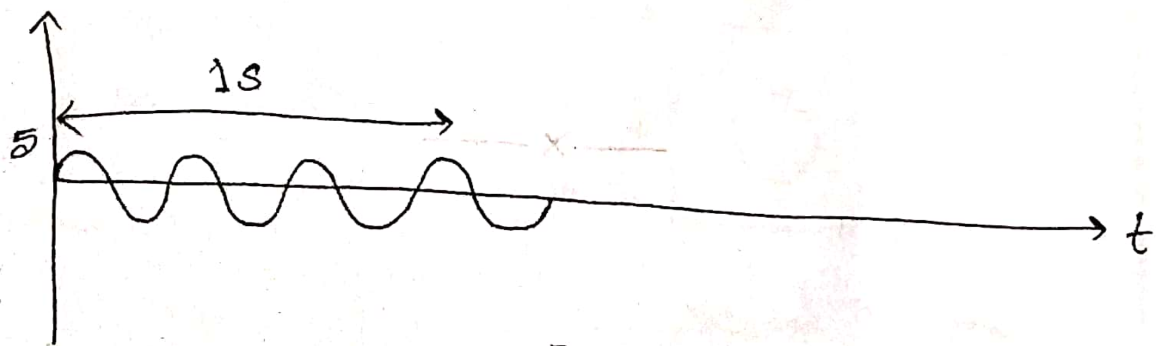
Image Restoration

Image compression

Image Segmentation

Morphological Analysis

Object Recognition



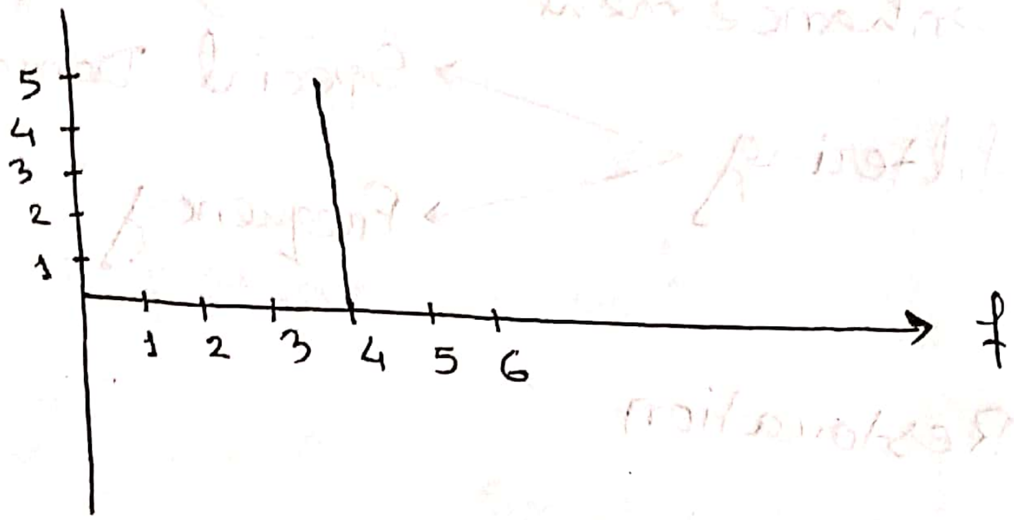
Time Domain Representation

$s(t) = A \sin(\omega t + \phi)$

Amplitude — Angular Frequency — Phase Angle

$$f = \frac{1}{T} = \frac{1}{4} = 0{\cdot}25 \text{ Hz}$$

e,
ength
me.



Frequency Domain Representation

If $T = 0{\cdot}25$

then, $f = \frac{1}{0{\cdot}25}$

$= 4 \text{Hz}$

—x—

16.01.19.

$x(t)$ $x(t_1, t_2)$

Signals: A function containing information about the behavioro or nature of some phenomenon of interest.

2 types of signals:

1. Analog (Acoustic signal)
2. Digital

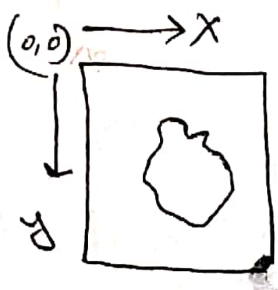
Acoustic signal → electrical signal → A/D → process → D/A → electrical signal → Acoustic signal

A/D
- → Sampling ⟶ discrete-time signal
- → quantization ⟶ discrete Amplitude

} Digital

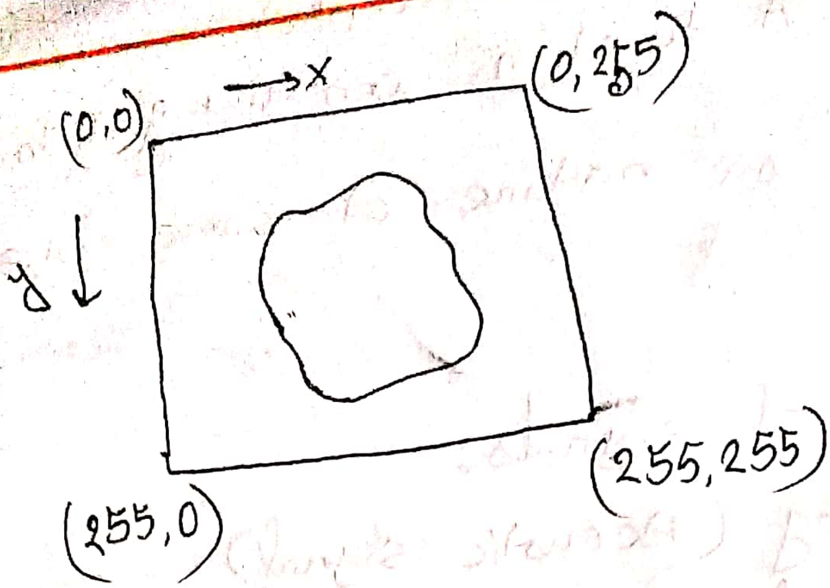
$f(x, y)$ ⟶ value (intensity)

↑ ↑ Spatial coordinate



Digital Machine

image → 2D array



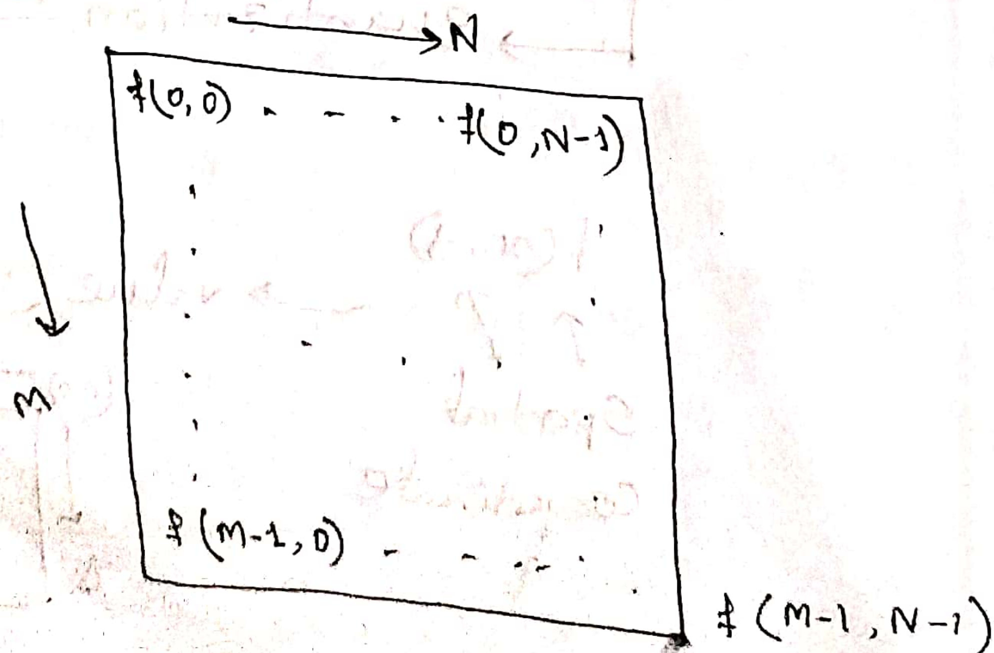
Black & White → 1 bit representation

—— x ——

"LAB"

17.01.19

f(x, y)



Default → Unsigned bit.

```
I = imread ('img.PNG');
```

I = 272X394X3

K = 272X394

```
I = imread ('img.PNG')
subplot (2, 1, 1);
imshow (I);
subplot (2, 1, 2);
K = rgb2gray (I);
imshow (K);
```

Command window

help imread

Subplot (2, 1, 1)

row col No.

~~Supt~~ Subplot (2, 2, 1)

1	2
3	4

row all col.

P = K (3, :)

all row

q = K (:, 2)

col.

rb = K (2, 3)

row col.

"Akhtar Sir" 17.01.19.

Agenda:

1. Introduction
2. Project plan.

Image transformation, 5, 6

Challenges:

1. Identity detection
2. Gender / Age / Profile identification
3. Representation
4. Freshness Detection.

1200 dpi (dot per inch)

dot pitch

mm (0.28)

Pixel

Image compression

Color Scheme

RGB (visual) | CMYK (Print)

Color TV

R | G | B

3 electron Gun

Image formation:

1. Geometry of image formation.
2. Physics of light.

$$\vartheta = n\lambda$$

$$\Rightarrow \lambda = \frac{\vartheta}{n}$$

AR → Augmented reality

* Image acquition & manipulation.

* Monochromatic images:

Black & White

Charged-coupled Device (CCD) cameras

Frame Grabber.

Image ~~deti~~ digitization

quantization noise/error.

Image file formats.

PGM format

* Project list:

1. Facial expression recognition
2. Visual Detection of autonomous Driving
3. System Based on deep learning
4. Traffic signs recognition
5. Target stealth.
6. ~~Gao~~ GAIT Analysis.
7. A study on Image segmentation
8. Activity Recognition
9. Eye-tracking & gaze capture

$\boxed{\text{Sigmind}}$

—x—

21.01.19.

Classification of Images:

Reflection Images

Emission "

Absorption "

Electromagnetic (EM) energy spectrum.

Tomography

CT-Scan → Tomography

PET → Positron Emission Tomography.

Image acquisition Process:

~~Scane~~

Scene element → Imaging system → Image Plan

→ Digital Image

Digital Image:

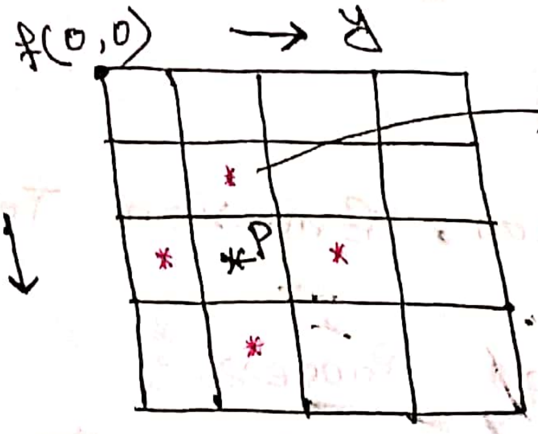
Sampling → Discretize co-ordinates in 2D array

Quantization → Discretize amplitude or intensity value.

pixel → smallest picture element.

Basic Relationship between pixel:

* Neighbors of a pixel (4 Neighbors) → $N_4(P)$

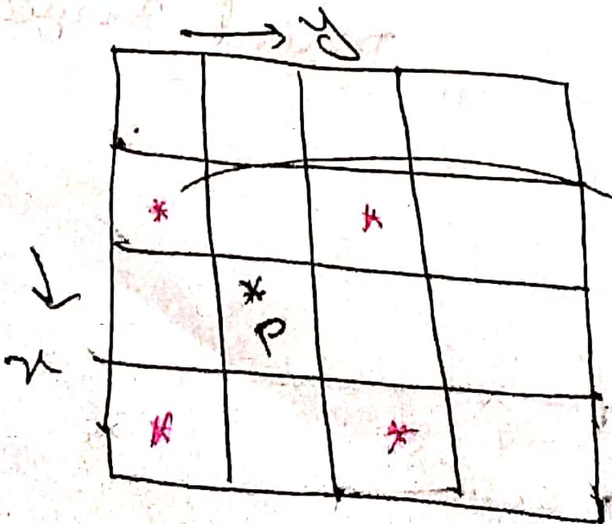


$(x-1, y)$, $(x, y+1)$, $(x+1, y)$, $(x, y-1)$

$f(x,y)$

→ Horizontally & vertically connected pixels.

Diagonally connected pixels



$N_D(P)$

$(x-1, y-1)$, $(x-1, y+1)$

$(x+1, y-1)$, $(x+1, y+1)$

8 - Neighbors :

$N_8(P)$

$\downarrow$

$N_4(P) + N_D(P)$

Adjacency :

1. 4-adjacency :

(Depends on intensity value)

$V = \{1\}$

$\rightarrow y$

$\downarrow x$

0	1	1
0	p 1	0
0	0	1

This pixel is the only 4-adjacen of P.

*To be 4-adjacency, the pixel value should exists in set and must be a 4-Neighbo

1. Two pixel p & q with values from V are 4-adjacency if q is in set $N_4(P)$.

2. 8-adjacency :

Two pixel p & q with values from V are 8-adjacency if q is in set $N_8(P)$.

M - adjacency:

1. q is in $N_4(p)$

2. q is in $N_D(p)$ and $N_4(p) \cap N_4(q) = \varphi$ (NULL)

0	1 *	1 q
0	1 p	0
0	0	1

$V = \{1\}$

$N_D(p)$

$N_4(p)$

$N_8(p)$

Here p & q are not m - adjacent, as (*) this pixel falls in both $N_4(p)$ and $N_4(q)$. So $N_4(p) \cap N_4(q) \neq \phi$.

—×—

Exercise (2.1.1) $\longrightarrow$ H.W.

2'11

Given two Sub sets S_1 & S_2 are.

	S_1				S_2				
0	0	0	0	0	0	0	1	1	0
1	0	0	1 (p)	0	0	1 (q)	0	0	1
1	0	0	1	0	1	1	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	1	1	1

For, $V = \{1\}$, Let p and q be two pixels.

(a) For two different subsets S_1 and S_2, p and q are not 4-adjacent as nor p is in the set of $N_4(q)$, neither q is in the set of $N_4(P)$.

(b) Here p and q are not 8-adjacent, as both of their values are in set of $V = \{1\}$ and ~~q is~~ but, q is not in set $N_8(P)$

(c) p and q are not m-adjacent, as q is not in $N_4(P)$.

Here, again, if we consider p and q, :-

	S_1				S_2				
0	0	0	0	0	0	0	1	1	0
1	0	0	1	0	0	1	0	0	1
1	0	0	1	0	1 q	1	0	0	0
0	0	1	1	1 p	0	0	0	0	0
0	0	1	1	1	0	0	1	1	1

(a) S_1 and S_2 are not 4-connected as q is not in the set $N_4(p)$.

(b) ~~S_2 a~~ S_1 and S_2 are 8-connected because, q is in the set $N_8(p)$.

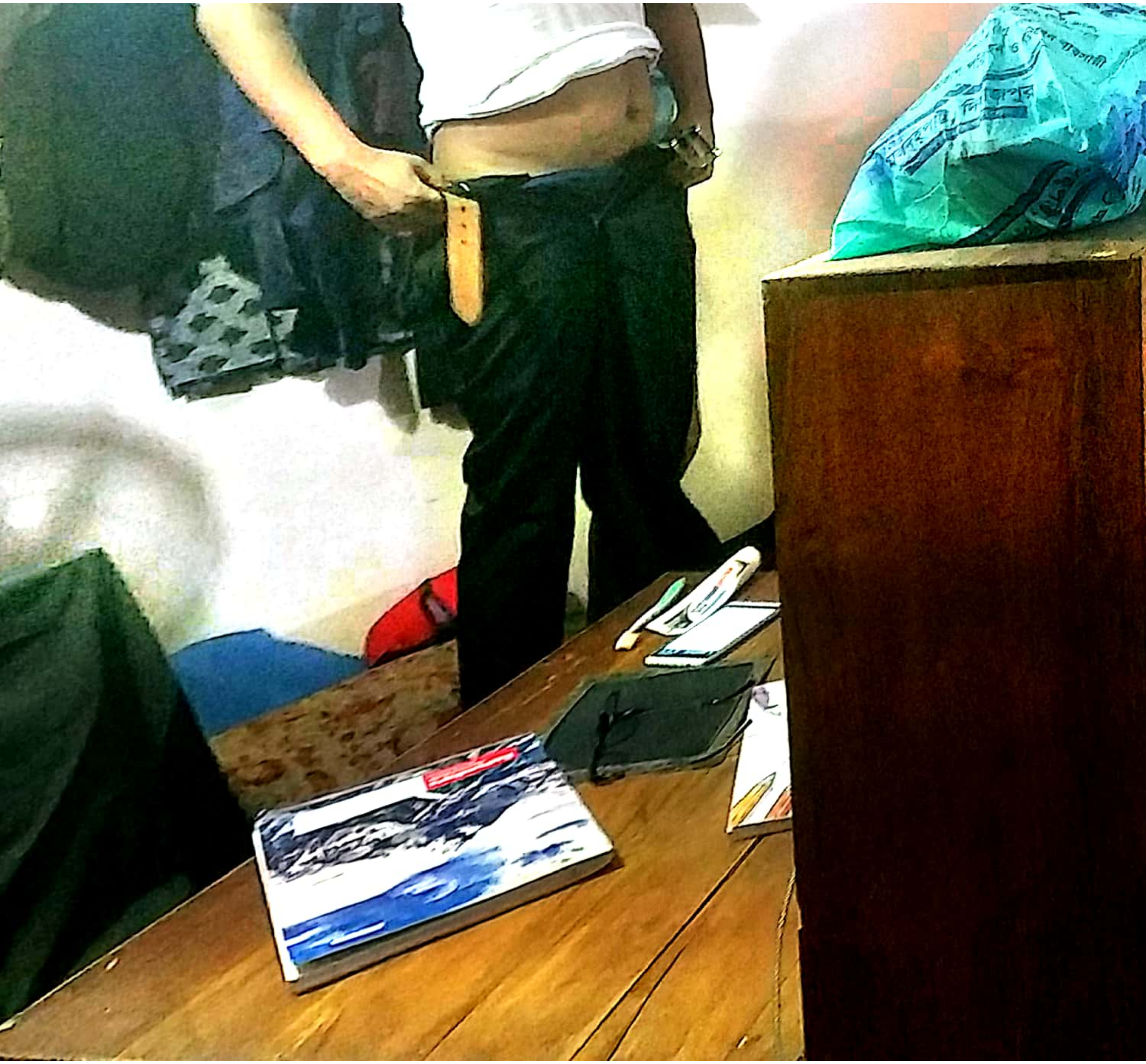
(c) S_1 and S_2 are m-connected, as

(i) q is in $N_D(p)$ and

(ii) the set $N_4(p) \cap N_4(q) = \phi$.

(Ans).

——x——



28.01.19.

Spatial Domain Vs. Transform Domain:

Image enhancement:

1. Spatial Domain (co-ordinate value)
2. Frequency Domain (Fourier Transform).

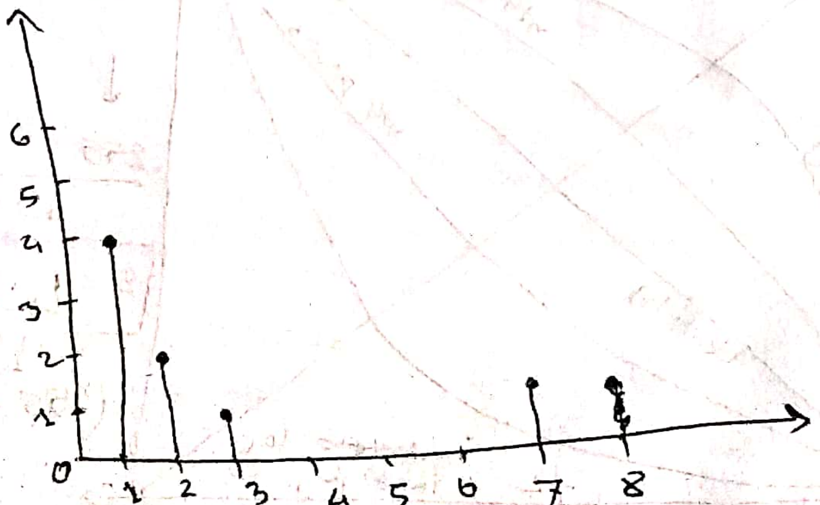
$g(x,y) = T[f(x,y)]$

$f(x,y)$ → Input image

T → Operation

$g(x,y)$ → Processed image.

* Point operation (individual pixel)
* Local operation (Neighbor pixels)
* Global operation (Histogram) → find frequency



1	1	2
~~8~~7	⑦	1
1	2	3

intensity value scale: 0–

Spatial Domain Process:

Intensity transformation function:

$s = T(r)$

0 — 255

Black — White

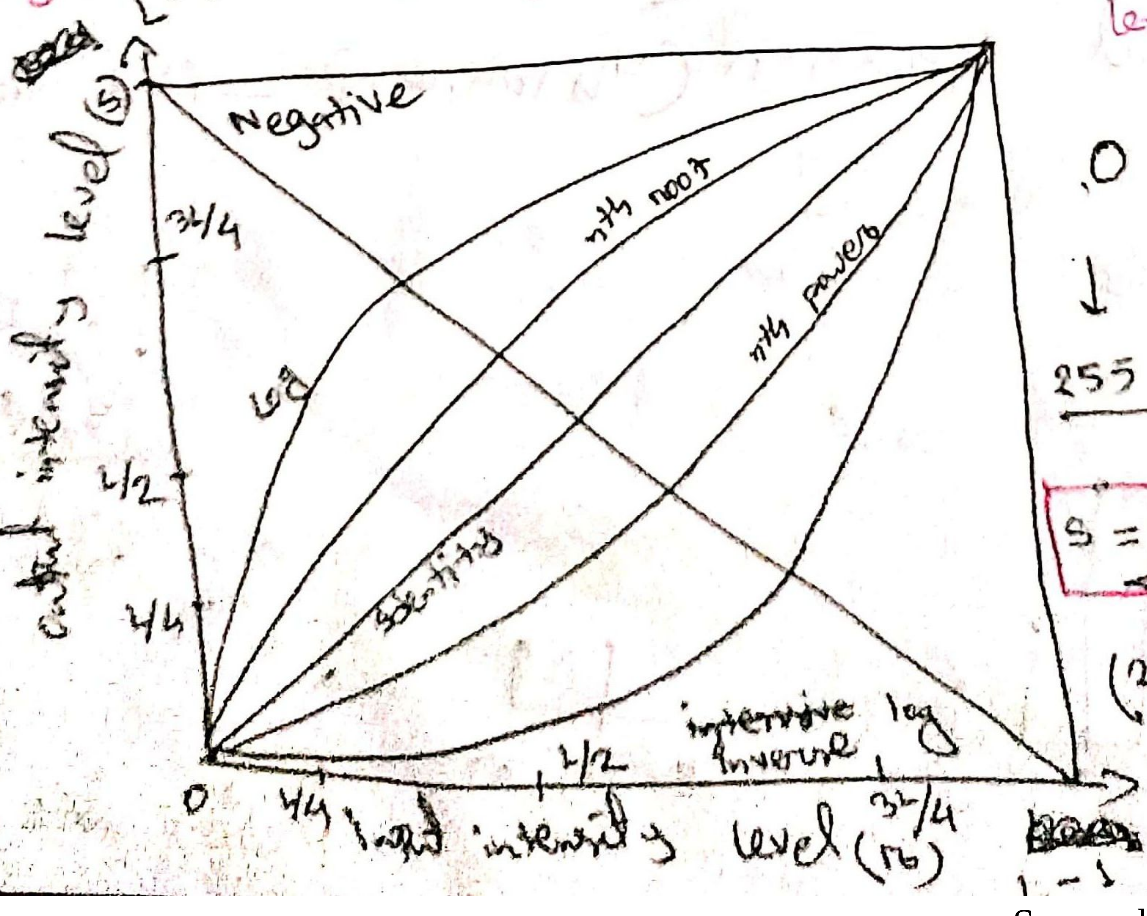
50 ~ 100

10 ~ 240

More clear, more contrast after streching (value of intensity increases)

Image Negative:

L = max intensity level.



0 → 255

255 → 0

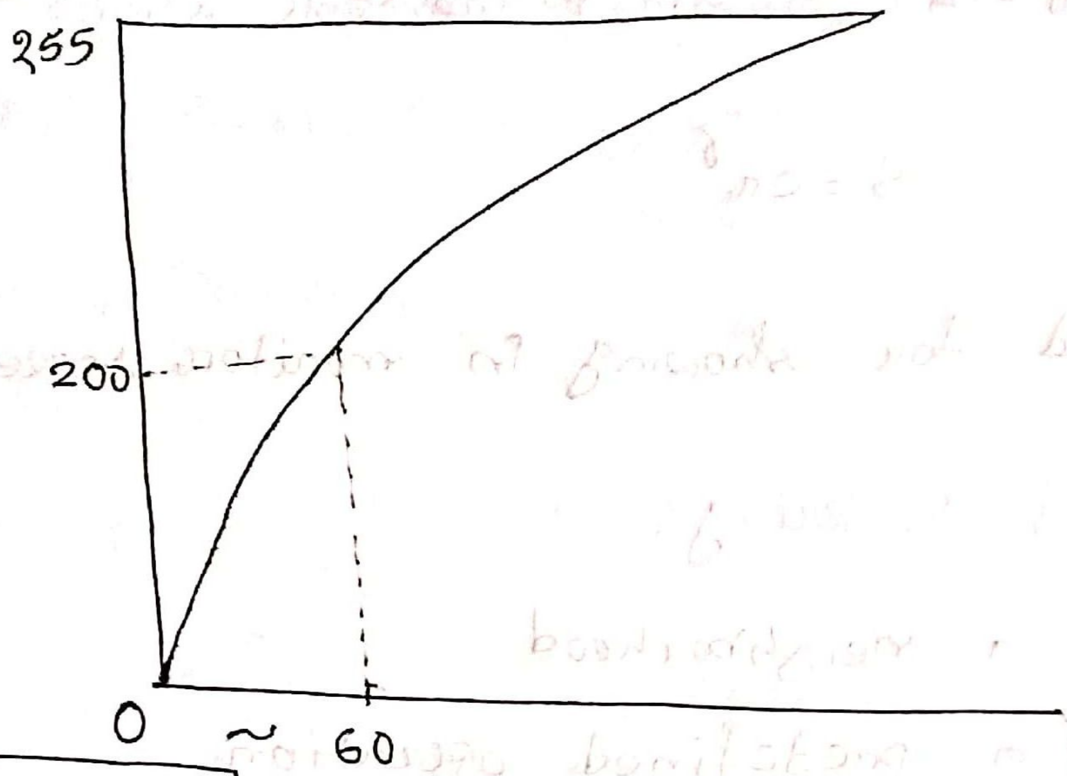
130

$\boxed{s = L-1-r}$

130

(255 − 125)

Log Transform:



$0 \sim 60 \rightarrow 0 \sim 200$

$$\boxed{s = c \log(1 + r)}$$

Power-Law (Gamma) Transformations:

$$\boxed{s = c\, r^{\gamma}}$$

CT-1

06.02.19

Till tomorrow's class

Power-Law (Gamma) Transformations:

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

→ Used for showing in monitor screen.

Spatial Filtering:

(a) a neighborhood

(b) a predefined operation.

* Histogram:

Contrast stretching:

*To identify different images or frequency range.

Image 1

1	1
3	0
1	1.

Image 2

0	1
1	1
3	1

Image 1

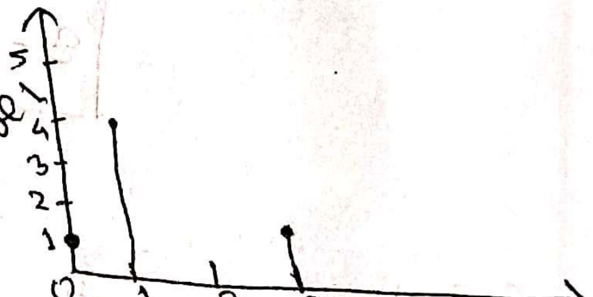
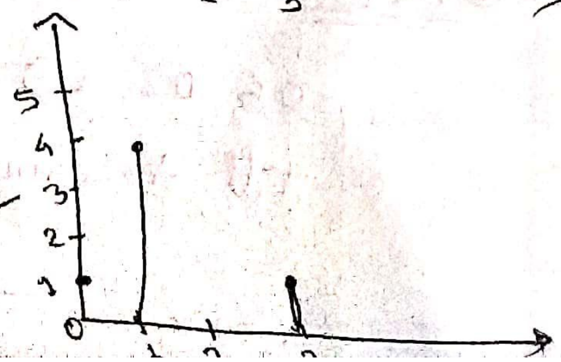


Image 2



* Same Histogram for both images which are different.

We can not identify image through histogram, but can have idea on it's contrast level.

Frequency Domain
Spatial "

Spatial Filtering:

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} \omega(s,t) f(x+s, y+t)$$

linear spatial filtering of an image of size $M \times N$ with a filter of $m \times n$.

Image smoothing
" Sharpening

—x—

31.01.19.

"LAB"

Image Negative:

```
I = imread ('pic.PNG');
Subplot (2, 1, 1);
imshow( I)
Subplot (2, 1, 2);
K= rgb2gray(I);
imshow(K)

s= (256 - 1 - K);
imshow (s).
```

Log Transformation:

$g = c . \log(1+f)$

$c = 1$ f = image.

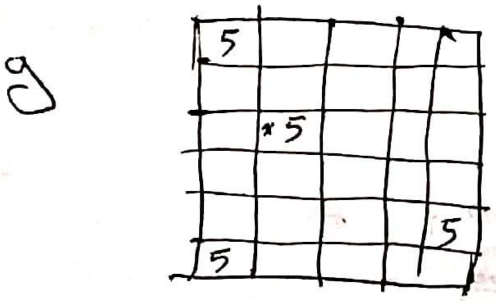
```
g = log (1 + dable (I)) * 1;
Subplot (2,2, 4);
imshow (g)
```

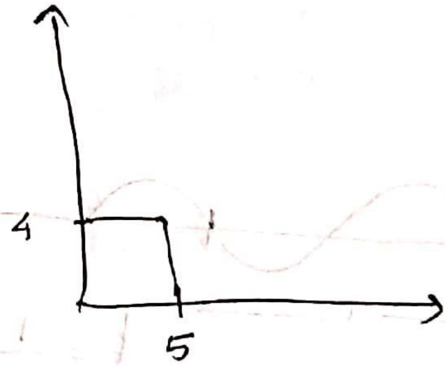
Power-law (Gamma) Transformations:

$$s = c r^{\gamma}$$

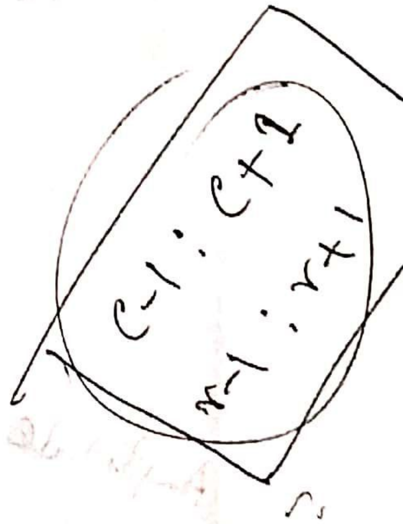
```
f = uint8(10 * (K .^ 2));        or, f = uint8(10 * (I .^ 2));
subplot (3,3,5);
imshow(f)
```

Image Histogram:





$x = g(3,2) = 5$




```
[row, col, d] = size(K)
for c = 1 : col
    for r = 1 : row
        value = ~~K(c,r)~~ K(r,c)
```

H.W. → ① Image Histogram plot

② Normalize Histogram
↓
plot (probability plotting)

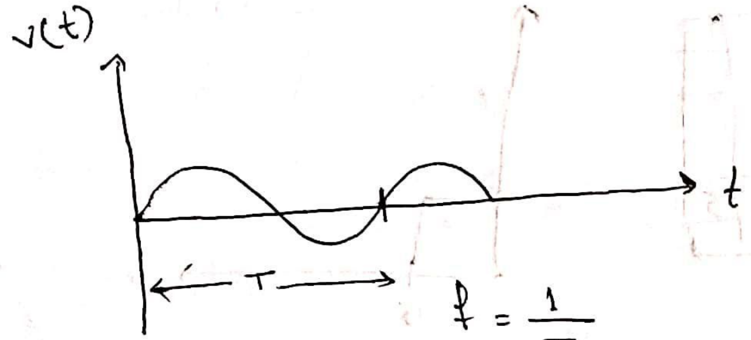
31.01.19

"Akhtaru Siru"

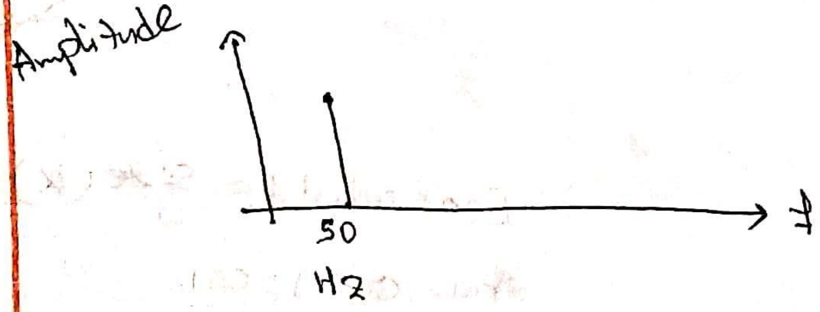
Frequency Domain: (Image enhancement)

Signal
|
Domain

- Time → Amplitude ↓ Variation with time
- Frequency ↓ variation with frequency
- Space ↓ Variation with space.



$f = \frac{1}{T}$



Time, frequency, Amplitude → Spectogram

Analog signal → Fourier Transformation → Discrete / Digital Signal.

Time Domain → Fourier Transformation → Frequency Domain.

Original function in spatial Domain $\xrightarrow{\text{Fourier Transform (FT)}}$ Image in Frequency Domain → Apply filter in frequency Domain $\xrightarrow{\text{Inverse Fourier Transform}}$ Enhanced Image in spatial Domain

Fig: Processes in Fourier Transform.

1-D FT → Signal processing

2D " → Image "

3D " → computer vision.

✱ Application:

1. Image enhancement
2. " restoration
3. " encoding/decoding
4. " description

1D FT:

$$F(u) = \int_{-\infty}^{\infty} f(x)\, e^{-j2\pi ux}\, dx \quad \text{where } j = \sqrt{-1}$$

$$f(x) = \int_{-\infty}^{\infty} F(u)\, e^{j2\pi ux}\, du.$$

* Filtering Using FT:

$f(x,y) \rightarrow \text{DFT} \xrightarrow{F(u,v)} \otimes \xrightarrow{G(u,v)} \text{Inverse DFT} \rightarrow g(x,y)$

Filter Design $H(u,v)$ $\rightarrow \otimes$

$\boxed{\text{DFT} \rightarrow \text{Discrete FT}}$

* High Pass (HP), Low pass filter (LPF):

1. Ideal
2. Butter~~wall~~worth (Smooth transition between low & high)
3. Gaussian.

$\boxed{\text{ringing effect}}$

Frequency Bands:

The Convolution Theorem

$g = f * h$	$g = f \cdot h$.
implies	implies
$G = F \cdot H$	$G = F * H$

Low frequency to high frequency → Butterworth.

$\boxed{\uparrow D_0 \rightarrow \downarrow \text{Ringing radius} + \downarrow \text{blur}}$

* Gaussian effect:

Softer ~~bod~~ blurring + no ringing

~~Smo~~ Smoothing → Low pass filter

Sharpening → High " "

Band Pass filtering → certain range pass.

Band rejection filtering :

$\boxed{\text{Scikit}}$

04.02.19

CT-1 → 11.02.19 (Monday)

Time : 10:45 AM.

1. Fundamental of digital image processing
2. Sampling & Quantization
3. Adjacency, Neighborhood
4. Intensity transformation.

(Image negative, log transform, gamma transform)

Frequency Domain : (Filtering)

Image smoothing (Low pass)

" Sharpening (High pass)

Spatial Filtering:

Spatial convolution.

origin f(x,y)

original image.

0	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	0
0	0	0	0	0

w (x, y)

1	2	3
4	5	6
7	8	9

filter

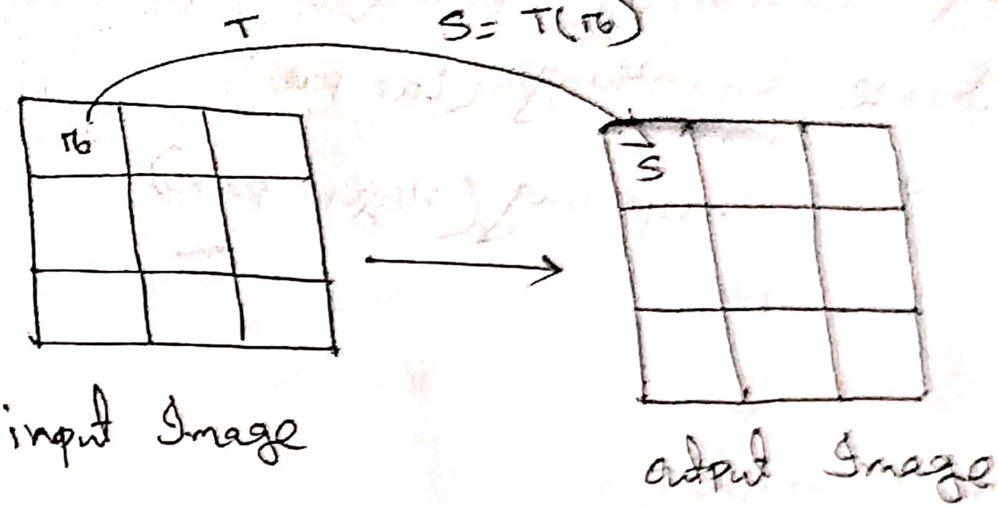
↓ Padding

```
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 0 0 0 0 0
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
0 0 0 0 0 0 0 0 0
```

initial position →

```
1 2 3 0 0 0 0 0 0
4 5 6 0 0 0 0 0 0
7 8 9 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
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
0 0 0 0 0 0 0 0 0
```

Smoothing Spatial Filters: (to remove noise)



Smoothing → Low pass filter.

Sharpening → High " "

input image

12	15	20
25	10	50
30	5	0

→ output 1

12	15	20
25	10	50
30	5	0

Filter 1

0	0	0
0	1	0
0	0	0

Filter2 (as 3x3 matrix)

$\frac{1}{9} *$

1	1	1
1	1	1
1	1	1

→ output 2

12	15	20
25	18	50
30	5	0

Average filter.

Avg.

$$\frac{1}{9}\left((1\times12)+(1\times15)+20 +25+10+50 +30+5+0 \right)$$

Salt & pepper Noise

Median filter

0 5 7 12 15 20 25 30 255

↑

median 15

12	15	20
25	255	7
30	5	0

$\xrightarrow{\text{Median filter}}$

12	15	20
25	15	7
30	5	0

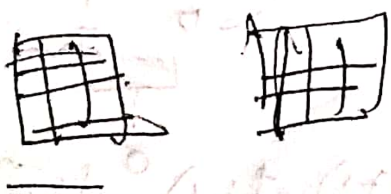
—x—

13.02.19

3x3

256x 256

n x m   m x z



—x—

13.02.19

Spatial Filtering:

"LAB" 14.02.19.

Hw. → Image Filtering
(using average, max, min, median)

—x—

18.02.19

Sharpening Spatial filters:

[High Pass filters]

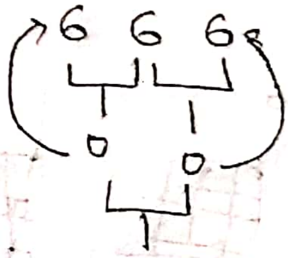
derivative:

$$\frac{\delta f}{\delta x} = f(x+1) - f(x).$$

6	6	6	6	5	4	3	2	1	1	1	1	1	1	6	6	6	6

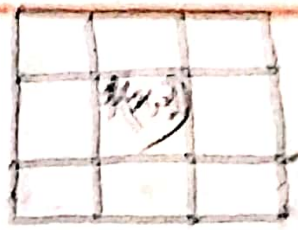
$\frac{\partial f}{\partial x}$ 0 0 0 -1 -1 -1 -1 -1 0 0 0 0 0 5 0 0 0

$\frac{\partial^2 f}{\partial x}$ 0 0 -1 0 0 0 0 1 0 0 0 0 5 -5 0 0



$$\frac{\partial^2 f}{\partial x} = f(x+1) - f(x) - f(x) + f(x-1)$$
$$= f(x+1) + f(x-1) - 2f(x).$$

$$\frac{\partial^2 f}{\partial y} = f(y+1) + f(y-1) - 2f(y)$$



operator)

$$\frac{\partial^2 f}{\partial^2 x} + \frac{\partial^2 f}{\partial y} = f(x+1) + f(x-1) - 2f(x) + f(y+1) + f(y-1) - 2f(y)$$

$$= f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1) - 4f(x,y)$$

Mask:

	1	
1	−4	1

2nd order derivative.

20.02.19.

CT-2

27.02.19.

10:00 AM

Syllabus:

1 Spatial Filtering

- Image smoothing
- Image sharpening

—x—

"External" 20.02.19.

Agenda:

1. Image enhancement
2. Image processing using python

Image Enhancement in Frequency Domain:

Basics of Frequency Domain Filtering:

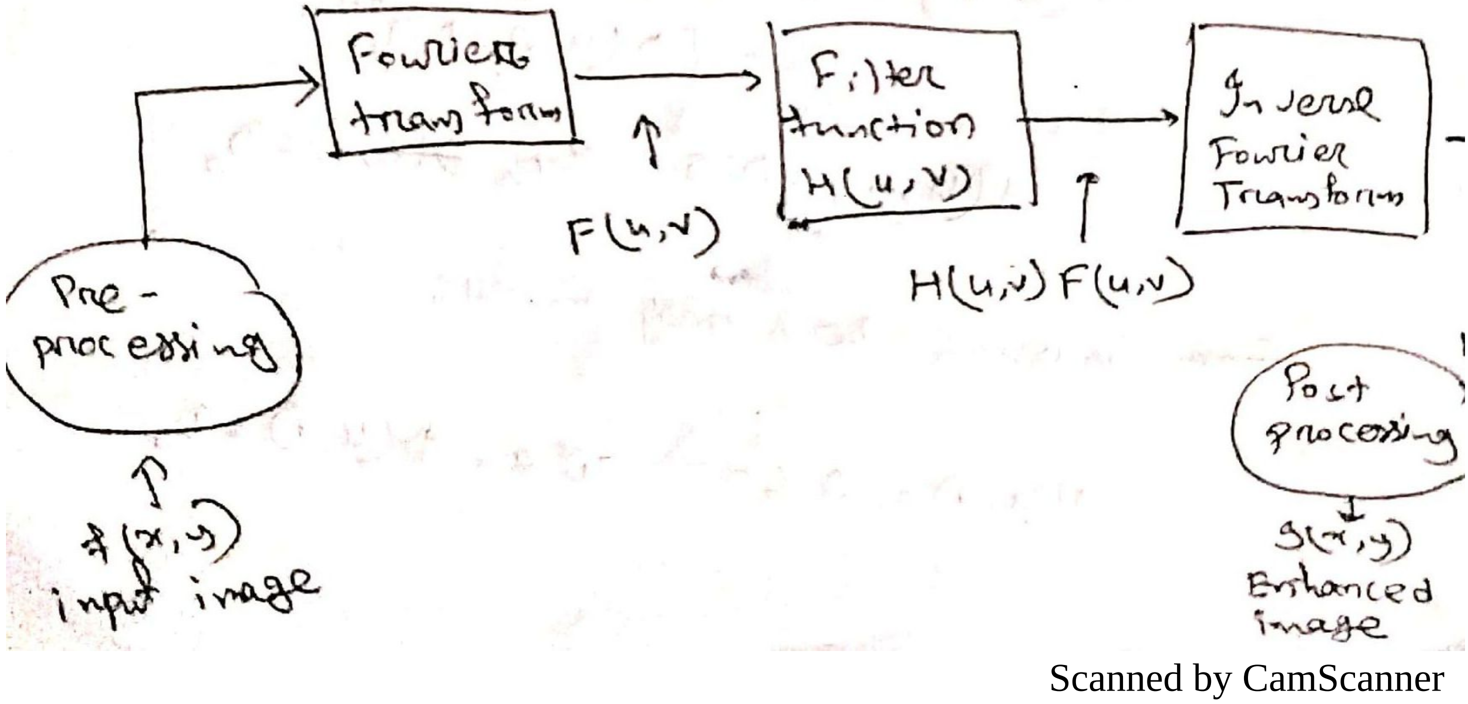
continuous time → Discrete time → Discrete Fourier Transform (DFT)

DFT of the image; $F(u,v) \longrightarrow F(u,v) *$ filter function $(H(u,v))$

↓

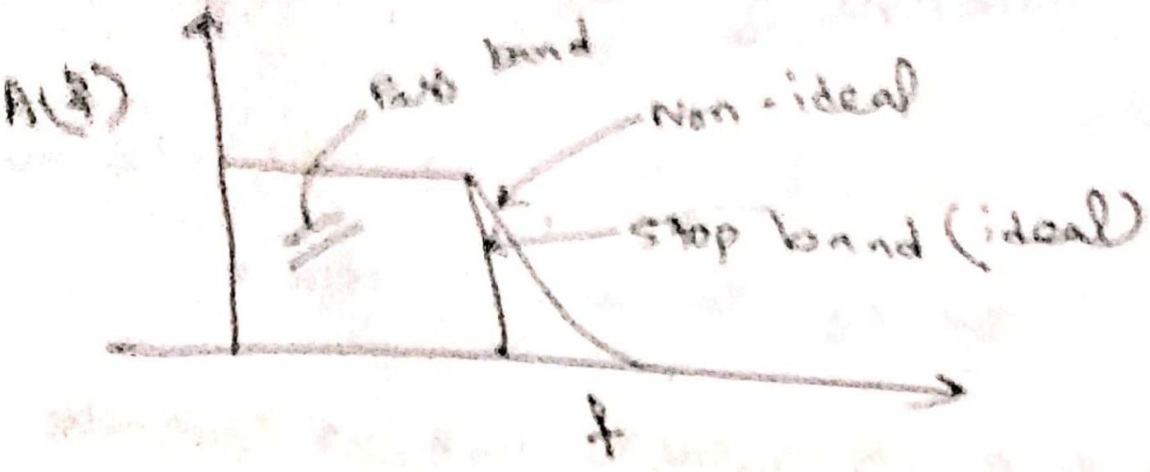
inverse DFT

Basic Steps:



Time domain filtering → convolution.

Ideal Low Pass Filter:



Smoothing Frequency Domain Filters:

G(u,v)

$\boxed{\text{Cut-off Frequency}}$

Butterworth Lowpass Filter:

Does not have sharp discontinuity,

$$H(u,v) = \frac{1}{1 + [D(u,v)/D_0]^{2n}}$$

$H(u,v) = 0.5$ when $D(u,v) = D_0$

~~Gau~~ Gaussian Low pass Filter:

$H(u,v) = 0.607$ when $D(u,v) = D_0$

Scanned by CamScanner

Convolution in the time domain is filtering in frequency domain.

Sharpening Frequency Domain Filters:

High Pass Filtering

$$H_{hp}(u,v) = 1 - H_{lp}(u,v)$$

Smoothing → Low pass Filter

Sharpening → High pass Filter.

Does not have sharp discontinuity.

$$H(u,v) = \frac{1}{1 + [D_0 / D(u,v)]^{2n}}$$

Gaussian Highpass Filter:

$$H(u,v) = 1 - e^{-\frac{D^2(u,v)}{2D_0^2}}$$

$H(u,v) = 0.607$ when $D(u,v) = D_0$

Scanned by CamScanner

Open CV (Open Computer vision)

—x—

25.02.19

27.02.19

"Histogram Processing"

Histogram equalization

" Matching

Local " processing

Using " statistics for Image enhancement.

CT-2 : 14.03.19

10:50 Am

previous syllabus

Histogram Equalization

+ Spatial filtering

(smoothing + sharpening (laplacian))

Normalized histogram, $P(r_k) = \frac{n_k}{MN}$

1	1	1
2	50	70
5	7	10

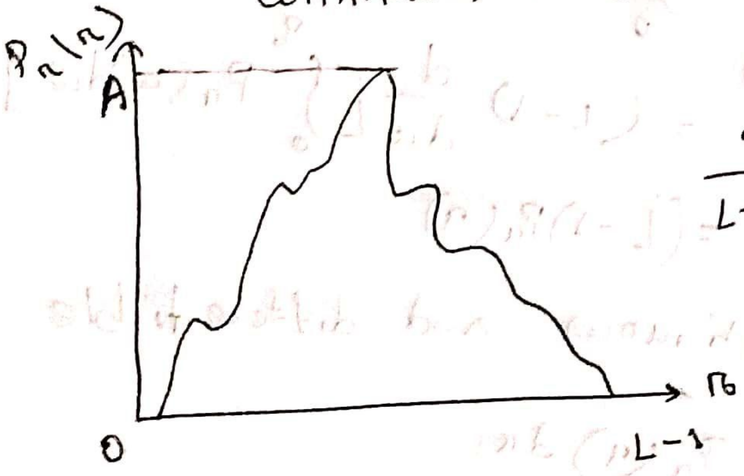
for 1, $= \frac{3}{9} = 0.33$

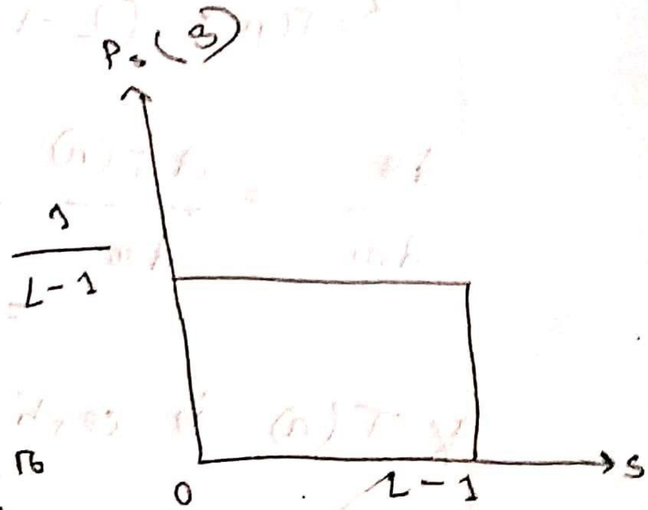
* Histogram Equalization:

(continuous) Pdf → Probability ~~Des~~ Density Function / Factor

(discrete) Pmf → " match "

continuous image.

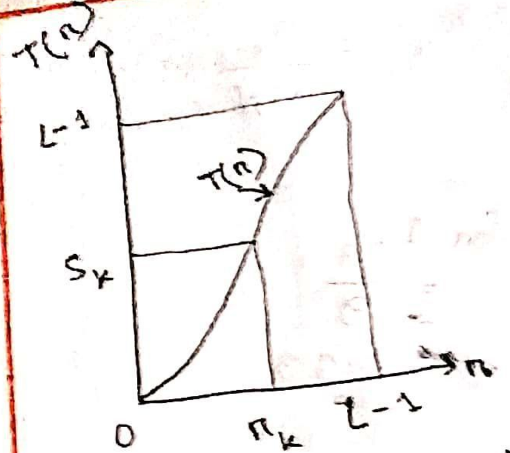




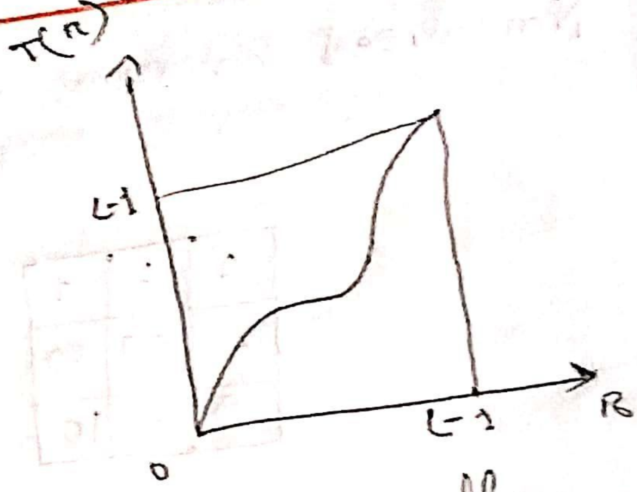
$$s = T(r) \qquad 0 \le r \le L-1$$

(a) $T(r)$ is a strictly monotonically increasing function in the interval $0 \le r \le L-1$

(b) $0 \le T(r) \le L-1$ for $0 \le r \le L-1$.



(a) Strictly monotonically increasing function



Monotonically increasing function, but not strictly.

$$s = T(r) = (L-1)\int_0^r P_r(\omega)\,d\omega$$

$$\frac{ds}{dr} = \frac{dT(r)}{dr} = (L-1)\frac{d}{dr}\left[\int_0^r P_r(\omega)\,d\omega\right]$$

$$= (L-1)P_r(r)$$

* $T(r)$ is continuous and differentiable

$$P_s(s)\,ds = P_r(r)\,dr$$

$$P_s(s) = \frac{P_r(r)\,dr}{ds} = P_r(r) \Big/ \left(\frac{ds}{dr}\right)$$

$$= P_r(r) \Big/ \left((L-1)P_r(r)\right) = \frac{1}{L-1}$$

Discrete values:

$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$$

$$= (L-1)\sum_{j=0}^{k} \frac{n_j}{MN} = \frac{L-1}{MN}\sum_{j=0}^{k} n_j$$

$k = 0, 1, \ldots, L-1.$