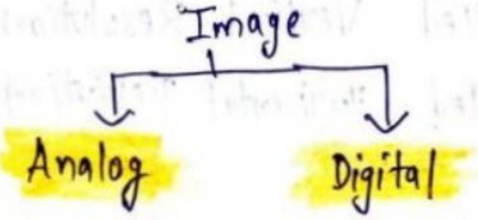
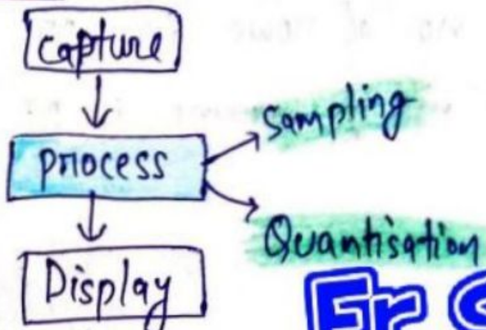
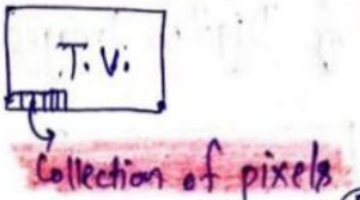
# Digital Image Processing
# [DIP]

## An Introduction to DIP ⇒



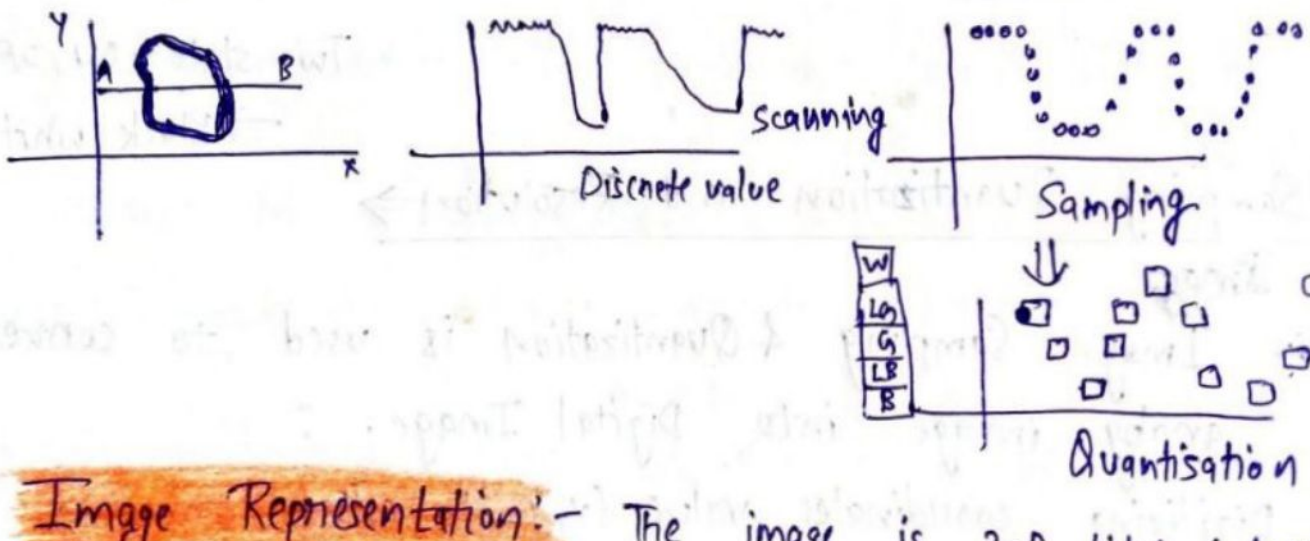


Pixel

RGB millions

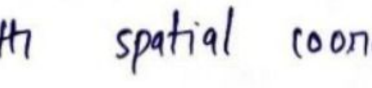


## Sampling & Quantisation :-




## Image Representation :-

The image is 2-D light intensity function $f(x,y)$. It is certified in both spatial coordinates and brightness.




$$0 < f(x,y) < \infty$$

$$f(x,y) = r(x,y) * i(x,y)$$

where

$$0 < r(x,y) < 1 \quad \text{and} \quad 0 < i(x,y) < \infty$$

$r(x,y)$ = Reflectivity of surface of corresponding image point.

$i(x,y)$ = Intensity of incident light.

object based on the information provided by its description.

**Knowledge Base**:- knowledge about a problem domain is coded into an image processing system in the form of a knowledge database.

## Introduction to Color Image Representation ⇒

Color is a powerful descriptor which simplifies object identification & extraction from a scene.

It is divided into 2 major categories:-

(i) Full color :- Eg-TV

(ii) Pseudo-color :- to a particular monochrome intensity or range of intensities. It is grayscale.

## * Characteristic of light:-

Radiance (Watts-W) :- Total amount of energy coming out of light source.

Luminance (Lumens-lm) :- measure of amount of energy an observer perceives from light source.

Brightness (no unit):- It is subjective measure that is practically impossible to measure.

It is corresponds to achromatic attribute of intensity.

## * Primary and Secondary Colors:-

Blue = 435.8nm , Green = 546.1nm , Red = 700nm

Color Image Representation

Magneta = Red + Blue

Cyan = Green + Blue

Yellow = Red + Green

### 3 attributes of color:-

→ Luminance (brightness)

→ Chrominance - Hue & Saturation

→ Represented by a "color cone"

| RGB | vs | CMY |
|---|---|---|
| Magneta = Red + Blue | | Magneta = White - Green |
| Cyan = Blue + Green | | Cyan = White - Red |
| Yellow = Green + Red | | Yellow = white - Blue |

### Color Representation Models:-

→ Three primary colors:- RGB, CMY, XYZ

→ Luminance & chrominance:- HSI, YIQ, $YC_bC_r$

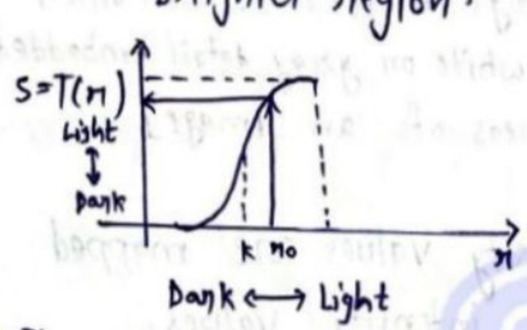
HSI: H ↓ Hue, S ↓ Saturation, I ↓ Intensity

**Pseudo color**:- To artifically assign colors to a grey scale.

# Image Enhancement Technique

## Contrast stretching

- Used to Enhance quality of image
- $r<k$, it will be mapped to narrow range of intensity levels towards dark region.
- To increase dynamic range of modified image.
- $r>k$, it will be mapped towards brighter region.




- It expands range of intensity levels in image so that it spans the full intensity range of recording medium or display device.

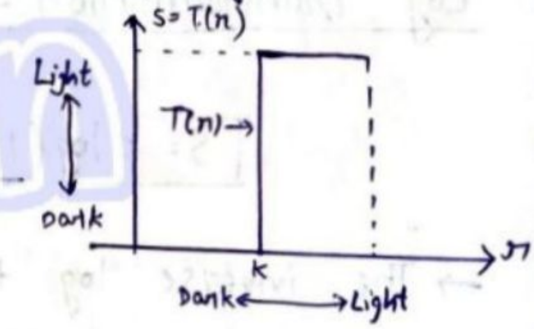
## Image thresholding

It is applied once to an input image it gives Binary o/p image.

Based on value of k.

$r<k$, assigned with black intensity level.

$r>k$, assigned with white intensity level.




# Histogram Equalization

**Histogram** is a graph showing no. of pixels in an image at each different value found in that image.

Eg – 8 bit grayscale image & 256 different possible intensities

**Histogram Equalization**:— This method is to boost the global contrast of an image it look more visible.

$$h(v) = \text{round}\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L-1)\right)$$

CDF → cumulative distribution function

L → max. intensity value (256)

M → image width, N → image height

h(v) → equalized value.

**Q.** Convert RGB values to HSI in range [0-1]

$R = 24, \quad G = 98, \quad B = 118$

**Ans-**

$R = \frac{24}{255} = 0.09 \quad ; \quad G = \frac{98}{255} = 0.38, \quad B = \frac{118}{255} = 0.46$

**HSI**

$$I :- \frac{1}{3}(R+G+B) = \frac{1}{3} \times (0.09 + 0.38 + 0.46)$$

$$\boxed{I = \frac{0.93}{3} = 0.31}$$

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

$$S = 1 - \frac{3}{0.09+0.38+0.46} \min(0.09, 0.38, 0.46)$$

$$S = 1 - \frac{3}{0.93} \times 0.09$$

$$S = 1 - \frac{0.09}{0.31} = 1 - 0.29 = 0.71$$

$$\boxed{S = 0.71}$$

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

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

$$\theta = \cos^{-1}\left( \frac{\frac{1}{2}((0.09 - 0.38) + (0.09 - 0.46))}{\sqrt{(0.09 - 0.38)^2 + (0.09 - 0.46)(0.38 - 0.46)}} \right)$$

$$\theta = \cos^{-1}\left( \frac{\frac{1}{2}((-0.29) - 0.37))}{\sqrt{(-0.29)^2 + (-0.37)(-0.08)}} \right) = \cos^{-1}\left( \frac{-0.33}{\sqrt{0.1137}} \right)$$

$$\theta = \cos^{-1}\left( \frac{-0.33}{0.33} \right) = \cos^{-1}(-1) = 180^\circ$$

$$H = 360^\circ - \theta = 360^\circ - 180^\circ = \boxed{180^\circ = H}$$

## Fourier Transformation ⇒ It is an image processing tool which is used to decompose an image into its sine and consine components.

→ The o/p of transformation represents image in fourier or frequency domain, while i/p image is spatial domain.

- Continuous & Discrete Fourier Transform
- Properties of fourier transform

**Fourier transformation:-**

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

**Inverse fourier transformation:-**

$$F^{-1}(F(u)) = f(x) = \int_{-\infty}^{\infty} F(u) \cdot e^{-j2\pi ux} \cdot du$$

where $x$ is time in seconds, units of $u$ are Hz or cycles/sec.

Fourier transformation Pair

$F(u) \rightarrow$ fourier transform of signal $f(x)$

$F(x) \rightarrow$ Original Signal

**Complex function** $F(u) = R(u) + j\, I(u)$

**Magnitude** of FT:- $|F(u)| = \sqrt{R^2(u) + I^2(u)}$

**Phase** :- $\phi(F(u)) = \tan^{-1} \frac{I(u)}{R(u)}$

**Magnitude - Phase:-** $F(u) = |F(u)|\, e^{j\phi(u)}$

**Power of $f(x)$:-** $|F(u)|^2 = R^2(u) + I^2(u)$

denoise 2 dimensional signals. It is a time-frequency analysis method which selects the appropriate frequency band adaptively based on characteristics of the signal.

$$f(x) = \sum_k c_{j_0}(k)\,\phi_{j_0,k}(x) + \sum_{j=j_0}^{\infty}\sum_k d_j(k)\,\psi_{j,k}(x)$$

**Scaling coefficients:**

$$c_{j_0}(k) = \int f(x)\,\phi_{j_0,k}(x)\,dx$$

**wavelet coefficients:** $d_j(k) = \int f(x)\,\psi_{j,k}(x)\,dx$

**DWT :-** $$f(n) = \frac{1}{\sqrt{M}}\sum_k W_\phi(j_0,k)\,\phi_{j_0,k}(n) + \frac{1}{\sqrt{M}}\sum_{j=j_0}^{\infty}\sum_k W_\psi(j,k)\,\psi_{j,k}(n)$$

**Scaling coefficients** $$W_\phi(j_0,k) = \frac{1}{\sqrt{M}}\sum_{n=0}^{M-1} f(n)\,\phi_{j_0,k}(n)$$

**Details coefficients** $$W_\psi(j,k) = \frac{1}{\sqrt{M}}\sum_{n=0}^{M-1} f(n)\,\psi_{j_0,k}(n) \quad \text{for } j \geq J_0$$

$$M = 2^J, \quad J_0 = 0$$

**2-D Wavelet Transform:-** We need 2D scaling function & 3 2-D wavelet functions are required.

$$\phi(x,y) = \phi(x)\,\phi(y)$$

**variations along columns** $\psi^H(x,y) = \psi(x)\,\phi(y)$

**variations along rows** $\psi^V(x,y) = \phi(x)\,\psi(y)$

**variations along diagonals** $\psi^D(x,y) = \psi(x)\,\psi(y)$

$$W_\phi(j_0,m,n) = \frac{1}{\sqrt{MN}}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)\,\phi_{j_0,m,n}(m,n)$$

$$W_\phi^i(j,m,n) = \frac{1}{\sqrt{MN}}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)\,\psi^i_{j_0,m,n}(m,n), \quad i = \{H,V,D\}$$

Inverse:-

$$f(m,n) = \frac{1}{\sqrt{MN}}\sum_m\sum_n W_\phi(j_0,m,n)\,\phi_{j_0,m,n}(m,n) + \frac{1}{\sqrt{MN}}\sum_{i=H,D,V}\sum_{j=j_0}^{\infty}\sum_m\sum_n W_\psi^i(j,m,n,k)\,\psi^i_{j,m,n}(m,n)$$

$j_0 = 0, \quad N = M = 2^J$

$m = n = 0,1,2 \ldots M-1, \quad j = 0,1,2 \ldots J-1, \quad k = 0,1,2 \ldots 2^J - 1$

Q2 **Noise**:- It is random variation of brightness or color info in image captured.

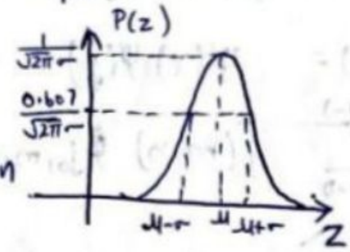
(A) Sources of image Noise:- Sending, Sensor heat, ISO factor

## Types of Noise Models ⇒ Probability density function (PDF)

### (i) Gaussian Noise: [Normal noise model]

$$P(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(z-\mu)^2/2\sigma^2}$$

- $z \to$ gray level
- $\mu \to$ mean of $z$
- $\sigma \to$ standard deviation
- $\sigma^2 \to$ variance



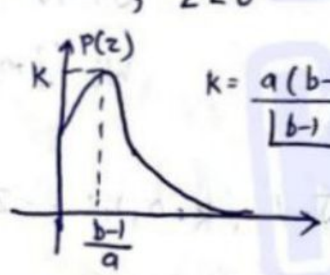

70% of values → $[(\mu-\sigma), (\mu+\sigma)]$

### (ii) Gamma Noise:-

$$P(z) = \begin{cases} \frac{a^b z^{b-1}}{(b-1)!} e^{-az}, & z \geq 0 \\ 0, & z < 0 \end{cases}$$

mean: $\mu = b/a$

variance: $\sigma^2 = b/a^2$



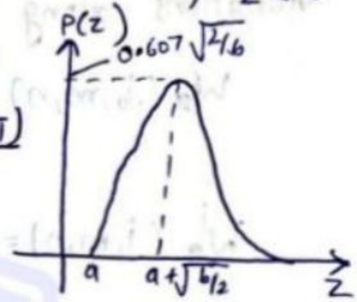

$$K = \frac{a(b-1)^{b-1}}{\lfloor b-1} e^{-(b-1)}$$

### (iii) Rayleigh Noise:-

$$P(z) = \begin{cases} \frac{2}{b}(z-a) e^{-(z-a)^2/b} ; & z \geq a \\ 0 ; & z < a \end{cases}$$

mean: $\mu = a + \sqrt{\pi b/4}$

Variance: $\sigma^2 = \frac{b(4-\pi)}{4}$

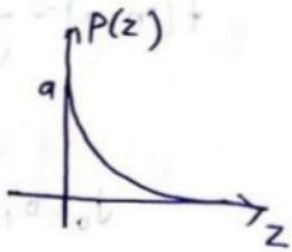



### (iv) Exponential Noise:-

$$P(z) = \begin{cases} a \cdot e^{-az}, & z \geq 0 \\ 0, & z < 0 \end{cases}$$

$\mu = 1/a$

$\sigma^2 = \frac{1}{a^2}$

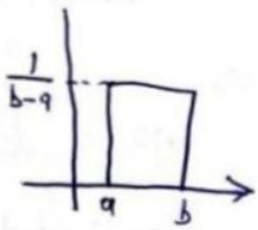



### (v) Uniform Noise:-

$$P(z) = \begin{cases} \frac{1}{b-a} ; & a \leq z \leq b \\ 0 ; & \text{otherwise} \end{cases}$$

$\mu = (a+b)/2$

$\sigma^2 = \frac{(b-a)^2}{12}$




$m = \frac{a+b}{2}$, $\sigma^2 = \frac{(b-a)^2}{12}$

### (vi) Salt & Pepper Noise [Impulse Noise]:-

$$P(z) = \begin{cases} P_a & ; z = a \\ P_b & ; z = b \\ 0 & ; \text{otherwise} \end{cases}$$


if $b > a \Rightarrow$ graylevel $b \to$ light dot
gray level $a \to$ dark dot

$P_a = 0$ or $P_b = 0 \to$ unipolar

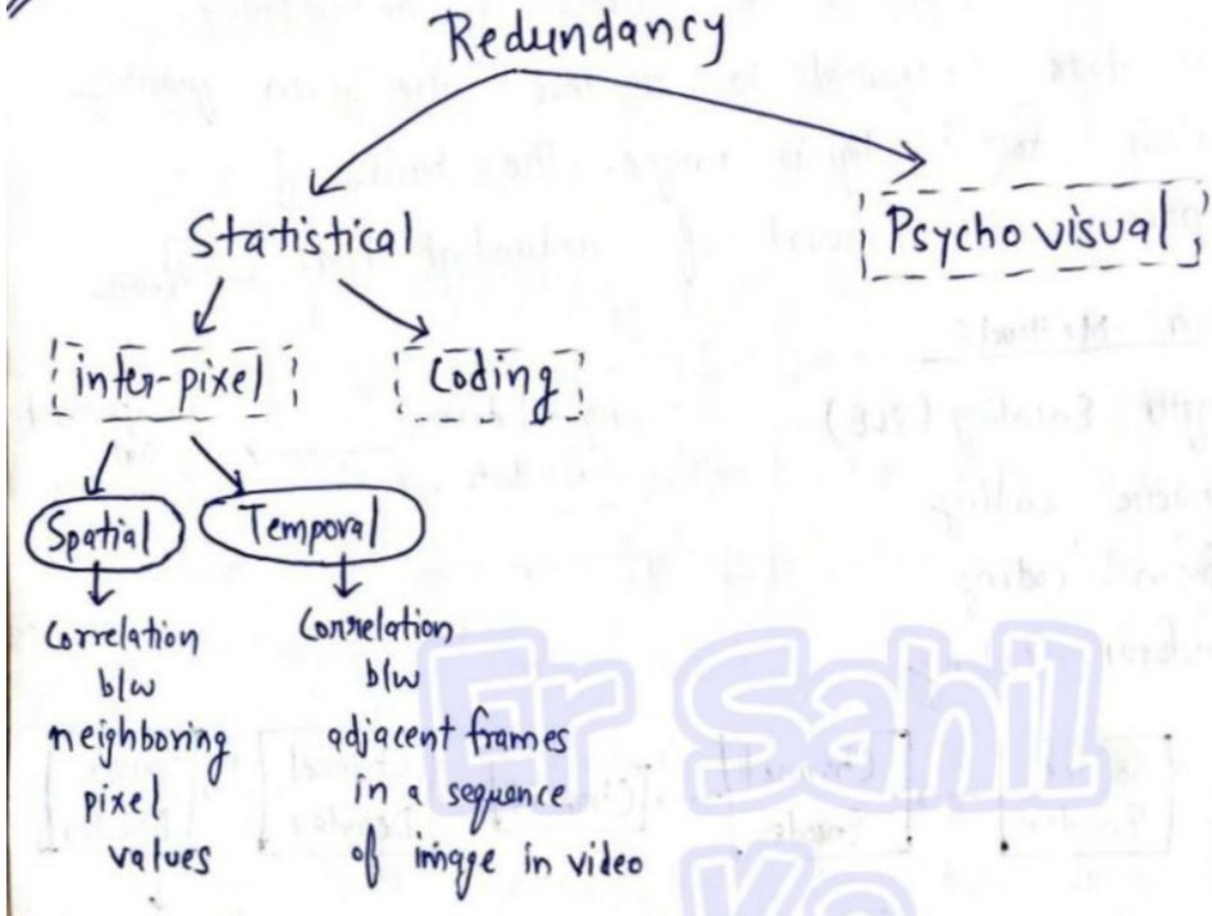
$P_a \simeq P_b \to$ Salt & pepper granules

-ve impulses → Black (Pepper) point

+ve impulses → White (Salt) point

8 bit = $a = 0$ (Black)
$b = 255$ (white)

**Redundancy** ⇒ Redundancy means repetitive data.




(i) **Coding Redundancy** :- • It happens due to poor selection of coding technique.

- Wrong choice of coding technique create unnecessary additional bits. These extra bits are called redundancy.

★ **Coding Redundancy = Average bits used to code − Entropy**

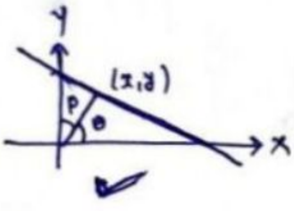
$$CR = \sum_{k=0}^{n} l(r_k) \cdot p(r_k) - H$$

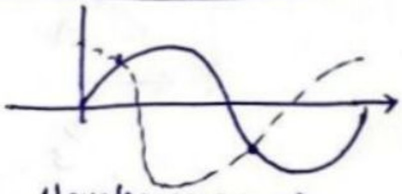
$l(r_k)$ → length of code; $p(r_k)$ → probability; $r_k$ → greylevel; $H \rightarrow -\sum_{i=1}^{n} P_i \log_2(P_i)$

$$CR = \sum_{k=0}^{n} l(r_k) \cdot p(r_k) - \sum P_i \log_2\left(\frac{1}{P_i}\right)$$

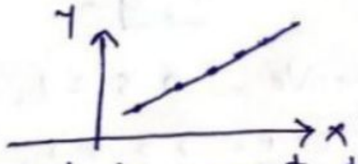
Line's equation $y = mx + c$ into single point in $(p, \theta)$ plane

$p = x\cos\theta + y\sin\theta$



Houghspace $(p, \theta)$




(used to connect disjoint edge points)

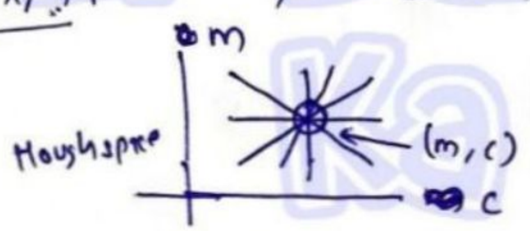
→ Hough Transform approach is to find the points of intersection in the curves, each of which corresponds to a line in the Cartesian xy plane.

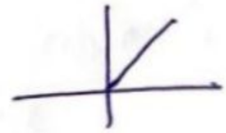
$p = x\cos\theta + y\sin\theta$

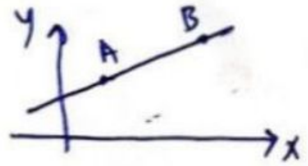
in circle $(x-a)^2 + (y-b)^2 = r^2$

$\Rightarrow$ $y_i = mx_i + c$ $\Rightarrow$ $c = -x_i m + y_i$

Steps Hough Transform






$\Rightarrow$


in Hough Space

$\Rightarrow$ find local maxima in parameter space

Region Based Segmentation:— Region growing is a procedure that groups pixels into large regions based on predefined criteria for growth.

→ $f(x,y)$ denotes an input image array.

→ $S(x,y)$ denotes a seed array containing 1s at locations of seed points.

→ $Q$ denote a predicate to be applied at each location.

→ Array f & S are same size

Er Sahil ka Gyan

# 🔥 Steps for getting NOTES and Most Questions -

👉 Do payment using UPI ID -

sahilkagyan337@ybl

👉 Take screenshot of transaction and send me on Email -

ersahildrive@gmail.com

Then finally access all Notes and most questions 🔥

Scan & Pay Using PhonePe App

SAHIL KHAN