12:52 Pm [27 January 2023]

Digital Image Processing

Topics and [BSc Sem-V VBU CS] Syllabus

- Pixel Relationship
  - Pixel
  - Pixel Neighbourhood and type of Neighbourhood.
  - Pixel connectivity
  - Con. Define Connectivity in Grey level
  - Mixed connectivity
  - Connected Component
  - Connected Component Label
  - Algorithm (Group Identification)
  - Algorithm Steps
  - Algorithm Demo
  - Distance Measure and technique
  - Arithmatic/Logical Operators

- Neighbourhood Operation

- Image Enhancement
  - Image Enhancement main concept.
  - Spatial Domain Technique
  - Frequency Domain Technique
    - point processing Techniques
    - Histogram Based Techniques
    - Mask Processing Technique
      - Image Negative
      - Contrast streching
      - Gray level slicing and result
      - Histogram equalization
      - Histogram Specification/Matching
      - Histogram Exercise
  - Image Differencing
  - Application Image Differencing

Image Averaging and result

Mask Processing Techniques

- Linear ~~Smooth~~ Smoothing Filters
- Median Filter (non-Linear)
- Sharpening Filter

Desirable Response of Derivative Filters

- First Order Derivative Filter
- Second Order Derivative Filter

Observation

Laplacian Operators and result

Introduction

- Introduction To Digital Image Processing
- Importance of Image Processing
- Noise filtering
- Contrast Enhancement
  - contrast Enhancement, Deblurring

Image Registration

- Image Registration Concept
- Application of Image Registration
- Template Matching
- Match / Similarity Measure
- Match or Mismatch Measure
- Cauchy - Schwartz - Inequality
- Normalized Cross - Correlation

- Remote Sensing
- Weather Forecasting, Atmospheric Study
- Machine Vision Application
- Astronomy
- Automated Inspection
- Image Digitization
- Image Compression
  - Lossless
  - Lossy
- Sampling
- Convolution
- Aliasing
- Image Representation
- Quantization
- Staircase Quantizer
- Steps In DIP
- Quantization Rule

☐ Color Image Processing

- ☐ Color Image Processing Full Concept ✓
- ☐ Full color processing
- ☐ Pseudo Color Processing ✓

☐ Color Fundamental ✓

- ☐ Attributes of Color ✓
- ☐ ☐ Achromatic light ✓
  - ☐ Chromatic light ✓

☐ Electromagnetic Spectrum ✓

☐ Quality of light ✓

- ☐ Radiance ✓
- ☐ Luminance ✓
- ☐ Brightness ✓

☐ Primary Colours ✓

☐ Secondary Colours ✓

- Colour characteristics [Brightness, Hue, Saturation]
  Hue + Saturation → Chromacity
- Tristimulas
- Chromatic Diagram
- Color Model
  - RGB Model
  - CMY & CMYK Model
  - HSI Model
    - RGB To HSI Conversion
  - Colour Perception in HSI Model
- Pseudo color Image Processing
  - Intensity Slicing
  - Gray To colour Transmission
- Full colour Image Processing
  - colour Transformation
  - Colour Image Smoothing
  - Colour Image Sharpening

- Per-Colour-Plane Processing
- Vector Based Processing

- Colour Transformation

- Application of Colour Transformation
  - Intensity Modification and result
- Colour Complement
- Colour Slicing and result
- Tone Correction
- Smoothening
- Averaging result
- Sharpening and result

Extra Topics

- Mean and Median filtering
- Types of Neighborhood
- Translation, Rotation, Scaling
- Adjacency and Connectivity
- lossy and lossless compression

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Digital Image Processing

Topic: Hand Notes Starts here →

- A digital image processing is processing of image which is digital in nature.

↳ A digital image is an image composed of picture elements, also known as pixels, each with finite discrete quantites of numeric representation for its intensity or grey level that is an output from its <u>2-D functions</u> fed as input by its spatial coordinates denoted by x and y on the x-axis and y-axis respectively.

↳ The 2-D function can be written as $f(x, y)$ where x and y are spatial coordinates.

↳ The amplitude of "f" is called intensity or gray level at the point (x,y).

Digital Image Processing

It is the use of a digital computer to process digital images through an algorithm. It covers low, mid and high-level processes.

→ low-level : inputs and outputs are image

→ mid-level : outputs are attributes extracted from input images.

→ High-level : an ensemble of recognition of individual objects.

Pixel

It is the smallest controllable element in a picture represented on the screen.

[If we have a 8-bit grayscale picture
Then its intensity is 0-255]

→ we know that an object is represented in the form of a 2-D image.

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Neighbourhood, Grey level color slicing, Histogram, ~~Color~~ Image Processing, Contrast Streching, Image Registration

Mean & Median
Laplacian, RGB to HSI
Digitization, Compression

[Nptel Playlist]

[1, 2, 3, 6, 7, 8, 9, 10, 16, 17, 30, 32, 33, 34, 35,
36, 37, 38, 39, 40, 48, 49, 50, 51, 52, 53, 54, 55]

→ 17 ESE

→ For an image to be produced there should be a light source illuminating the object.

→ When an image is generated from a physical process, its value are proportional to the energy radiated by a physical source [ex: electromagnetic wave]

↳ also, the intensity/amptitud of 'f' at any spacial coordinates is a positive scalar quantity whose physical meaning is determined by the souce of the image.

↳ Therefore, the function must be non-zero and finite, ie,

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

↳ The function may be characterized by 2 components:

→ The amount of source illumination incident on the scene being viewed.

→ The amount of illumination reflected by the objects in the scene.

↳ These illumination and reflectance components can be denoted by $i(x,y)$ and $r(x,y)$ respectively.

→ These 2 functions combine to form f(x,y);

$$\boxed{f(x,y) = i(x,y) * r(x,y)}$$

where, $f(x,y)$: intensity at the point (x,y)

$i(x,y)$: illumination at the point (x,y)

$r(x,y)$: reflectance/transmissivity at the point (x,y)

$$0 \leq i(x,y) < \infty$$

$$0 \leq r(x,y) \leq 1$$

→ Reflectance is bounded by 0 (total absorption) and 1 (total reflectance)

→ The nature of $i(x,y)$ is determined by the illumination source.

→ The nature of $r(x,y)$ is determined by the characteristics of the image objects.

CamScanner

Importance of Image Processing

Enhancing pictorial Information.

Improving the pictorial information for human interpretation.

- Noise Filtering
- content enhancements
  - ↳ Contrast Enhancement (Low to High contrast)
  - ↳ Deblurring (Hazy image to clear image)

Remote Sensing

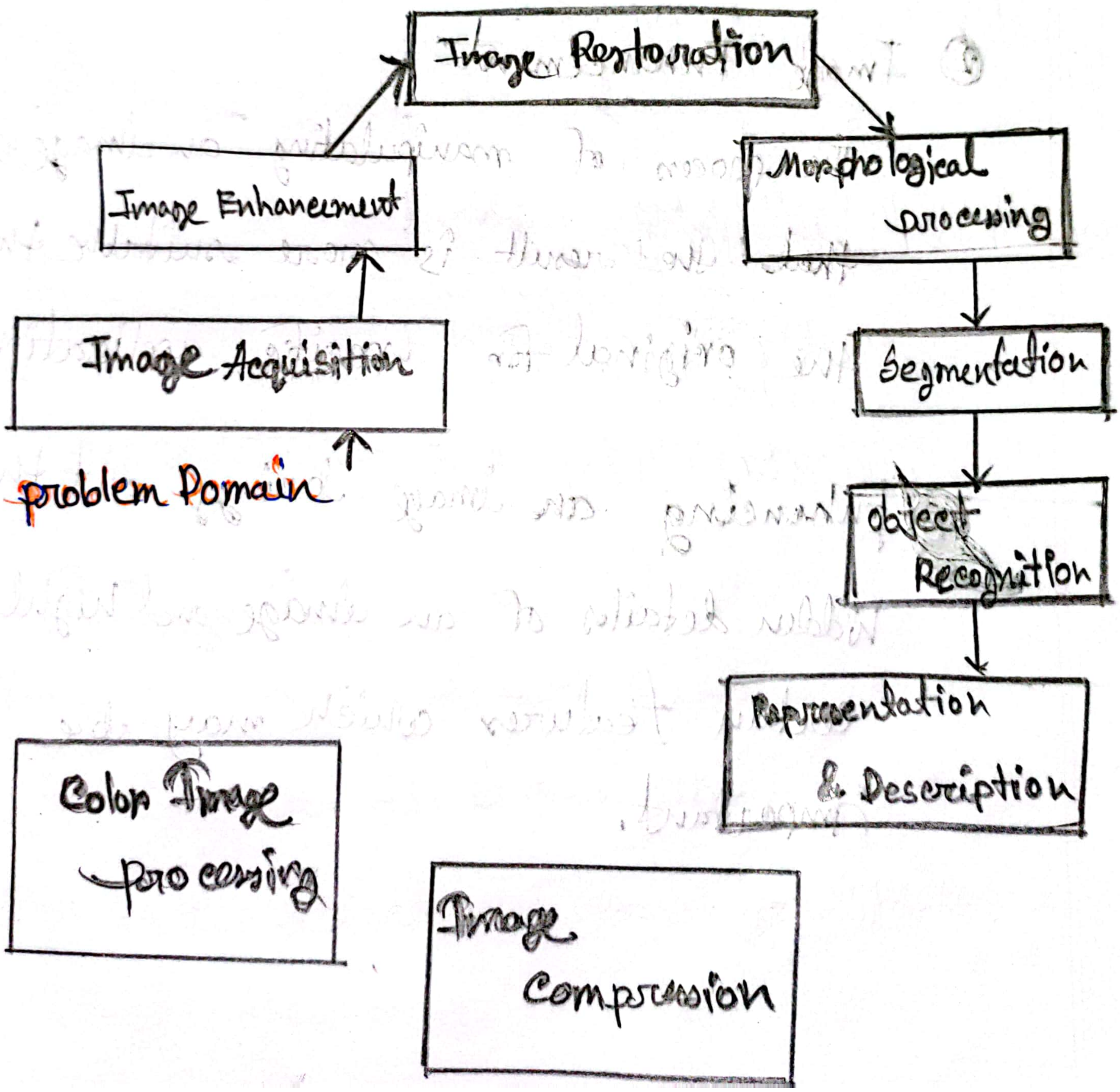
- ↳ weather forecasting
- ↳ Atmospheric study
- ↳ Astronomy

Machine Vision Application

- Image processing for Autonomous machine application (Medical, Mechanical Engg etc)
  - ↳ Industrial Machine vision for Product Assembly & inspection

- Automated Target detection & Tracking.
- Fingerprint Recognition.
- Satelite Image for weather forecasting.
- Movement Detection.

Key Stages or Steps of DIP



① Image Acquisition

→ The image is captured by a sensor (camera) and digitized if the output of the camera or sensor is not ready in digital form, using analogue-to-digital converter.

② Image Enhancement

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

Enhancing an image brings out the hidden details of an image and highlights certain features which may be important.

③ Image Restoration

The process of improving the appearance of an image this maily ~~incl~~ includes mathematical or probabilistic models of Image degradation ~~is~~ instead of human subjective preferences used in enhancement.

④ Morphological Processing

It deals with tools for extracting image components that are usefull in the representation and description of shape

⑤ Image Segmentation

Segmentation procedures partition an image into its ~~o~~ constituent parts or objects.

The more accurate the segmentation the more likely the recognition is to succeed.

⑥ Object Recognition

The process that assigns a label to an object based on the information [redacted] provided by its description.

⑦ Representation and description

choosing a representation is only part of the solution for transforming raw data into a form suitable for subsequent computer processing (mainly recognition)

Description: also called feature selection, deals with extracting attributes that result in some information of interest.

(8) Image Compression

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

- Image compression is needed for efficient storage and transmission of an image.

- An image contains a lot of redundancy that can be exploited to achieve compression.
  - Pixel redundancy
  - Coding redundancy
  - Psycho visual Redundancy

- Image contain two entity "information" and "Redundancy". In image compression we try to keep information content intact and we are removing the redundancy

CamScanner

Lossless Image Compression

- Only the redundancy is removed. The information remains intact.
- In case of medicine science we can not afford to loss any information.

Lossy Compression

- Loss of information can be compromised for some cases so we can afford to do lossy compression (in case of photographic Image some information loss can not affect the quality of the image)

S.No.	Lossless Data Comp.	Lossy data comp.
①	There is no loss of any data and quality.	There is a loss of quality and data, which is not measurable.
②	The file is restored in its original form.	The file does not restore in its original form.
③	Mainly used to compress text, sound and images.	Mainly used to compress audio, video and images.
④	It holds more data then lossy	It holds less data then lossless
⑤	File quality is ~~low~~ high	File quality is low
⑥	Mainly supports RAW, BMP, PNG, WAV, FLAC and ALAC file types.	Mainly supports JPEG, GIF, MP3, MKV and OGG file types.

Difference between Mean & median Filtering

The mean filter uses the average value of the pixels in a neighborhood to replace the value of the center pixel. The median filter on the other hand, replaces the value of the center pixel with the median value of the pixels in the neighborhood. The main difference between the two is that the mean filter is sensitive to outliers, while the median filter is not. This makes the median filter more effective at removing noise from an image.

⇒ In simple words, noise filtering is a method to remove or reduce the ~~unwant~~ unwanted particles from a Digital Image

Image Filter

It is a technique for modifying or enhanceing an image. As an Example we can filter an image to emphasize certain features or remove other ~~features~~. Image processing operations implemented with filtering include smoothing, sharpening and edge enhancements.

It is a neighbourhood related operation. In this process " any given pixel in the out image is determined by applying some algorithm to the values of the pixels in the neighbourhood of the corresponding ~~Image~~. input Image.

Noise filtering is a set of processes that is performed to remove the noise contained with the data acquired on construction and infastructure sites.

↳ Filtering image Data is a Standard process used in almost all image processing System.

It is used to remove noise from digital image while keeping the details of image preserved.

The choice of filter is determined by,

- ✓ The nature of the task performed by filter.
- ✓ Filter behavior.
- ✓ types of data.

There are 2 types of techniques in Filtering

① Linear

② Non- Linear.

Linear

- Linear filters are used to remove certain types of noise.
  - The linear filters works best with the salt and pepper noise, and Gaussian noise.
  - Gaussian and mean filters.
  - Simple to design

- These filters also
  - tends to blur the sharp edges
  - destroy the lines and ~~and~~ other fine details of image.

Non-Linear

- can preserve edges.
- very effective at removing impulsive noise.

- They are more powerfull then Linear as they do not blur the edges to reduce noise level.
- can be difficult to design.
- Median filter is the Example.

Median Filter

- Median filter is a simple and powerful non-linear filter.
- It is used for reducing the amount of intensity variation between one pixel and other pixel.
- In this filter, we replace pixel value with the median value.
- The median is calculated by first sorting all the pixel value into ascending order and then replace the pixel being calculated with the middle pixel value.
- Salt and the pepper noise is the example.

Dis-Adv → Tends to remove image details when the impulsive noise percentage is more than 0.4%.

Mean Filter

- Mean Filter (average filter) is a simple linear filter.
- Replace each pixel value in an image with the mean value of its neighbors, including itself.
- Gaussian noise.

Adv

✓ Easy To implement.

✓ Used to remove the impulse noise.

dis. Adv

✓ It does not preserve details of image

✓ Some details are removes of image with using the mean filter.

Gaussian Filter

- Gaussian is smoothing filter in the 2D convolution operation that is used to remove noise and blur from image.

- probably the most useful filter
  - although not the ~~fastest~~

- Gaussian filtering is done by convolution each point in the input array with a Gaussian kernel and then summing them all to produce the output array.

[Image Representation]

In CS, the representation of an image can take many forms. Most of the time, it refers to the way that the conveyed information such as color, is coded digitally and how the image is stored.

An image is a 2D light intensity function $f(x,y)$

⇒ A digital image $f(x,y)$ is considered as a matrix whose row, column indices specify a point in the image and the element value identify grey level value at that point.

⇒ These element are refferred to pixel or pel.

Digitization

It is the process of converting information into a digital (i.e. computer-readable) format. The result is the representation of an object, image, sound, document or signal (usually an analog signal) obtained by generating a series of numbers that describe a discrete set of points or samples. The results is called digital representation or, more specifically a digital image, for the object and digital form, for the signal.

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Image Registration

→ Registration is a process which make the pixels in two image precisely coincide to the same point in the scene.

Once registered the image can be fused/combined In a way that improves information [redacted]

[redacted] extraction.

Application of Image Registration

Stereo imaging where two image are taken from different position.

Remote sensing where the image may be taken by different sensor.

Image taken at different instance of time.

Finding a place in a picture where it matches a given pattern or temple. (Automated navigation)

**Once a correspondence is established between the pictures, the study of the link between two or more photos can typically be simply regulated or dealt with. The process of establishing this correlation is known as image registration.

It could be said that Image registration is the process of calculating spatial transforms which align a set of images to a common observational frame of reference, ~~ofthen~~ often one of the images in the set. Registration is a key step in any image analysis or understanding task where different sources of data must be combined. During the registration process, two situations become evident.

[The use of Image Registration]

- Image-Image Registration

⇒ Two or more picture are alligned to integrate ~~to~~ or fuse matching pixels representing the same objects.

- Image to Map Registration

⇒ In this step, the input image is distorted to Match the map information of a base image while keeping its original spatial resolution.

Working of Img. Regi.

There are major four steps that every method of image registration has to go through for image alignment. These could be listed as follows:

- Feature detection
- Feature Matching
- Establishing the transform Model
- Image resampling and transformation.

Feature Detection

Detects closed boundary areas, edges, contours, line intersections, corners etc.

↓

Feature Matching

The correspondence between the features in the reference and sensed image is established.

↓

Transform [redacted] model estimation

aligning the second image with the reference image

↓

Image resampling & Transformation

The detected image is chaged using mapping functions.

Drawbacks

The key disadvantages of correlation approaches are the flatness of the similarity measure maximum (owing to the self-similarity of the picture) and the high processing complexity. The maximum can be successfully sharpened by pre-processing or by applying edge or vector correlation.

Template Matching

Basically, template matching is the process of looking for the location of a template (aka reference) image from the source/input image.

The algorithm is implemented as it can be likened to how a convolution works since the template image slides through the source image one pixel at a time.

The algorithm slides a template image over a source image, creating an output image with pixel values representing similarity. It then locates peaks in the output image to find the template in the source image.

USES

Template matching is primarily used in image recognition and object detection. Template matching with skimage can be used for object detection without training a machine learning model, but it can be as accurate or versatile as neural network models.

Match / Similarity Measure

let $g \rightarrow$ given image

$f \rightarrow$ template image

A similarity measure find over region A

So the similarity measure is given by

① $\max |f-g|$

② $\iint |f-g|$

③ $\iint |f-g|^2$

⇒ Here difference means pixel by pixel difference.

In discrete form we can write

$\iint_A |f-g| = \sum\sum [f(i,j) - g(i,j)]$ for all

$i,j \in A$ [Sum of absolute difference]

$\# \iint_A |f-g| = \sum\sum [f(i,j) - g(i,j)]^2$

For all $i, j \in A$

Sum of difference Square

$\# \iint_A |f-g|^2 = \iint_A f^2 + \iint_A g^2 - 2 \iint_A f.g$

fixed as it is the template image

fixed as it is the bigger image

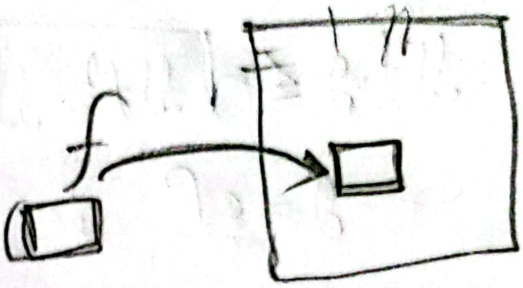
where $\iint_A |f-g|^2$ is mismatch. Hence only its minimum value can give best matching.

$\iint_A f.g \rightarrow$ match measure and only for maximum value match the value of mismatch $\iint_A |f-g|^2$ will be minimum.

$f \qquad g \qquad g$

$\Downarrow$

template/pattern



Match

Given Image $\rightarrow g$ $\qquad$ $A \rightarrow$ region

Template $\rightarrow f$

$$\max_{A} |f - g| \qquad \begin{bmatrix} 5 & 1 \\ 3 & 0 \end{bmatrix} - \begin{bmatrix} 5 & 1 \\ 3 & 2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 2 \end{bmatrix}$$

$$\iint_{A} |f - g| \Rightarrow \sum\sum_{i,j \in A} [|f(i,j) - g(i,j)|]$$

$$\iint_{A} \frac{(f-g)^2}{2} = \sum\sum_{i,j \in A} [f(i,j) - g(i,j)]^2$$

— Instances for

[Cauchy-Schwartz inequality]

$$\iint f \cdot g \le \sqrt{\iint f^2 \cdot \iint g^2}$$

$$g = cf$$

$$\Rightarrow \sum\sum f(i,j) \cdot g(i,j)$$

$$\le \sqrt{\sum_{i,j\in A}\sum f^2(i,j) \cdot \sum_{i,j\in A}\sum g^2(i,j)}$$

$$g(i,j) = cf(i,j)$$

$$\iint_A f(x,y) \cdot g(x+u, y+v)\, dx\, dy$$

$$\le \left[\iint_A f^2(x,y)\, dx\, dy \cdot \iint_A g^2(x+u, y+v)\, dx\, dy\right]$$

not constant

LSH

$$\iint_{-\infty}^{\infty} f(x,y) \cdot g(x+u, y+v)\, dx\, dy.$$

→ Cross correlation between f and g.

$$\iint_{-\infty}^{\infty} f(x,y)\, g(x+u, y+v)\, dx\,dy = C_{fg}$$

$$C_{fg} \Big/ \left[\iint_A g^2(x+u, y+v)\, dx\,dy\right]^{1/2}$$

$$C_{fg} \Big/ \left[\iint_A g(x+u, y+v)\, dx\,dy\right]^{1/2}$$

→ Normalized cross correlation

$$\left[\iint_A f^2(x,y)\, dx\,dy\right]^2$$

$$(u, v)$$

$$g = cf$$

Color Image Processing

- Human eye can distinguishes about thousand numbers of color shade wheather in gray scale ~~image~~ are only distinguishes roughly 2 dozens of shade.

- Color is very powerful descriptor.

- We can use color to identify objects

In Full colour processing we take all the colour considered in the image.

Pseudo Color Processing

- Here we try to assign certain color ~~of~~ to grey level image.
- 0–255 divided in different range
- We can divide range 0–255 into

range 0-50, 50-100, 100-150 and so on.

- And we asign different colour to different range of intensity value into gray scale image.

  - Say 0-50 is colour A

    - we can extract information from gray level image.

Attributes of Color

Achromatic light

- Intensity of light matters.
- Achromatic light: what we observe on black and white television set.
- Grey level refer to scalar measure to intensity that range from black to white.

chromatic light

- wavelength of light matters
- The chromatic light span in the electromagnetic spectrum from 400 nm to 700 nm

UV	visible spectrum	Infrared
200	400 500 600 700	1000 1500

Quality of light

Radiance

⇒ It is the total amount of energy coming out of the light source

⇒ It's measuring unit is Watt

Luminance

⇒ It is the amount of energy perceive by object.

⇒ Its measuring unit is lumens.

Brightness

⇒ It is only the practical observation.

⇒ We can not measure it.

[Primary Colors]

⇒ Red, Green, Blue are the three primary colors.

⇒ By mixing these colors in different proportions we can generate different colors.

We choose RGB as primary color as there are around 6 to 7 million cone cells in our eye for sensing colours.

among them,

65% of cone cell sense Red
33% of " " " Green
2% of " " " Blue

[Secondary color]

⇒ Primary colors are combined to create secondary color.

Red + Blue = Magenta

Green + Blue = Cyan

Red + Green = Yellow

[Color Characteristics]

Brightness

⇒ It is nothing but chromatic notion of intensity.

⇒ It gives the sensation.

Hue

⇒ It represents the dominant (color) wavelength in a mixture of color.

Saturation

⇒ ~~what~~ It describes the purity of a colour and along with hue and value it represents one of the three properties of colour.

Hue and ~~it~~ Saturation together represents chromaticity.

[Tristimulus]

The amount of red, green and blue to form any particular colour is known as tristimulus value and it is denoted as X, Y and Z.

A colour is then ~~denoted~~ specified by its tri-chromatic co-efficient and defined as;

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

and

$$z = \frac{Z}{X+Y+Z}$$

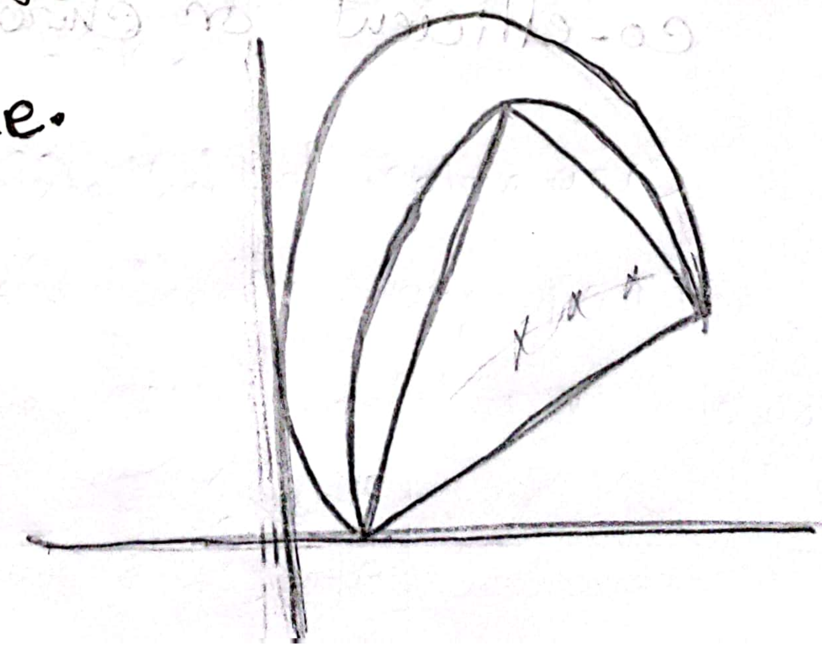
Sum of the co-efficient is

$$x+y+z = 1$$

[Color can be specified by chromatic co-efficient or chromatic diagram.]

Chromatic Diagram

- Using the chromatic diagram we can obtain any color.
- A straight joining any two point in the chromatic diagram define different colors along that line.
- To determine the range of color that can be obtained from any three point in the chromatic diagram is found by simply joining those three color points to form triangle.



Color Model

RGB → used in Monitor

CMY → Cyan + Magenta — Yellow

→ Used in printers

CMYK → Cyan - Magenta - Yellow - Black

→ Used in printers.

HSI (Hue-Saturation-Intensity)

RGB → Three color mix in appropriate proportion to form different colours.

→ RGB is 24 bit Color Model

There are $(2^8)^3 = 16,777216$ color can be possible using 8 bit of red

8 bit of blue

8 bit of green.

256 is the minimum Number of colour.

that can be reproduce.

Among them 40 colors are processed differently by the Operation System.

So, actually 216 colours remains in the safe.

Where 12 row and 18 columns represents the RGB safe color.

[CMY & CMYK Model]

CMY is simply obtained from RGB.

→ assuming that all colors are normalized in the range [0 1].

If so the CMY model is as follows

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

Here cyan – Red [from white]

Magenta – Green [from white]

Yellow – Blue [from white]

[CMYK is a CMY model where an additional pigment color is black.]

HSI Model

- HSI Model is useful for Human interpretation
- Hue & Saturation gives chromacity information
- Intensity gives brightness (intensity) information

RGB To HSI

assuming RGB is normalized in the range [0, 1], and θ is measured from the red axis in the HSI

[redacted] color space.

[redacted] HSI in [redacted] terms of RGB is given as

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

where, θ is,

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

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

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

$R = 24/255 = 0.09$
$G = 98/255 = 0.38$
$B = 118/255 = 0.46$

Here $B > G$

$$\left(\frac{1}{3}\right) 0.09 + 0.38 + 0.46$$
$$= \frac{0.93}{3} = 0.31$$

$I = 0.31$

$$S = 1 - \frac{3}{R+G+B} \times \min(0.09)$$

$$= \left(1 - \left(\frac{3}{0.09 + 0.38 + 0.46}\right.\right.$$

$$1 - \frac{0.27}{0.93} = \underline{\underline{0.71}}$$

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

$$= \cos^{-1}\left\{\frac{\frac{1}{2}\left[(-0.29) + (-0.37)\right]}{\sqrt{0.0841 + 0.0296}}\right\}$$

$$= \cos^{-1}\left\{\frac{\frac{1}{2}[-0.66]}{0.337}\right\}$$

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

$$= \cos^{-1}(-1) = 180^\circ$$

as here, $B > G$.

$$\therefore H = 360 - \theta = 360 - 180$$
$$= 180^\circ.$$

$$\therefore HSI = 180^\circ, \underline{0.71}, 0.31$$

= HSI to RGB

$$\boxed{\begin{array}{l} RG = 0^\circ \le \theta \le 100^\circ \\ \quad B = I(1-S) \\ \quad R = I\left(\frac{1 + S\cos(H)}{\cos(60^\circ - H)}\right) \\ \quad G = 1 - (R+B) \end{array}}$$

$GB \quad 120^\circ \le \theta \le 240^\circ$

$$R = I(1-S)$$

$$G = I\left(\frac{1+S\cos(H)}{\cos(60^\circ-H)}\right)$$

$$B = 1-(R+B)$$

$BR = 240^\circ \le \theta \le 360^\circ$

$$G = I(1-S)$$

$$B = \frac{I(1+S\cos(H'))}{\cos(60^\circ-H)}$$

$$R = 1-(G+R)$$

where $H = H' - 180^\circ - 120^\circ = 60^\circ$

$H = H - 120^\circ$
$= 180^\circ - 120^\circ$
$= 60^\circ$

Pseudo Color Image Processing

[Sharpening]

Laplacian Operation is used for sharpening an image hence the laplatian vector in case of color image processing is defined as

$$\nabla^2(C(x,y)) = \begin{bmatrix} \nabla^2 R(x,y) \\ \nabla^2 G(x,y) \\ \nabla^2 B(x,y) \end{bmatrix}$$

Color Image Smoothing

RGB color planes are independently smoothed and then combined to form a smoothed Image.

Smoothening in color image processing is averaging of different RGB component in the color image.

In HSI only the intensity part is smoothed.

By averaging two different color pixel it becomes mixture.

By smoothing only intensity image, pixel maintain Hue & Saturation

Full Color Image Processing

- Color Transformation
  - Intensity modification
  - Color Complement
  - color Slicing
  - Tone and color Correction
- Color image Smoothening
- color image Sharpening.

Full color image processing divided into two category.

- Per color Plane category
  Process each color Component.
- vector based Processing
  Process the color vector of each pixel.

$$c(x,y) = \begin{bmatrix} c_R(x,y) \\ c_G(x,y) \\ c_B(x,y) \end{bmatrix} = \begin{bmatrix} R(x,y) \\ G(x,y) \\ B(x,y) \end{bmatrix}$$

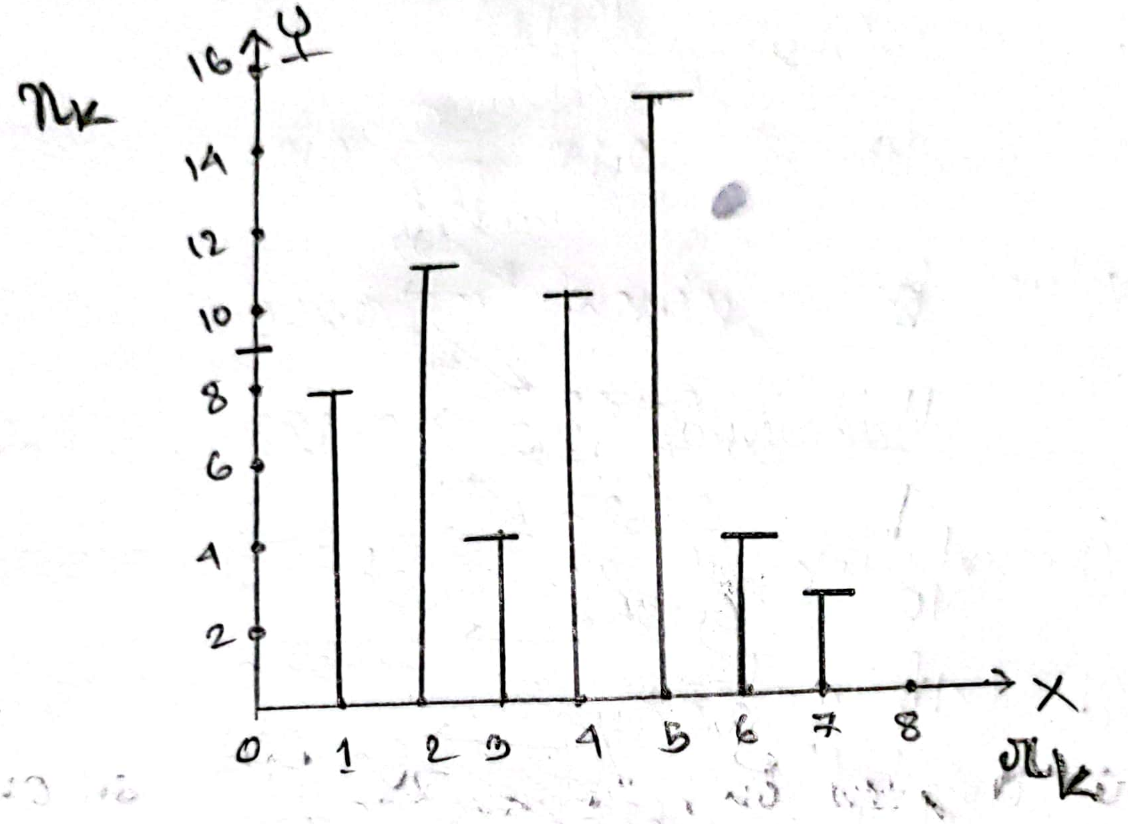
Histogram Equalization

Histogram Equalization is a computer image processing technique used to improve contrast in images. [It spreads out the most common intensity values in an image to make the intensity range wider.]

Now lets take a table as an example for an 8x8 image

Gray LvL	0	1	2	3	4	5	6	7
No. of Pixels	9	8	11	4	10	15	4	3

Then make a graph from the table



Histogram of input Image

Here, we can see,

0 to X $\xrightarrow{r_k}$ is X-axis represents the number of Gray levels.

and 0 to Y $\xrightarrow{n_k}$ is Y-axis represents the number of pixels.

Gray Level (r_k)	No of Pixel (n_k)	$P(r_k) = n_k/N$ (PDF)	S_k (CDF)	$S_k \times 7$	New H.E. Level
0	9	0.141	0.141	0.987	1
1	8	0.125	0.266	1.862	2
2	11	0.172	0.438	3.066	3
3	4	0.0625	0.5005	3.5035	4
4	10	0.156	0.6565	4.5955	5
5	15	0.234	0.8905	6.2335	6
6	4	0.0625	0.953	6.671	7
7	3	0.047	1	7	7

$$\sum n_k = N = 64$$

So, the New Equalized version of table (i).

Gray level	1	2	3	4	5	6	7
No of pixel	9	8	11	4	10	15	7

PDF → Probability Density Fuction

CDF → Cumulative Distribution Function

Difference Between Histogram & H.E

⇒ In image processing a histogram shows the number of pixel for each intensity value in a given image.

A histogram is a statistical representation of an image. It doesn't show any information about where the pixel are located in the image.

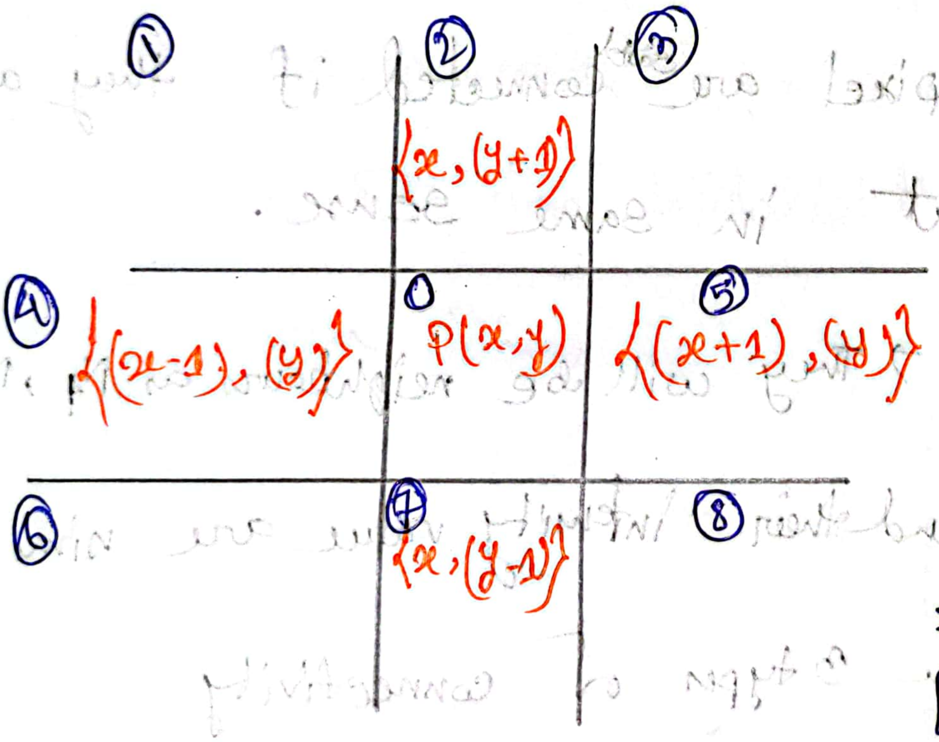
⇒ In H.E or Histogram Equalization the goal is to improve contrast in images that might be blurry or have a back ground and foreground that are either both dark or both white. It helps sharpen an Image.

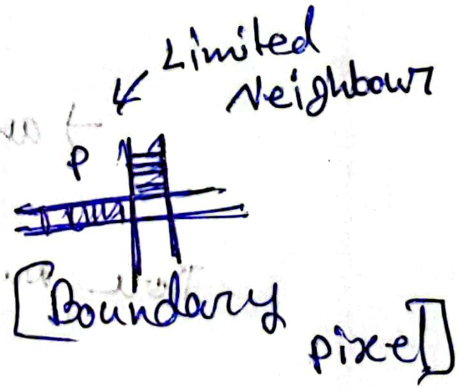
Pixel and Neighbourhood

Pixel is the smallest element of an image.

Each pixel corresponds to any one value.

In an 8-bit gray scale image, the value of the pixel is ~~in~~ between 0 to 255.





0 and 2, 4, 5, 7 are $N_4(P)$

0 and 1, 3, 6, 8 are $N_D(P)$

Both together $N_4 \cup N_D = N_8(P)$

Contrast Stretching

⇒ It is a process of increasing low contrast image to high contrast image.

Connectivity / Adjacency

Two pixel are said connected if they are adjacent in same sense.

→ They will be neighbours as N_4, N_D or N_8

→ and their intensity value are similar.

There are 3 types of connectivity

4 - connectivity

8 - connectivity

M - connectivity

Binary image

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

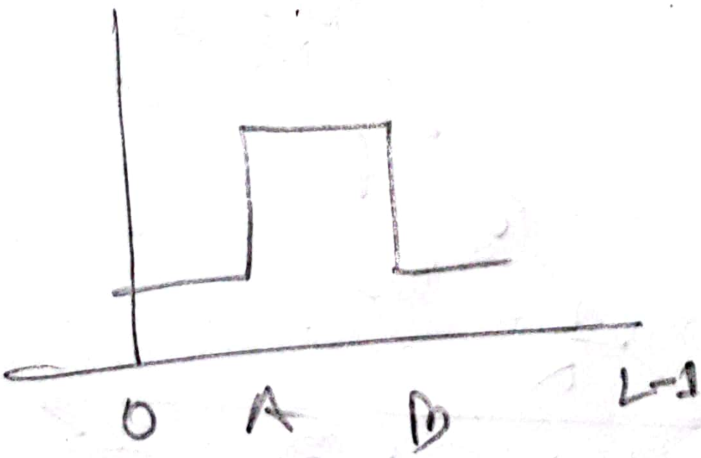
[Grey level Slicing]

Highlights a specific range of grey level.

→ similar to thresholding

→ other level can be suppressed or maintained.

→ Useful for highlighting features in an image.

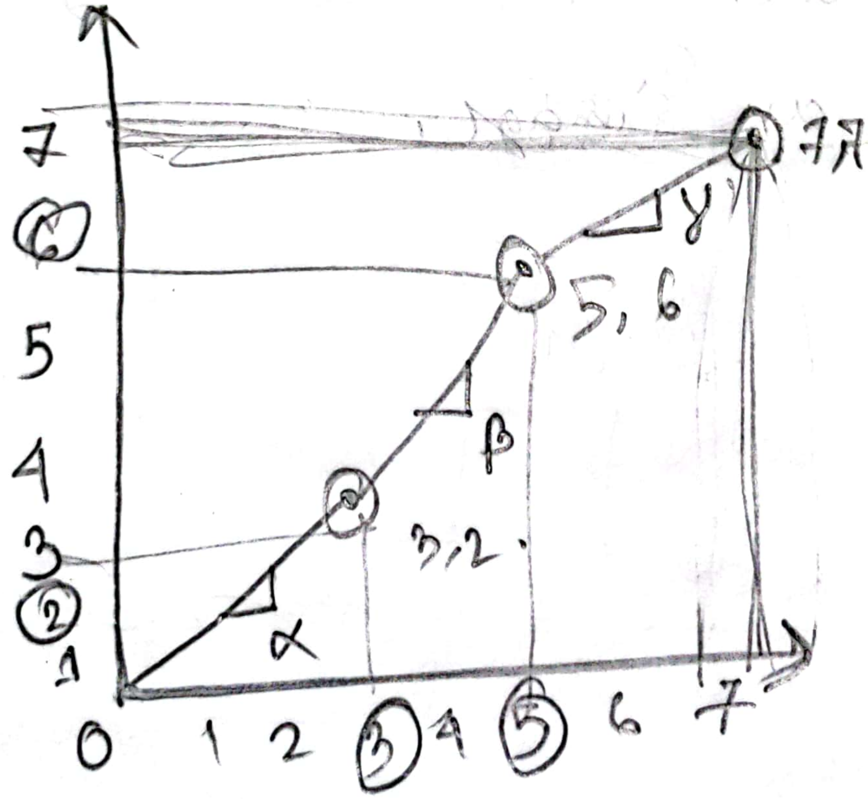


Contrast Stretching

4	3	5	2
3	6	4	6
2	2	6	5
7	6	4	1

Given, $r_1 = 3$ and $r_2 = 5$

$s_1 = 2$ $s_2 = 6$



$$M = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\alpha = \frac{y_2 - y_1}{x_2 - x_1} = \frac{2}{3} = 0.66$$

$$\beta = \frac{y_2 - y_1}{x_2 - x_1} = \frac{4}{2} = 2$$

$$\gamma = \frac{y_2 - y_1}{x_2 - x_1} = \frac{1}{2} = 0.5$$

$$S = \begin{cases} \alpha \cdot r & 0 \leq r < 3 \\ \beta \cdot (r - r_1) + S_1 & 3 \leq r < 5 \\ \gamma (r - r_2) + S_2 & 5 \leq r \leq 7 \end{cases}$$

r	S
0	$S = \alpha . r$
1	
2	
3	
4	
5	
6	
7	