Introduction:

--- DIP(Digital image processing) comes from two application areas:

--improvement of pictorial information for human interpretation.

-- processing of scene data for autonomous machine perception(observation).

--- One of first applications of image processing techniques was ...digitalized newspaper pictures sent by submarine cable between London and New York. (with less than 3 hours) at 1920.

--- The first image enhancement and restoration held at NASA's JPL(Jet Propulsion Laboratory)

Application areas:

1. Industrial machine vision applications.
   - Automated visual inspection.
   - Process control.
   - Parts identification.
   - Robotic guidance and control.
2. Space exploration.
3. Astronomy.
4. Diagnostic medical imaging.
   - Medical image processing
   - Medical image reconstruction
5. Scientific analysis
6. Military guidance and reconnaissance(intelligence)/investigation
7. Remote sensing
   - Meteorology (prediction about weather)
   - Natural resource location
   - Environmental monitoring
   - Cartography (map making)
8. Information technology system (DIP- document image processing)
   - Image data compression
   - Analysis of document content
9. Telecommunications
   - Facsimile (transmit the copy by wire or radio)
   - Videotext
   - Video conferencing and video phones
10. Security, surveillance (close observation of a person) and law enforcement
    - Verification of identity
    - Monitoring and surveillance
    - Forensic investigations
11. Entertainment and consumer electronics
12. Printing and the graphics arts

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Questions:

Definitions
History
Areas of application
Components of digital Image Processing
Fundamental Stapes in Digital Image Processing
Analog Image
Digital Image
Common Values
Special Topics
- Resolution
- Pixel
- Aspect Ratio
- Simple Maths about resolution and aspect ratio
- Monitor size/ Resolution of monitor
- Video Parameters
- Binary Image
- Monochrome Image
- Resolution of Photography, Good eye.

Conversion of an analog to digital Image
Effect of Different Quantization parameters on Image
Image Acquisition
Special Topics
- Pixel Operations
- Mask Operations

Image Processing

Definition:
An image may be defined as a two dimensional function, f(x,y), were x and y are *spatial* (plane) coordinates, and the amplitude of f at any pair of coordinates (x,y) is called the *intensity* or *gray level* of the image at that point.

The term 'image processing' means modifying images such that they are either:
--- correction for errors introduced during acquisition or transmission ('restoration').
--- enhanced to overcome the weaknesses of the human visual system ('enhancement').
Finally,
' a process which takes an image input and generates a modified image output'

Keywords:
Computer Vision, machine perception, machine vision, image understanding.

Video Parameters

We do not propose to describe the processing of dynamically changing images in this introduction. It is appropriate--given that many static images are derived from video cameras and frame grabbers-- to mention the standards that are associated with the **three standard video schemes** that are currently in worldwide use - NTSC, PAL, and SECAM. This information is summarized in Table 3.

Standard / *Property*	**NTSC**	**PAL**	**SECAM**
images / second	29.97	25	25
ms / image	33.37	40.0	40.0
lines / image	525	625	625
(horiz./vert.) = aspect ratio	4:3	4:3	4:3
interlace	2:1	2:1	2:1
us / line	63.56	64.00	64.00

Table 3: Standard video parameters

-In an interlaced image the odd numbered lines (1,3,5,...) are scanned in half of the allotted time (e.g. 20 ms in PAL) and the even numbered lines (2,4,6,...) are scanned in the remaining half. The image display must be coordinated with this scanning format. (See Section 8.2.)

-The reason for interlacing the scan lines of a video image is to reduce the perception of flicker in a displayed image. If one is planning to use images that have been scanned from an interlaced video source, it is important to know if the two half-images have been appropriately "shuffled" by the digitization hardware or if that should be implemented in software.

-Further, the analysis of moving objects requires special care with interlaced video to avoid "zigzag" edges.

-The number of rows (N) from a video source generally corresponds one-to-one with lines in the video image. The number of columns, however, depends on the nature of the electronics that is used to digitize the image. Different frame grabbers for the same video camera might produce M = 384, 512, or 768 columns (pixels) per line.

Fundamental Stapes in Digital Image Processing:

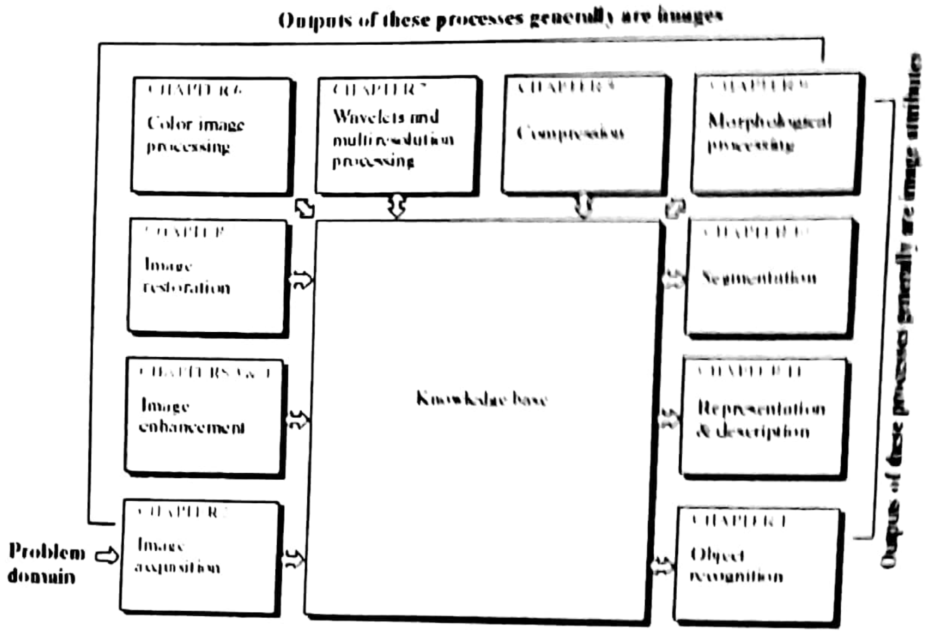


FIGURE 1.23 Fundamental steps in digital image processing.

Components of digital Image Processing:

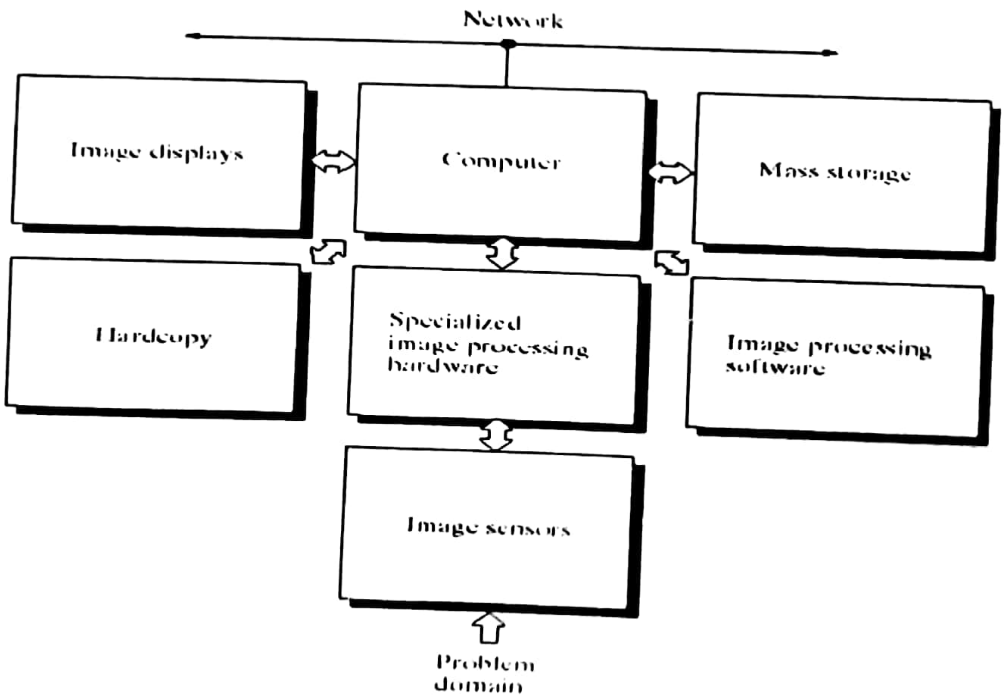


FIGURE 1.24 Components of a general-purpose image processing system.

Sensing:

Two elements are required to acquire digital images:

1. Physical device that is sensitive to the energy radiated by the object
2. Digitizer is a device for converting the output of the physical sensing device into digital form.

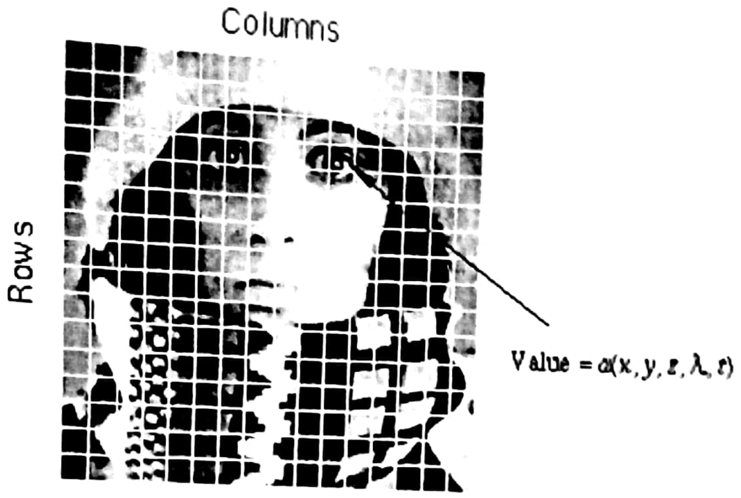


Figure 1: Digitization of a continuous image. The pixel at coordinates [m=10, n=3] has the integer brightness value 110.

The image shown in Figure 1 has been divided into N = 16 rows and M = 16 columns. The value assigned to every pixel is the average brightness in the pixel rounded to the nearest integer value. The process of representing the amplitude of the 2D signal at a given coordinate as an integer value with L different gray levels is usually referred to as amplitude quantization or simply *quantization*.

Common Values

There are standard values for the various parameters encountered in digital image processing. These values can be caused by video standards, by algorithmic requirements, or by the desire to keep digital circuitry simple. Table 1 gives some commonly encountered values.

Parameter	*Symbol*	*Typical values*
Rows	N	256,512,525,625,1024,1035
Columns	M	256,512,768,1024,1320
Gray Levels	L	2,64,256,1024,4096,16384

Table 1: Common values of digital image parameters

Quite frequently we see cases of M=N=2^K where $\{K = 8,9,10\}$. This can be motivated by digital circuitry or by the use of certain algorithms such as the (fast) Fourier transform (see Section 3.3).

The number of distinct gray levels is usually a power of 2, that is, L=2^l where l is the number of bits in the binary representation of the brightness levels. When l>1 we speak of a *gray-level image*; when l=1 we speak of a *binary image*. In a binary image there are just two gray levels which can be referred to, for example, as "black" and "white" or "0" and "1".

Chapter 2

(Mathematical) Model of an Image (Actually what is image):

Analog Image:

A two dimensional light intensity function f(x,y).

Where f(x,y)= intensity of the image at coordinate (x,y), $0<f(x,y)<\alpha$

Example: f(100,200)=250

f(x,y) depends on two things: f(x,y)=i(x,y).r(x,y)

3. Amount of light incident by object or point:
   Illumination (meaning:source of light) i(x,y)
   The value of i(x,y) is between 0 and α.
   Example:
   Some typical values of i(x,y)

Clear Sunny day	10,000 ft-candles.
Cloudy day	1,000 ft-candles.
Clear full moon	0.01 ft-candles.
Typical office	100 ft-candles.

4. Amount of light reflected on object or point:
   Reflectance or r(x,y). and $0<r(x,y)<1$.
   r=0 no reflection; total absorption
   r=1 full reflection; no absorption
   Some typical values of r(x,y)

Black velvet	0.01
Stainless steel	0.65
White wall	0.8
Silver-plated metal	0.9
Snow	0.93

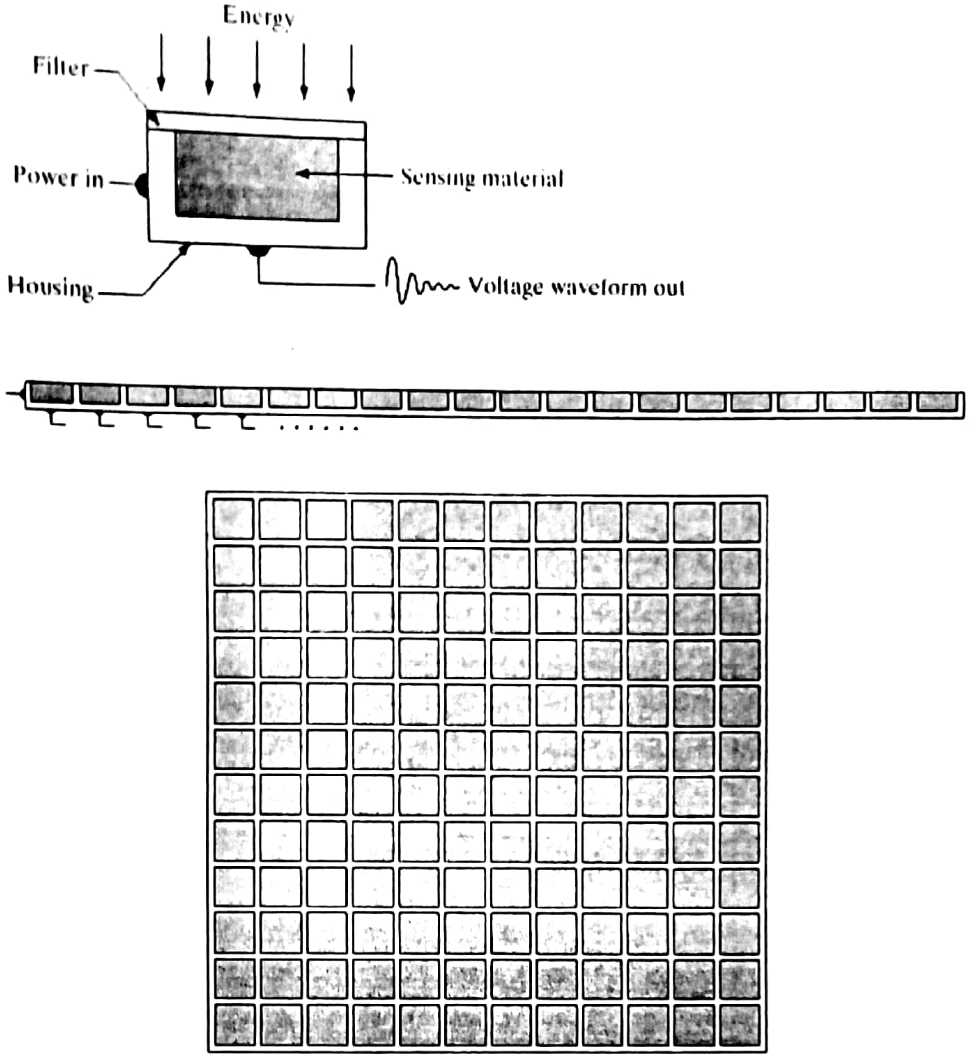
Digital Image:

A digital image $a[m,n]$ described in a 2D discrete space is derived from an analog image $a(x,y)$ in a 2D continuous space through a *sampling* process that is frequently referred to as digitization. The mathematics of that sampling process will be described in Section 5. For now we will look at some basic definitions associated with the digital image. The effect of digitization is shown in Figure 1.

The 2D continuous image $a(x,y)$ is divided into *N rows* and *M columns*. The intersection of a row and a column is termed a *pixel*. The value assigned to the integer coordinates $[m,n]$ with $\{m=0,1,2,\ldots,M-1\}$ and $\{n=0,1,2,\ldots,N-1\}$ is $a[m,n]$. In fact, in most cases $a(x,y)$--which we might consider to be the physical signal that impinges on the face of a 2D sensor--is actually a function of many variables including depth (z), color (λ), and time (t).

a
b
c

FIGURE 2.12
(a) Single imaging sensor.
(b) Line sensor.
(c) Array sensor.



Representation of image data:

1) it should facilitate convenient and efficient processing by means of a computer.
2) It should encapsulate all the information that defines the relevant characteristics of the image.

To fulfill these requirements:

a) Spatial quantization
b) Amplitude quantization

Special Topics: Pixels, AR, Resolution, Color Concepts, Memory requirements etc.

Maths on these topics and Monitor size/Resolution of monitor, Photographs.
•Resolution of a good eye at 15"= 600 dpi
• Photography negative (35mm) = 4000 dpi

Problem:
Find the resolution of a 15" monitor working with
-800 x 600

Conversion of an analog image into digital image:
(Sampling and Quantization)

Two processes:
• Digitalizing the coordinate values is called sampling. (Spatial quantization)
• Digitizing the amplitude values is called quantization. (Amplitude quantization)

Monochrome image:
One color image
Color Image:
$$f(x,y)=f_R(x,y)+f_G(x,y)+f_B(x,y)$$

Effects of Different Quantization parameters (m, n, l) on image quality:
•when m,n and l increase, quality increases but computation efficiency reduces.
• In many cases high m,n and l not required due to the specific nature of application.
• for visual inspection of an image, quality does no improve after a certain m, n, l due to limitations of the human visual system.
• For images with large amount of details, only a few amount of gray levels (l) are needed.

Elements of Digital Image Processing:
i) Image Acquisition
ii) Storage
iii) Processing
iv) Communication
v) Display

Image Acquisition:
Definition

Image sensor devices are based on two things:
• Illumination
• Reflection
(Incoming energy is transformed into a voltage by the combination of input electrical power and sensor material that is responsive .... digitizing its response.)

There are three types of acquisition devices:
--- Single Image Sensor
--- Linear sensor
--- Array sensor

Chapter-3

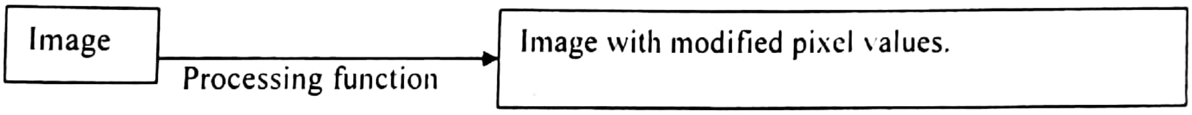
Image Enhancement & Processing:

For processing two methods is used.

1) Spatial domain processing.
2) Frequency domain processing.

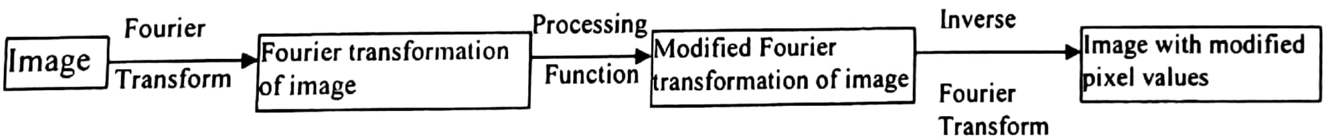
1) Spatial domain processing:

Processing image directly is called spatial domain processing.



2) Frequency domain processing:

Don't change it directly but transform.

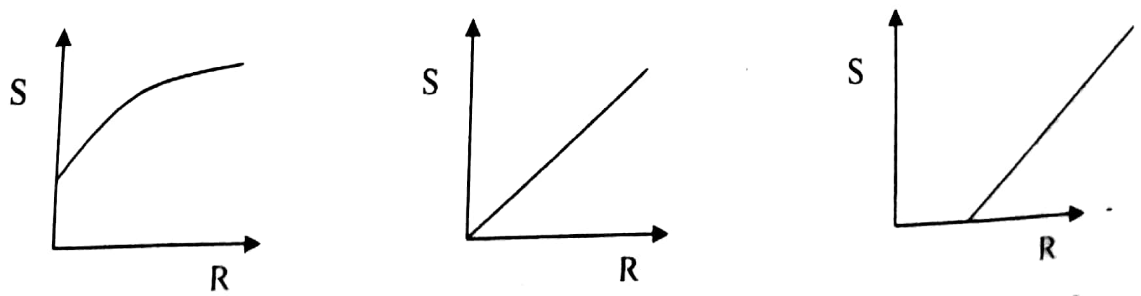


Especially it used in medical or such special field.

Spatial domain methods:

$g(x, y)=T[f(x, y)]$ where, $g(x, y)$= Processed image (output image)
$f(x, y)$= Original image (input image)
T= Operation on f.

Example:



-1024 x 768
-1280 x 1024
Calculate the resolution of a 14”x9” photo.

Some Basic Relationships Between Pixels:
Neighbors of a pixels:

- 4-neighbors of p, $N_4(P)$.
- diagonal neighbors of p, $N_d(P)$.
- 8-neighbors of p, $N_8(P)$.

Adjacency, Connectivity, Regions, Boundaries

- Structure of Human eye.
    - Image formation in the eye
    - Working principle of human eye
    - Blind spot
    - Monocular vision
    - Binocular vision
- Difference between Camera and Human eye
- Light and Electro-magnetic
- Concept of color
- Illusion

Types of operations

The types of operations that can be applied to digital images to transform an input image $a[m,n]$ into an output image $b[m,n]$ (or another representation) can be classified into three categories as shown in Table 2.

Operation	Characterization	Generic Complexity/Pixel
* *Point*	- the output value at a specific coordinate is dependent only on the input value at that same coordinate.	*Constant*
* *Local*	- the output value at a specific coordinate is dependent on the input values in the *neighborhood* of that same coordinate.	P^2
* *Global*	- the output value at a specific coordinate is dependent on all the values in the input image.	N^2

Table 2: Types of image operations. Image size = $N \times N$; neighborhood size = $P \times P$. Note that the complexity is specified in operations *per pixel*.

This is shown graphically in Figure 2.

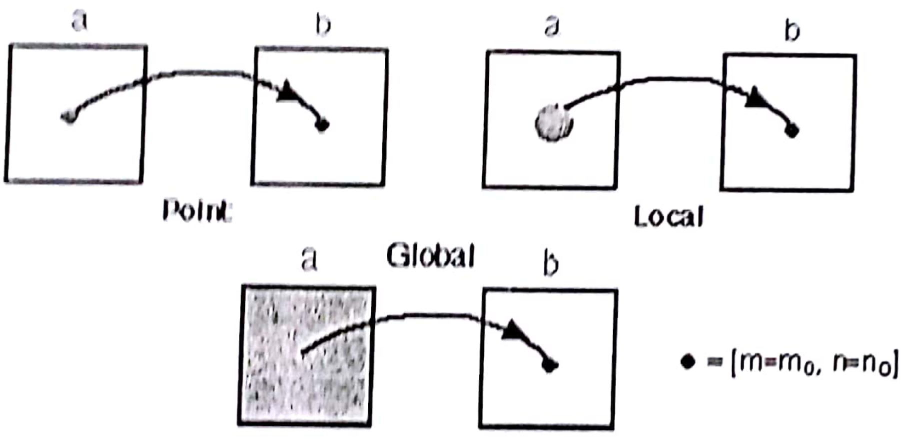
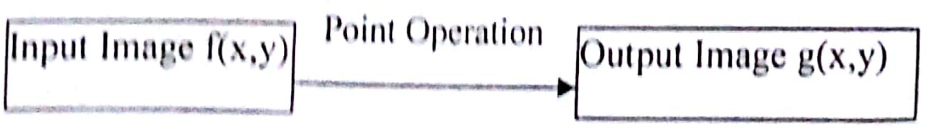


Figure 2: Illustration of various types of image operations

Another 5 types of processing:

1. Point Processing.
2. Spatial Filtering.
3. Temporal Processing.
4. Geometric Processing.
5. Morphological Processing.

Point Processing:



- Monadic operation
- Threshold
- Contrast stretching
- Gray level slicing
- Image histogram
- Histogram equalization
- Other spatial functions

Monadic operation:

Output image is obtained by applying arithmetic operation on input image.

-- Adding a constant: $g(x,y)= f(x,y) + k$ K=constant

-- Subtracting a constant: $g(x,y)= f(x,y) - k$ K=constant

-- Negative: $g(x,y) = k- f(x,y)$ [usually $k= 2^l-1$]

-- Multiply by constant: $g(x,y) = kf(x,y)$

-- Divide by constant: $g(x,y) = f(x,y)/k$

-- Divide into constant: $g(x,y) = k/f(x,y)$

-- OR constant: $g(x,y) = k \text{ or } f(x,y)$

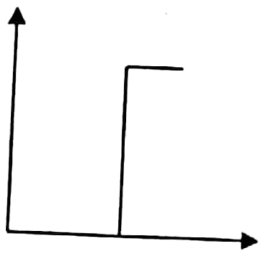
-- AND constant: $g(x,y) = k \text{ and } f(x,y)$

-- XOR constant: $g(x,y) = k \text{ xor } f(x,y)$

Assignment:

Threshold:

Operation to convert an image into two levels.

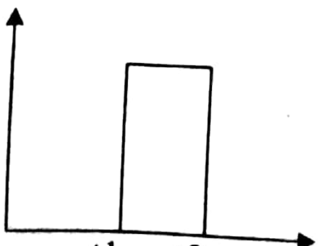


t

t= threshold value

$$g(x,y) = \begin{cases} 0 \\ M \end{cases}$$ [if $f(x,y) < t$ and if $f(x,y) >= t$ and usually $M= 2^l-1$]

Dual Threshold:



t1 t2

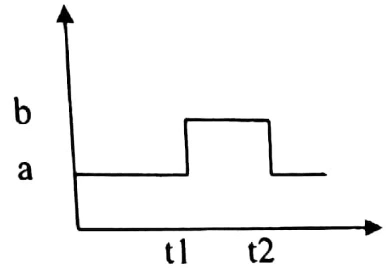
t1, t2 = threshold value

Gray level slicing:
Highlighting a specific range of gray levels in an image.

Example of applications:

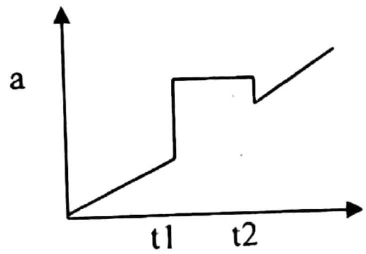
-- enhancing water bodies in satellite image.
-- enhancing flaws in X-ray image.

Two approaches:



t1. t2 = threshold value

g(x,y) = $\begin{cases} a \\ b \\ a \end{cases}$ [if f(x,y) <t1 and if t1<=f(x,y) <=t2 and if f(x,y) > t2 usually M= 2^l-1



t1. t2 = threshold value

g(x,y) = $\begin{cases} f(x,y) \\ a \\ f(x,y) \end{cases}$ [if f(x,y) <t1 and if t1<=f(x,y) <=t2 and if f(x,y) > t2 usually M= 2^l-1

Histogram processing:

$$p(r_k) = \frac{n_k}{n}$$

Where, r_k =k^{th} gray level.

n_k= number of gray level r_k.

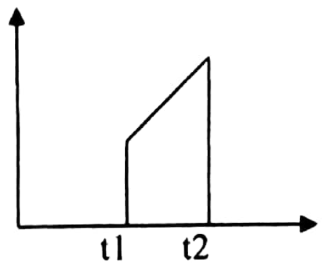
n= total number of pixels in the image.

Example:

7	3	2	1

$$g(x,y) = \begin{cases} 0 \\ M \quad [\text{ if } f(x,y) < t1 \text{ and if } t1 <= f(x,y) <= t2 \text{ and if } f(x,y) > t2 \text{ usually } M = 2^{l}-1 \\ 0 \end{cases}$$

Gray scale threshold:



t1. t2 = threshold value

$$g(x,y) = \begin{cases} 0 \\ f(x,y) \quad [\text{ if } f(x,y) < t1 \text{ and if } t1 <= f(x,y) <= t2 \text{ and if } f(x,y) > t2 \text{ usually } M = 2^{l}-1 \\ 0 \end{cases}$$

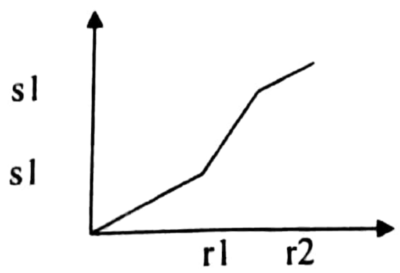
Contrast stretching:

Reasons for low contrast of an image:

--- Poor illumination.

--- Lack of dynamic range of image sensor.

$$g(x,y) = \begin{cases} \quad [\text{ if } f(x,y) < r1 \text{ and if } r1 <= f(x,y) <= r2 \text{ and if } f(x,y) > r2 \end{cases}$$



The method used to generate a processed image that has a specified histogram is called histogram matching or histogram specification.

Adaptive histogram:

Local Histogram:
In this process a square or rectangular neighborhood area is chosen. Then histogram equalization of specification is used to process the center of the area. And then work like filtering.

Temporal processing:
Processing involving more than one image (frame).
If 2 frame---- dyadic processing.

Addition: $g(x,y)= (f_1(x,y) + f_2(x,y)).k$
Subtraction : $g(x,y)= f_1(x,y) - f_2(x,y)$
Signal Averaging: $g(x,y)= 1/n(f_1(x,y) + f_2(x,y) + \ldots\ldots\ldots + f_n(x,y))$
Multiplication: $g(x,y)= f_1(x,y) * f_2(x,y)$
OR : $g(x,y)= f_1(x,y)$ OR $f_2(x,y)$
AND : $g(x,y)= f_1(x,y)$ AND $f_2(x,y)$
XOR : $g(x,y)= f_1(x,y)$ XOR $f_2(x,y)$

Geometric Processing:
Transpose/Rotation:

```
for i = 1 : 512
        for j = 1 : 512
                B(j; i) = A(i; j); OR >> B = A0;
```

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

$r_k = 0$
$n_k = 1$
$n = 16$
$p(r_0) = 1/16$
$r_k = 4$
$n_k = 2$
$n = 16$
$p(r_4) = 2/16$

$r_k = 1$
$n_k = 4$
$n = 16$
$p(r_1) = 4/16$
$r_k = 5$
$n_k = 1$
$n = 16$
$p(r_5) = 1/16$

$r_k = 2$
$n_k = 3$
$n = 16$
$p(r_2) = 3/16$
$r_k = 6$
$n_k = 1$
$n = 16$
$p(r_6) = 1/16$

$r_k = 3$
$n_k = 2$
$n = 16$
$p(r_3) = 2/16$
$r_k = 7$
$n_k = 2$
$n = 16$
$p(r_7) = 2/16$

Histogram equalization/linearization:

Convert image from uneven histogram to the even histogram is called histogram equalization.

$$N(g) = \max\left\{0, round\left(\frac{2^l.c(g)}{n}\right) - 1\right\}$$

Where, N(g) =new gray level of the pixel.

C(g) = cumulative pixel count upon old gray level g.

Round = rounding operation to nearest integer value.

2^l = number of gray levels.

N= total number of pixels.

Example:

g	f	C(g)	N(g)
0	8	8	0
1	22	30	2
2	20	50	5
3	2	52	5
4	2	54	5
5	8	62	6
6	2	64	7
7	0	64	7

Histogram Specification:

Here we use a specified histogram to process the image.

There are two types of spatial filtering:

1. Smoothing filtering:

Smoothing filtering are used for

-- Blurring image

-- Noise reduction

a) Low pass filtering:

It is also called averaging filtering.

By replacing the value of every pixel in an image by the average of the gray levels in the neighborhood defined by the filter mask.

This process results in an image with reduced "sharp" transitions in gray levels.

Because random noise typically consists sharp transitions in gray levels.

$\frac{1}{9} \times$

1	1	1
1	1	1
1	1	1

$\frac{1}{16} \times$

1	2	1
2	4	2
1	2	1

$$R = \frac{1}{9}\sum_{i=1}^{9} z_i$$

b) Median filtering:

To remove impulse noise, also called salt and pepper noise.

2. Sharpening filtering:

- High pass filtering

High frequency components of an image characterize edges and sharp details.
Low frequency components of an image characterize overall contrast and average intensity of an image.

-1	-1	-1
-1	8	-1
-1	-1	-1

- High boost filtering

```
        end
end
```

Flip:

The vertical flipped image B (N x M) of A (N x M) can be obtained as B(i,M+1-j) = A(i,j) (i = 1….N and j = 1….M).

```
for i = 1 : 512
        for j = 1 : 512
                B(i, 512 + 1 - j) = A(i, j);
        end
end
```

Crop:

The cropped image B (N1xN2) of A(NxM), starting from (n1; n2), can be obtained as B(k; l) = A(n1+k; n2+l) (k = 0;…..N1-1; l = 0……..N2-1).

```
for k = 0 : 64 -1
        for l = 0 : 128 - 1
        B(k + 1; l + 1) = A(255 + k + 1; 255 + l + 1); % n1=n2=255 N1=64.N2=128
        end
end
```

OR

```
B(1 : N1; 1 : N2) = A(n1 + 1 : n1 + N1; n2 + 1 : n2 + N2);
```

Spatial filtering:

FIGURE 3.33 Another representation of a general 3 × 3 spatial filter mask.

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

Some common examples of spatial degradation,

i) atmospheric turbulence
ii) motion blur
iii) defocused system

Noise Models:

--- PDF

- Gaussian noise
- Rayleigh
- Erlang
- Exponential
- Uniform
- Impulse

Various restoration techniques:

-- Restoration in the presence of Noise

$$g(x,y)= f(x,y)+n(x,y)$$

- Mean Filtering (arithmetic mean, Geometric mean, harmonic mean).
- Order Statistics Filtering (median, max-min, midpoint filtering).
- Adaptive Filtering.

Image Compression:

Definition:

Fundamentals:

The term data compression refers to the process of reducing the amount of data required to represent a given quality of information.

Original image= high pass+ low pass filter
High boost = A. original –low pass
= (A-1) original + High pass. [A=multiplication factor]

-1	-1	-1
-1	W	-1
-1	-1	-1

W=9A-1

- Derivative filtering

Prewitt operator:

Sobel operator:

Restoration

- Restoration is one of the major application areas of IP to improve the quality of the images.
- No imaging system gives images of perfect quality because of degradations caused by various reasons.
- Image restoration techniques deals with those images that have been recorded in the presence of one or more sources of degradations.
- The restoration technique can be define as the --

" Restoration attempts to reconstruct or recover an image that has been degraded by using a priori knowledge of the degradation phenomenon"

Model of the image Degradation or Restoration process:

$g(x,y)=h(x,y)*f(x,y)+n(x,y)$

$f(x,y)$ = Input image.
$g(x,y)$=Output image.
$n(x,y)$=Noise term.
$h(x,y)$=Spatial Processing/representation.