Image Enhancement
Histogram Equalization
Spatial Filtering

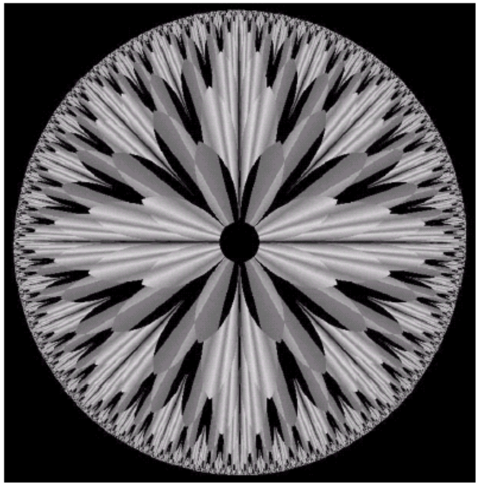

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Image Enhancement

Unit No.III:

Basic Techniques, Enhancement by point processing, Spatial Filtering, Enhancement in Frequency domain, histogram based processing, Homomorphic filtering.

Image Enhancement

- To process an image so that the result is more suitable than the original image for a *specific* application.

- Two methods for image enhancement:
  1. Spatial domain methods (On Image plane – processing on pixel value) and
  2. Frequency domain methods

  and/or combination of both domains

Spatial Domain Methods

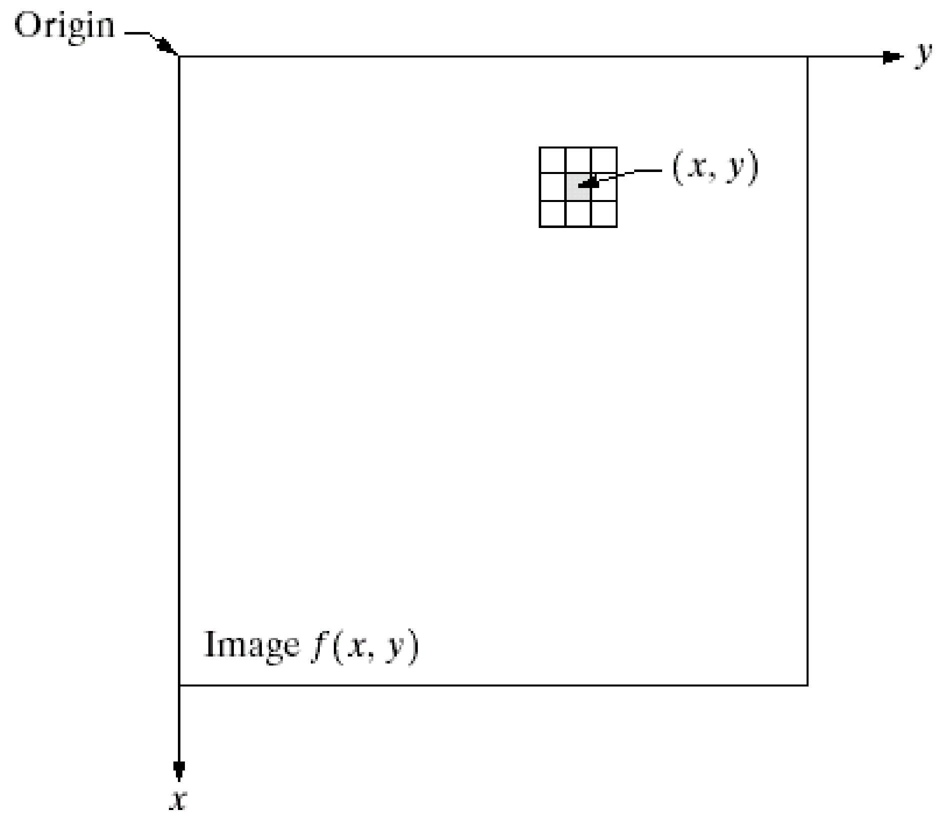
- Procedures that operate directly on the aggregate of pixels composing an image

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

- A neighborhood about (x,y) is defined by using a square (or rectangular) sub-image area centered at (x,y).

Image Enhancement in the Spatial Domain

FIGURE 3.1 A 3×3 neighborhood about a point (x, y) in an image.



Spatial Domain Methods

- When the neighborhood is 1 x 1 pixel then 'g' depends only on the value of f at (x,y) and T becomes a gray-level transformation (or mapping) function:

$$s = T(r)$$

r,s: gray levels of f(x,y) and g(x,y) at (x,y)

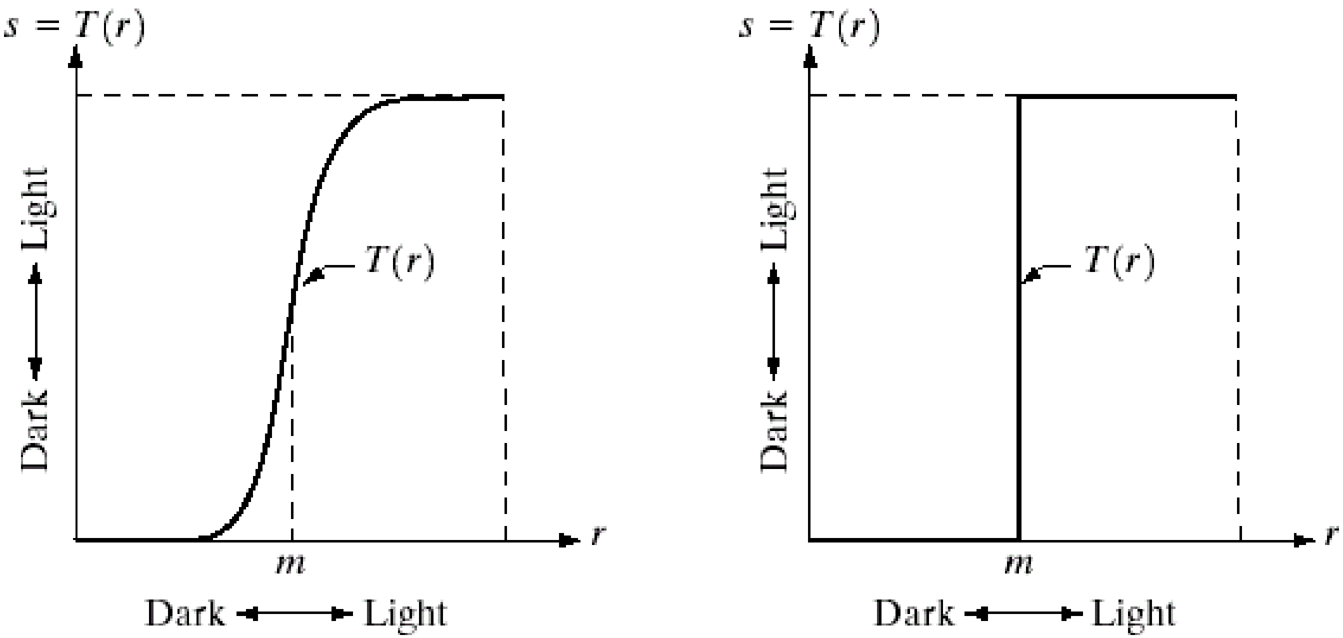
– Point processing techniques (e.g. contrast stretching, thresholding).

Contrast: The difference and distribution of light and dark tones (gray levels) in an image. The measure of contrast is called Gamma factor.

Enhancement-Point Processing

- These are methods based only on the intensity of single pixels.
  - r denotes the pixel intensity before processing.
  - s denotes the pixel intensity after processing.

Image Enhancement in the Spatial Domain



a b

FIGURE 3.2 Gray-level transformation functions for contrast enhancement.

Contrast Stretching **Thresholding (Two level or Binary Image)**

r : gray levels of f(x,y)

s : gray levels of g(x,y) at (x,y)

Spatial Domain Methods

- **Mask processing or filtering**: when the values of ‘f’ in a predefined neighborhood of (x,y) determine the value of ‘g’ at (x,y).
  - Through the use of mask-

    (or kernels, templates, windows, or filters).

Some Simple
Intensity Transformations

- Image negatives

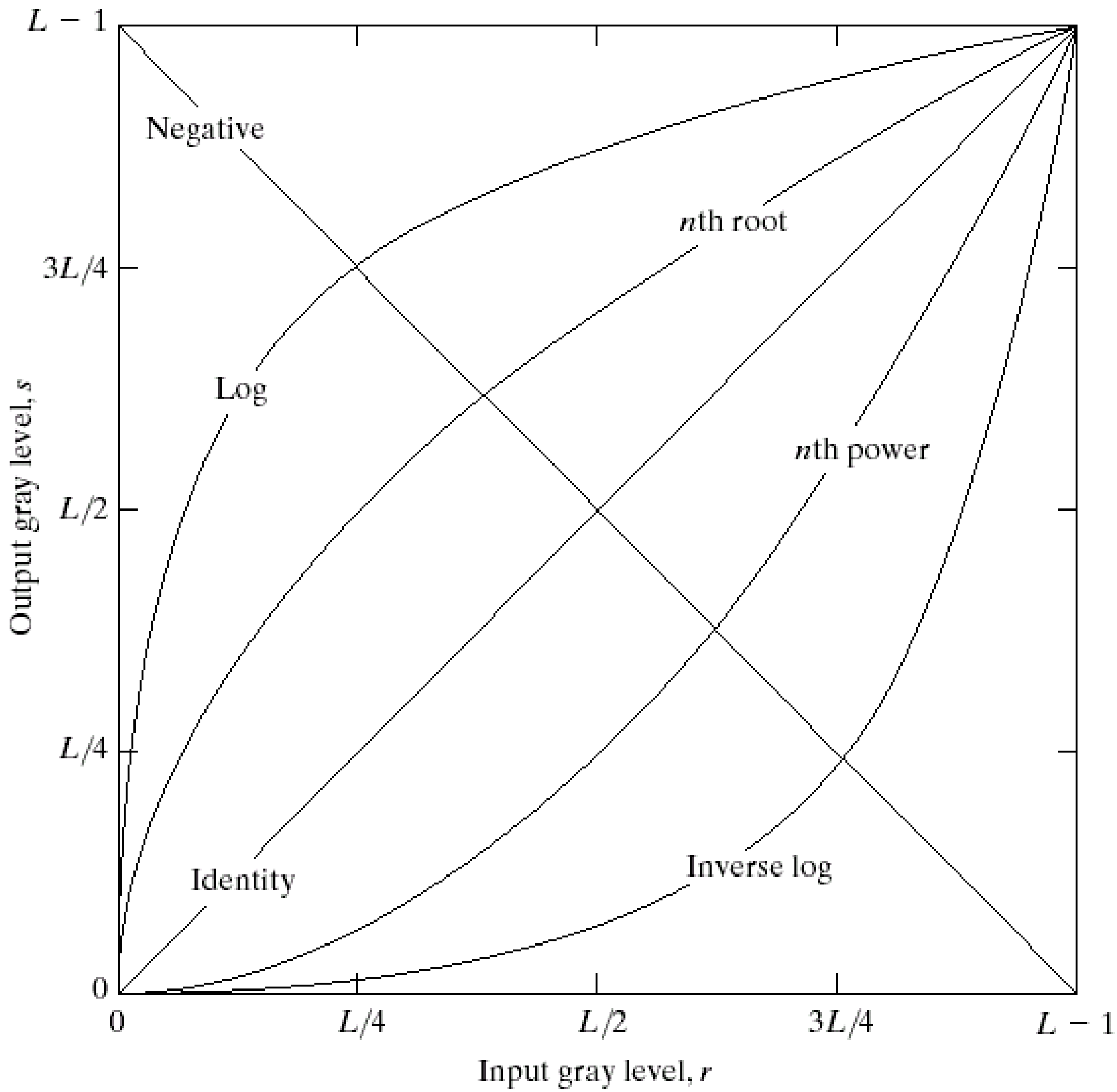
- Piecewise-Linear Transformation Functions:
  - Contrast stretching
  - Gray-level slicing
  - Bit-plane slicing

- Implemented via Look-Up Tables (LUT) where values of T are stored in a 1-D array

  (for 8-bit, LUT will have 256 values)

Image Enhancement - Spatial Domain

FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.



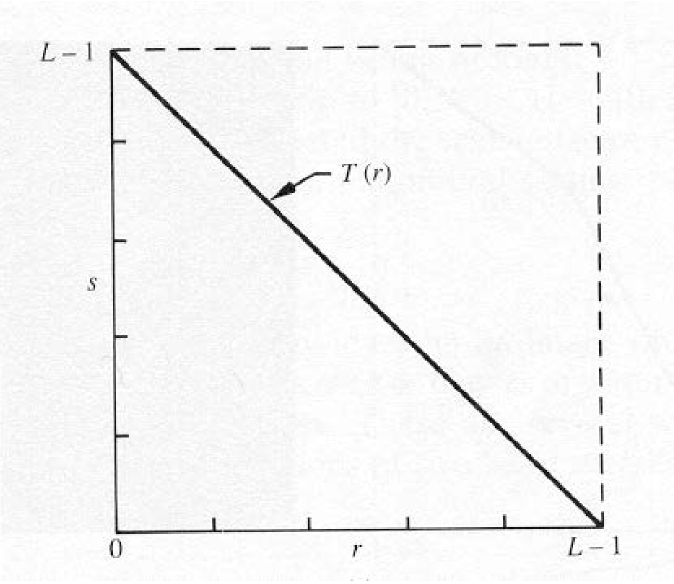
Linear: Negative, Identity

Logarithmic: Log, Inverse Log

Power-Law: *n*th power, *n*th root

Image Negatives

- Image Negatives are obtained by using the transformation function $s=T(r)$.



[0,L-1] the range of gray levels

$s= L-1-r$

Image Negatives

- Function reverses the order from black to white so that the intensity of the output image decreases as the intensity of the input increases.
- Used mainly in medical images and to produce slides of the screen.
- MatLab function can be used for negative image such as-

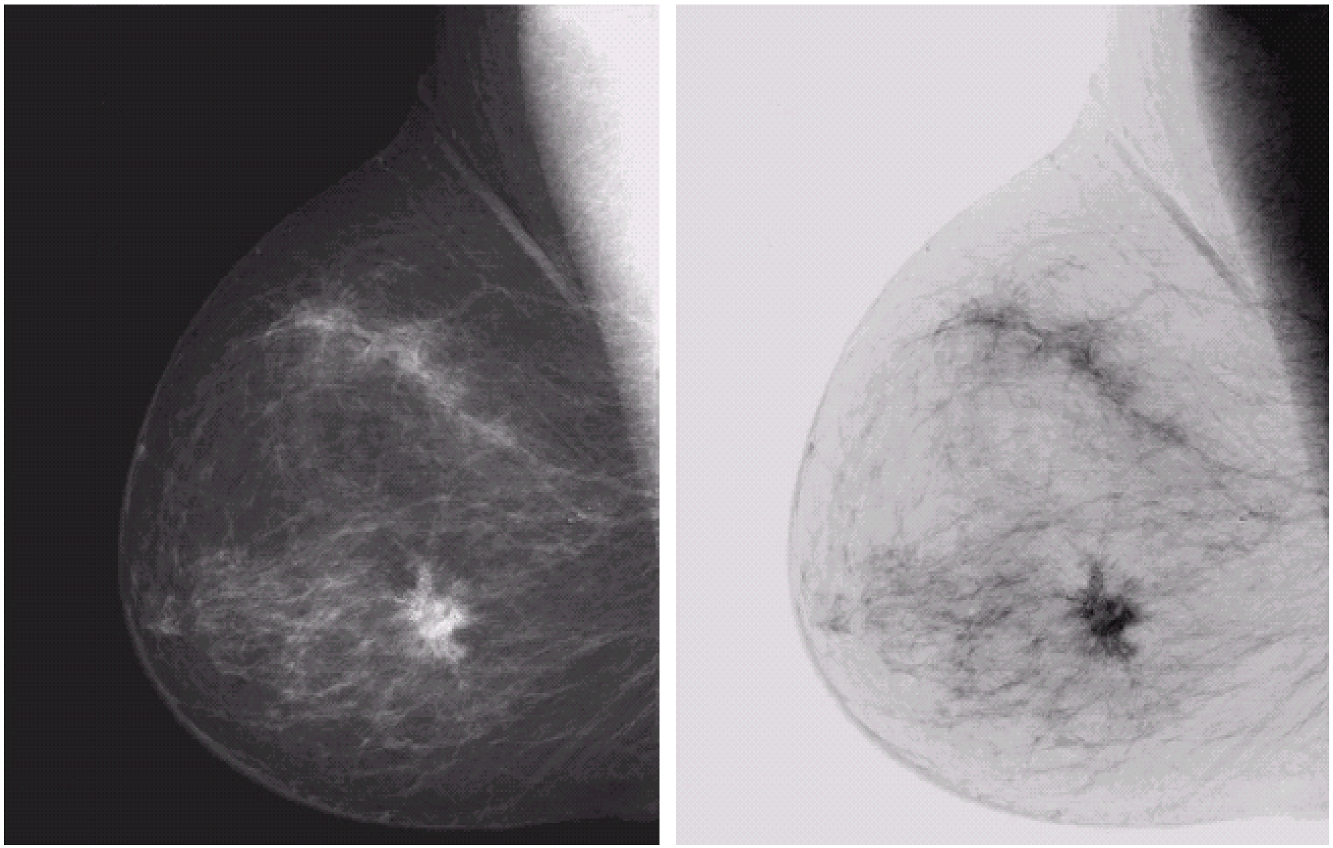
```
>>S2=imcomplement(r);
```
or
```
>>S2=(L-1)-r;
```

Image Negatives

Original Image

Negative Image

Image Enhancement in the Spatial Domain



Original Image　　Negative Image

a b

FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

Log Transformations

$$s = c \log(1+r)$$

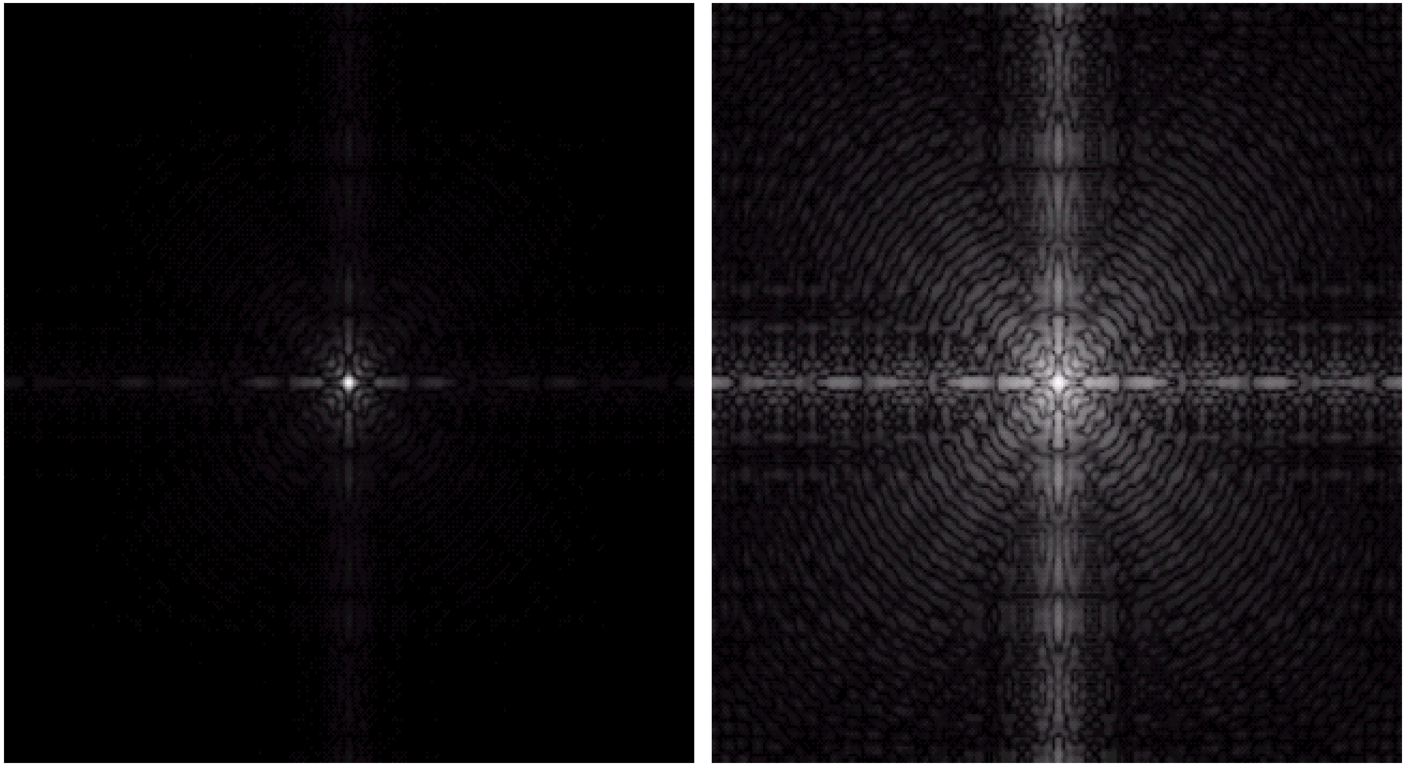
Where, c is constant

- Compresses the dynamic range of images with large variations in pixel values.

Image Enhancement in the Spatial Domain

a b

FIGURE 3.5
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.



$$s = c \log(1+r)$$

Power-Law Transformations

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

c, γ : positive constants

>>S=C ·r^(γ)

- Gamma correction

>>S=imadjust (r,[ ],[ ],1.5);

Image Enhancement in the Spatial Domain

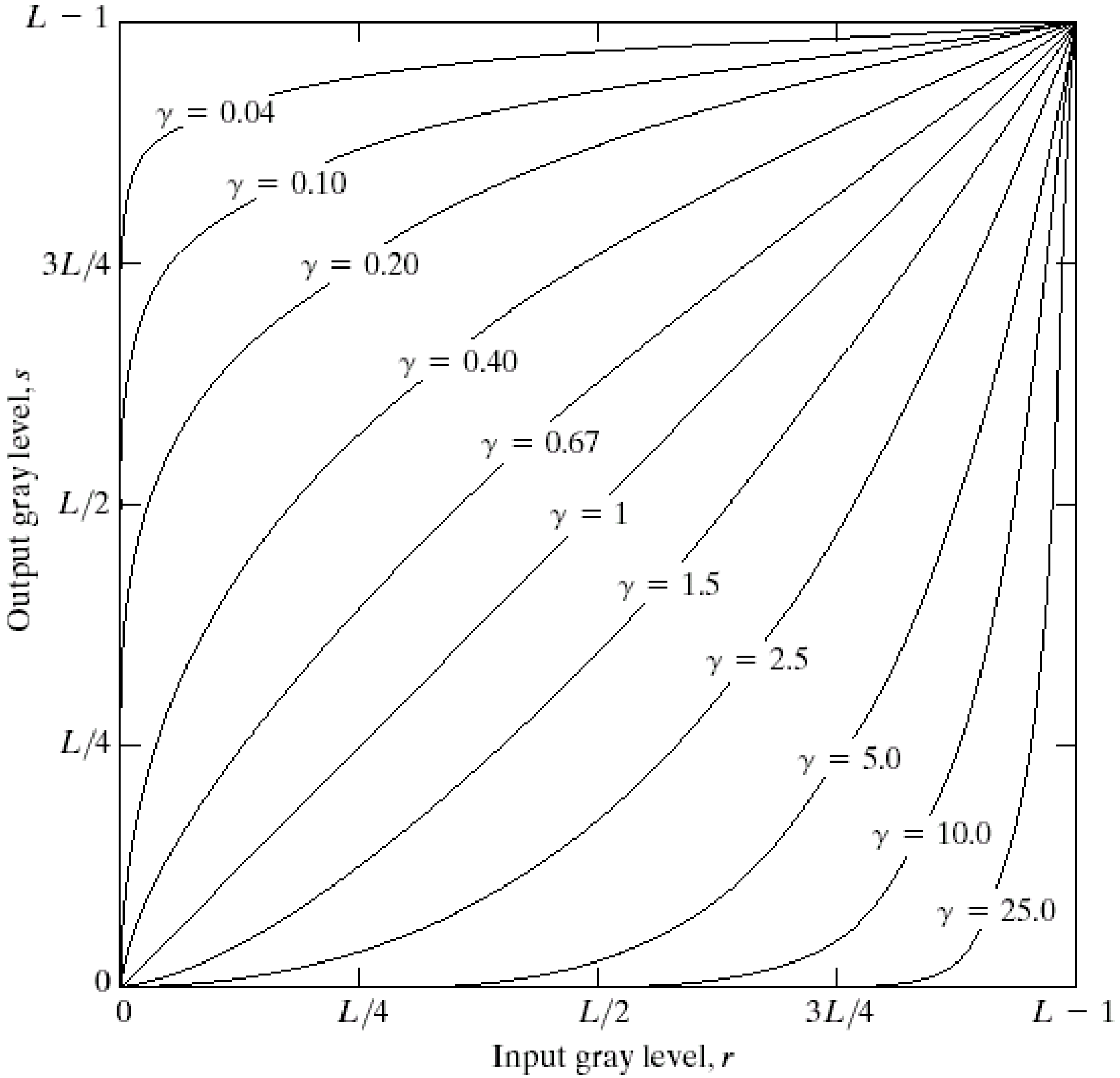
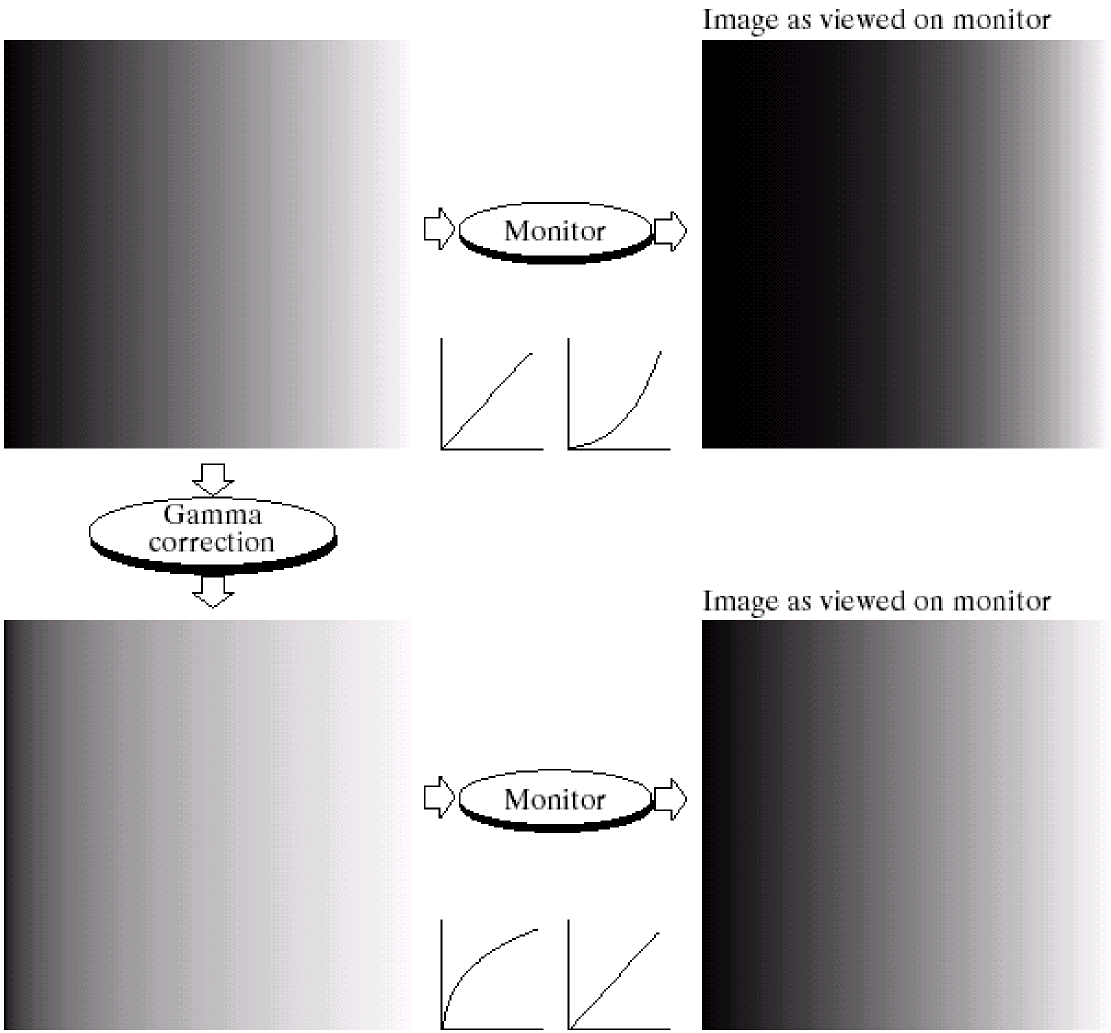


FIGURE 3.6 Plots of the equation $s = cr^\gamma$ for various values of γ ($c = 1$ in all cases).

γ=c=1: Identity

Image Enhancement - Spatial Domain



a b
c d

FIGURE 3.7
(a) Linear-wedge gray-scale image.
(b) Response of monitor to linear wedge.
(c) Gamma-corrected wedge.
(d) Output of monitor.

Image Enhancement - Spatial Domain

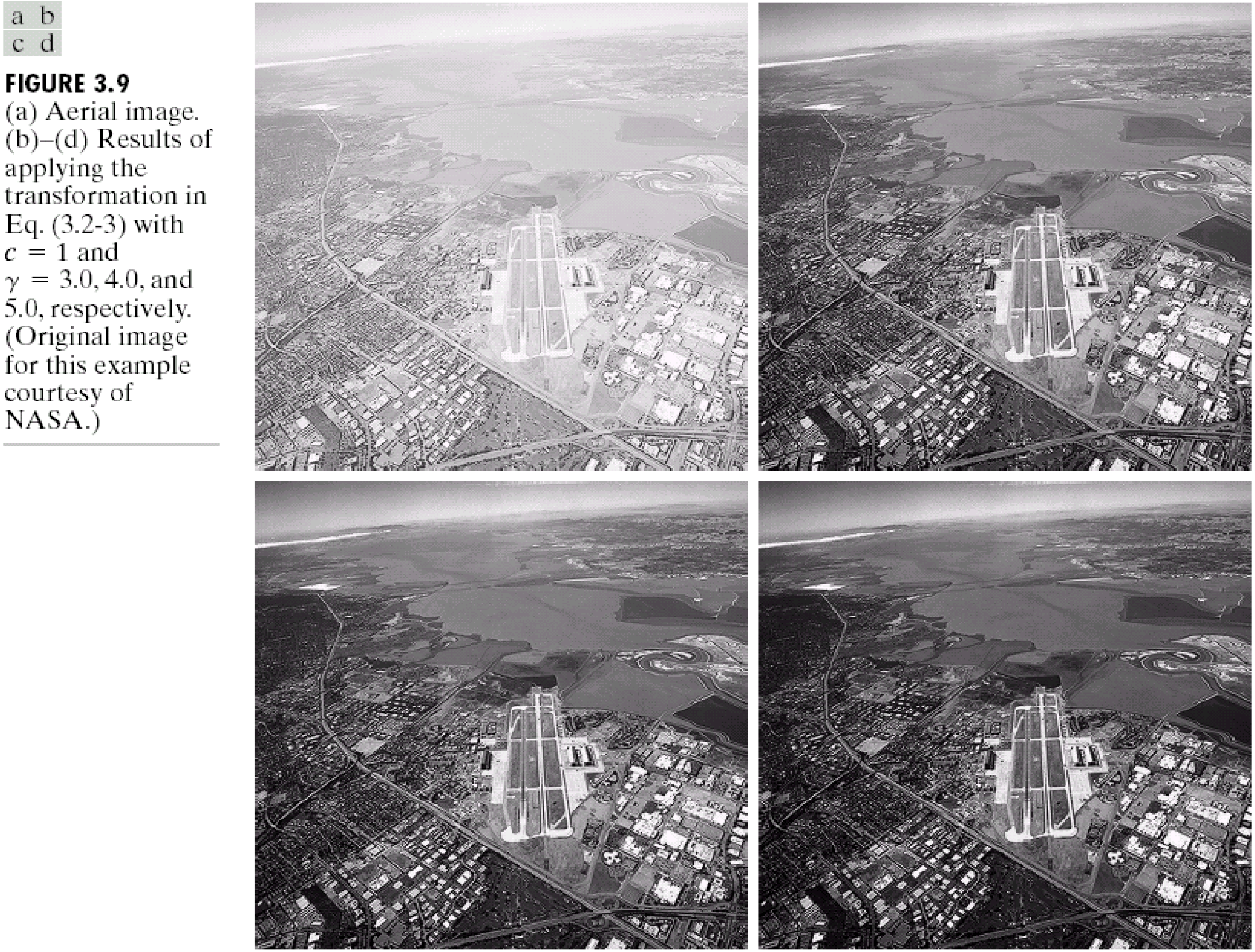
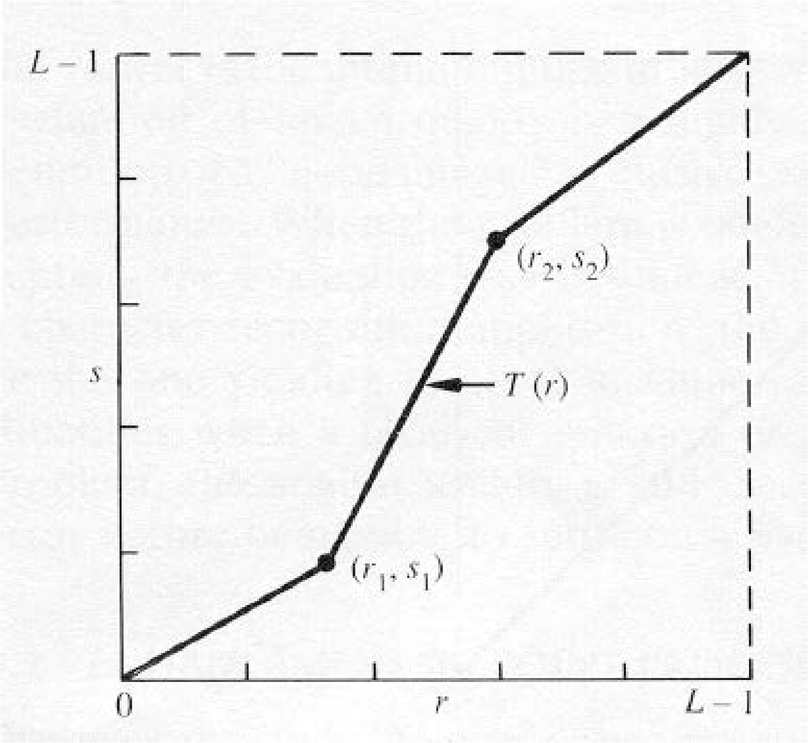


FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively. (Original image for this example courtesy of NASA.)

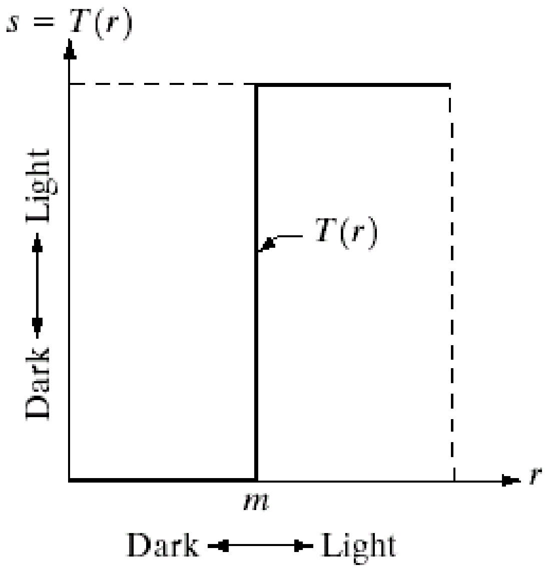
Piecewise-Linear Transformation Functions
Contrast Stretching

- To increase the dynamic range of the gray levels in the image being processed.



Contrast Stretching

- The locations of (r_1,s_1) and (r_2,s_2) control the shape of the transformation function.
  - If $r_1= s_1$ and $r_2= s_2$ the transformation is a linear function and produces no changes.
  - If $r_1=r_2$, $s_1=0$ and $s_2=L-1$, the transformation becomes a thresholding function that creates a binary image.



Contrast Stretching

- More on function shapes:
  - Intermediate values of (r_1,s_1) and (r_2,s_2) produce various degrees of spread in the gray levels of the output image, thus affecting its contrast.
  - Generally, $r_1 \leq r_2$ and $s_1 \leq s_2$ is assumed.

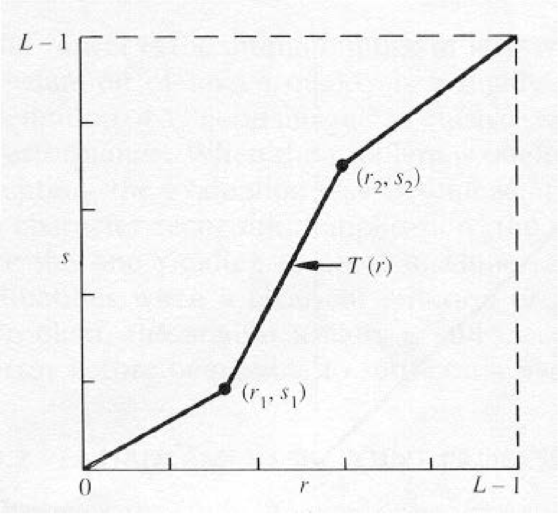
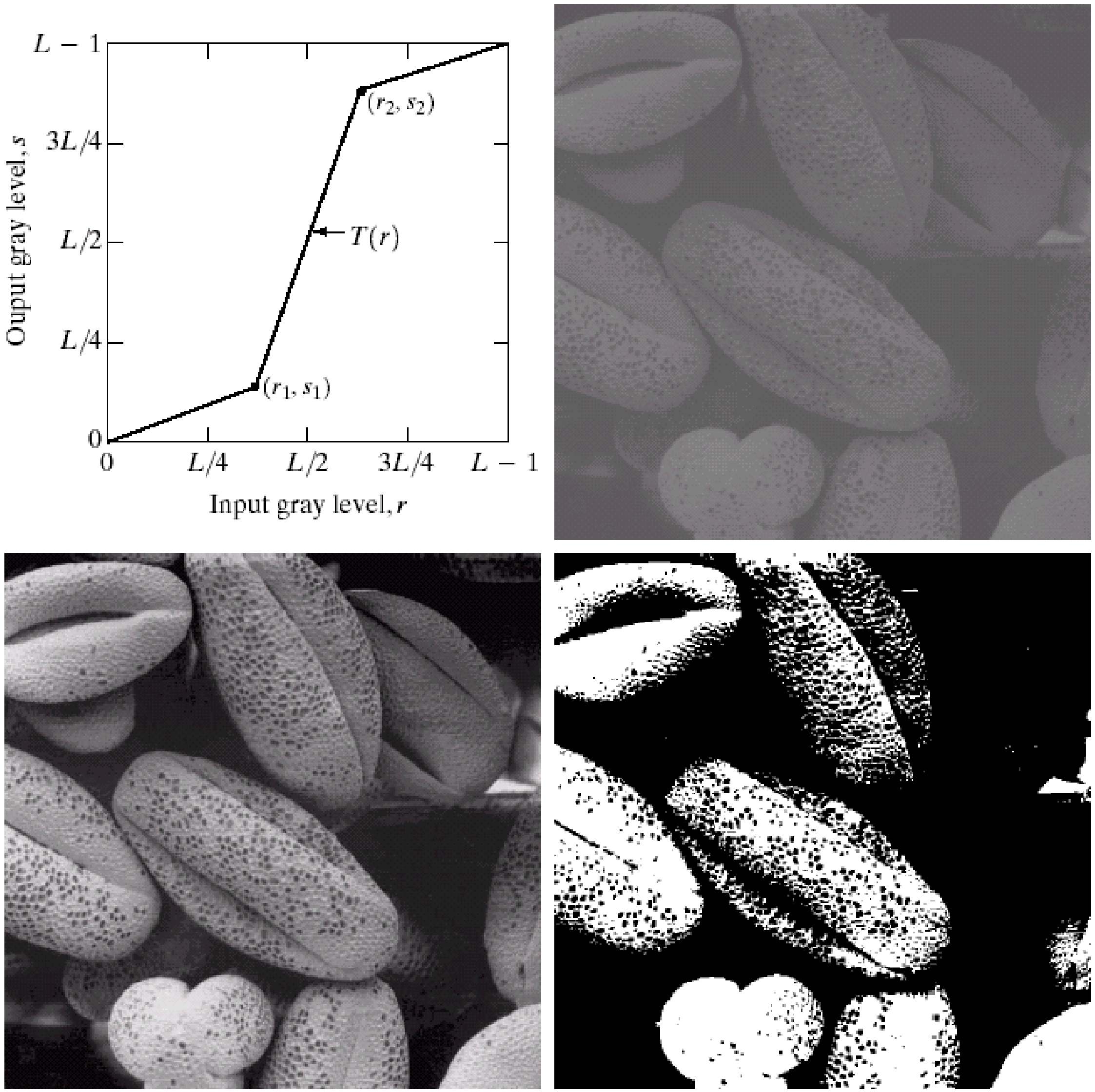


Image Enhancement - Spatial Domain

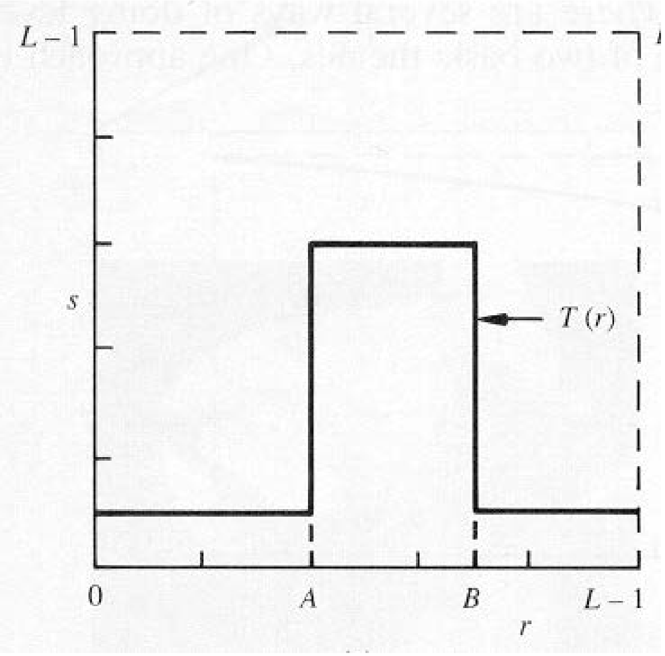


a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Gray-Level Slicing

- To highlight a specific range of gray levels in an image (e.g. to enhance certain features).



One way is to display a high value for all gray levels in the range of interest and a low value for all other gray levels (binary image).

Gray-Level Slicing

– The second approach is to brighten the desired range of gray levels but preserve the background and gray-level tonalities in the image:

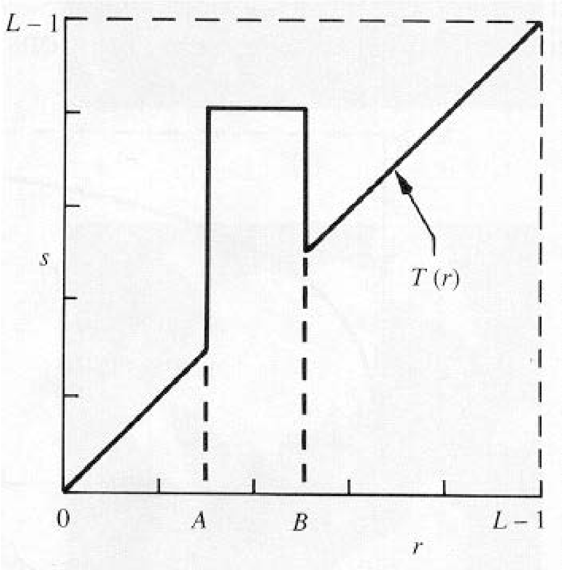
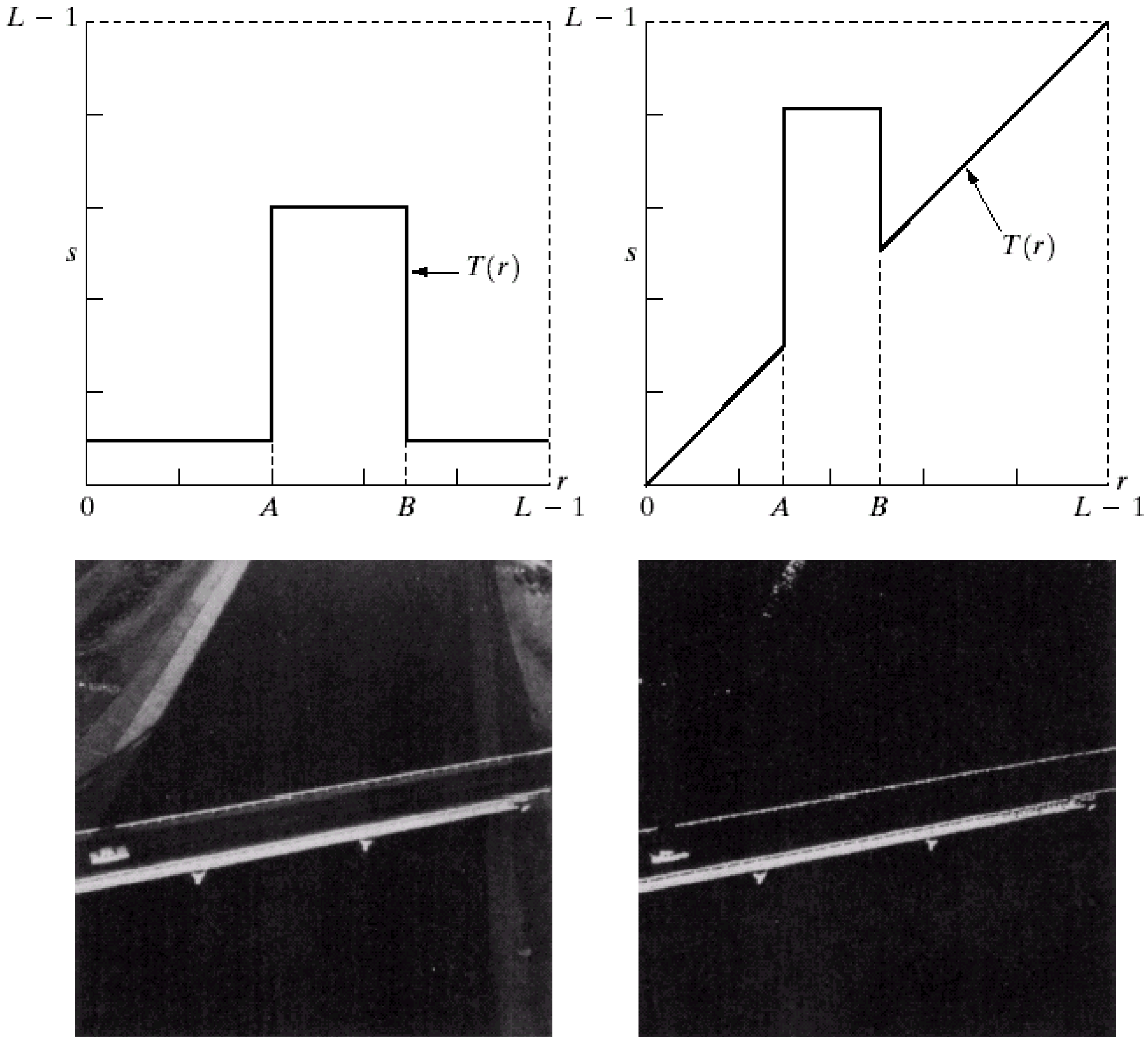


Image Enhancement - Spatial Domain



a b
c d

FIGURE 3.11 (a) This transformation highlights range $[A, B]$ of gray levels and reduces all others to a constant level. (b) This transformation highlights range $[A, B]$ but preserves all other levels. (c) An image. (d) Result of using the transformation in (a).

Bit-Plane Slicing

- To highlight the contribution made to the total image appearance by specific bits.
  - i.e. Assuming that each pixel is represented by 8 bits, the image is composed of 8 x 1-bit planes.
  - Plane 0 contains the least significant bit and plane 7 contains the most significant bit.

Bit-Plane Slicing

- More on bit planes:
  - Only the higher order bits (top four) contain visually significant data.
  - The other bit planes contribute the more subtle (faint) details.
  - Plane 7 corresponds exactly with an image threshold at gray level 128.

Image Enhancement - Spatial Domain

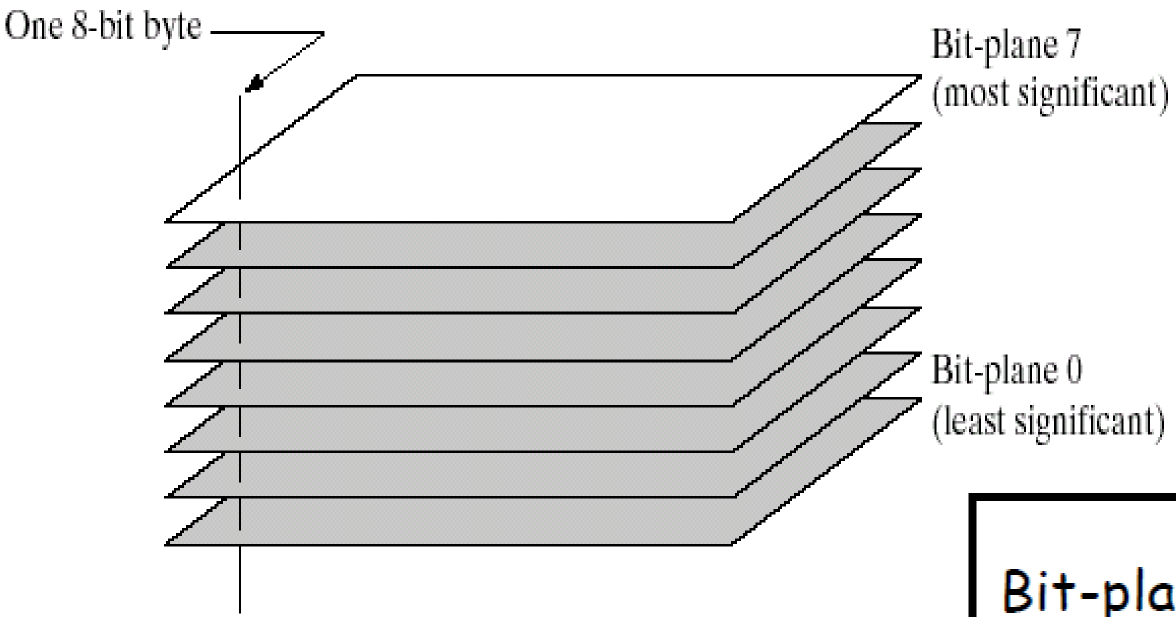


FIGURE 3.12 Bit-plane representation of an 8-bit image.

Bit-plane 7		Bit-plane 6
Bit-plane 5	Bit-plane 4	Bit-plane 3
Bit-plane 2	Bit-plane 1	Bit-plane 0

I=imread('Newton.bmp');
I1=bitand(I, 128); Bit anding by '128' ; 128 = $(10000000)_2$
imshow(I)
figure, imshow(I1)

Image Enhancement in the Spatial Domain

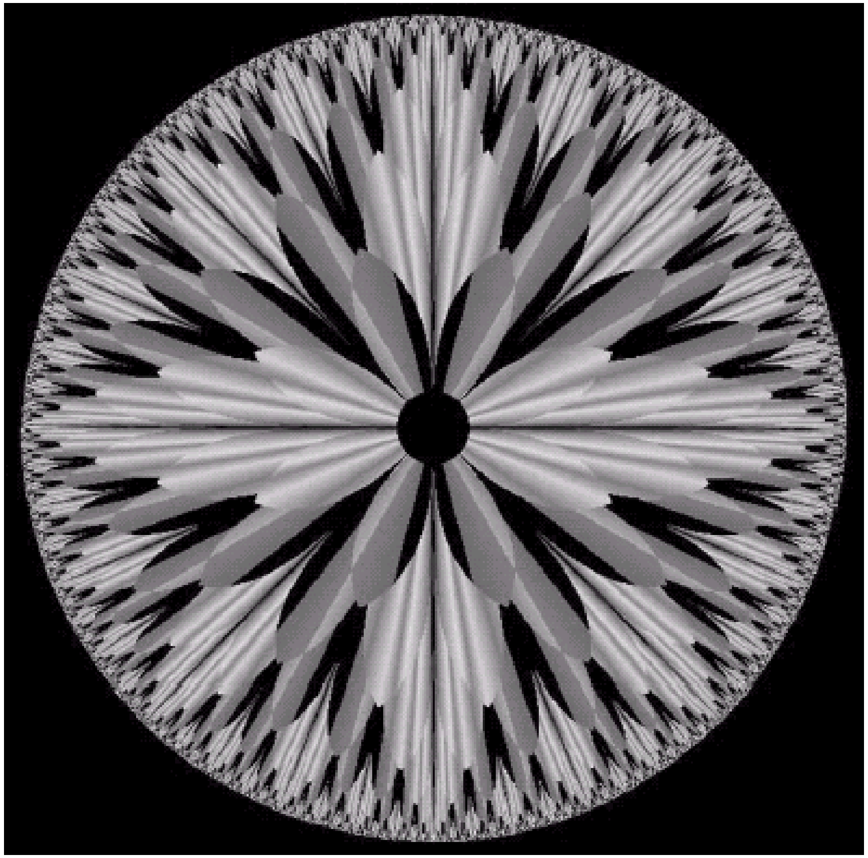


FIGURE 3.13 An 8-bit fractal image. (A fractal is an image generated from mathematical expressions). (Courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA.)

Image Enhancement in the Spatial Domain

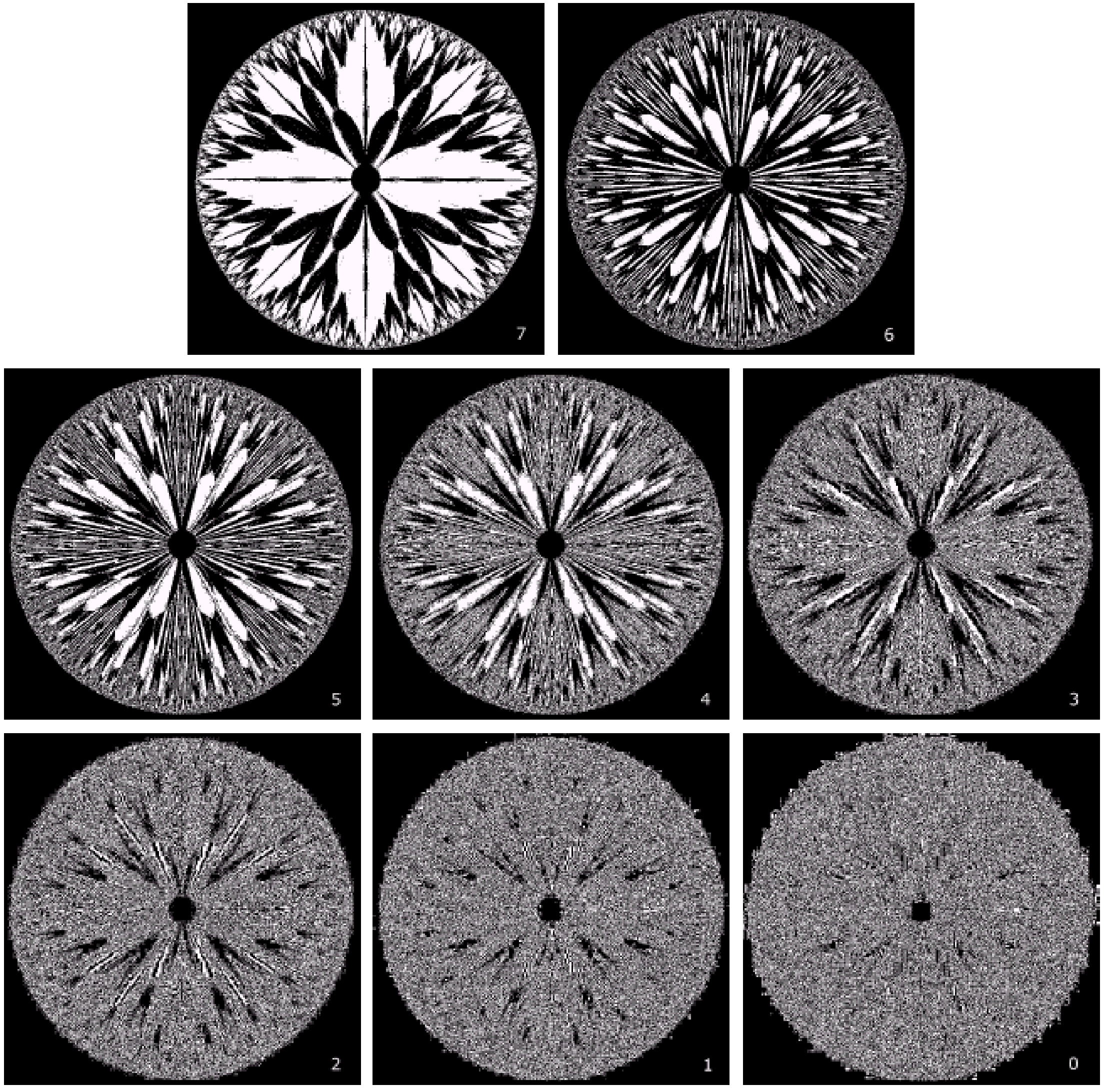


FIGURE 3.14 The eight bit planes of the image in Fig. 3.13. The number at the bottom, right of each image identifies the bit plane.

Image Subtraction

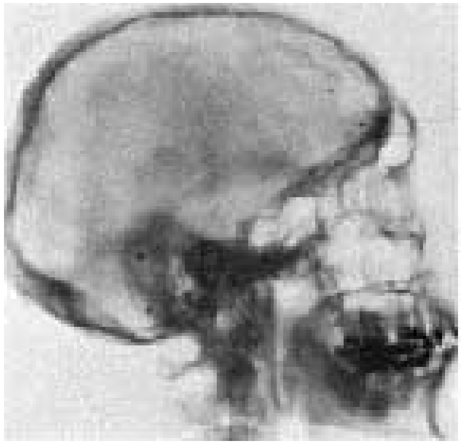
- $f(i,j)$ and $h(i,j)$ are input images

$$g(i,j) = f(i,j) - h(i,j)$$

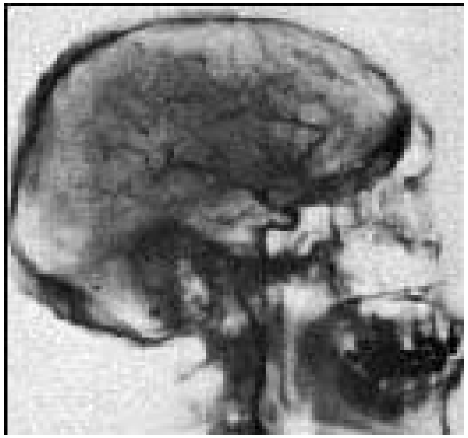
- $g(i,j)$ is subtracted or difference image

- Application in image enhancement and segmentation

Image Subtraction
(Digital Subtraction Angiography-DSA)



Original Brain Image



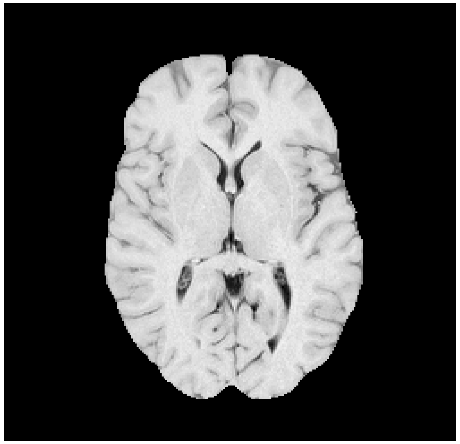
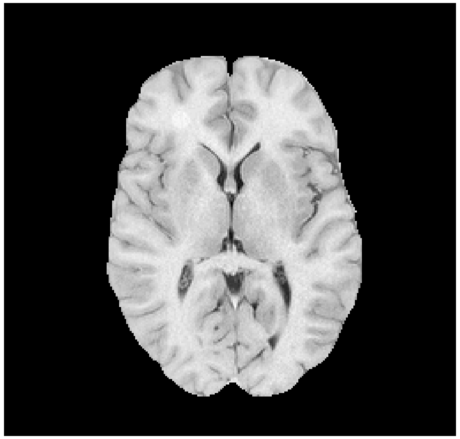
Mask

Subtracted Image

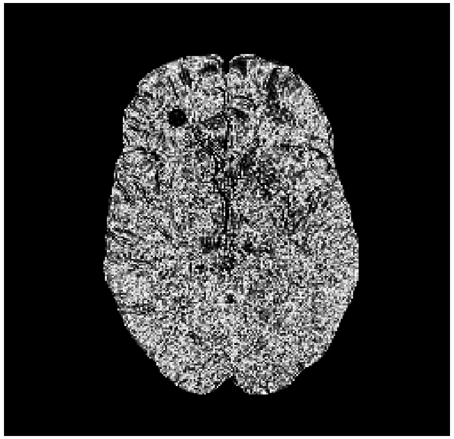
$$g(i, j) = f(i, j) - h(i, j)$$

- Digital Subtraction Angiography shows how the injected iodine dye propagates through the various arteries.
- Application: detection of blood clots (blocked arteries).

Image Subtraction…
(Non Parametric Image Subtraction)

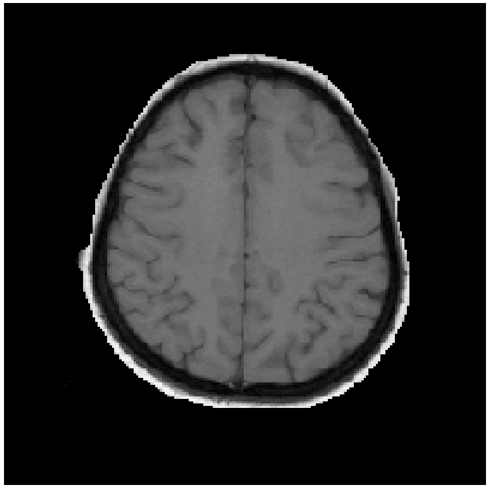
MRI scans of the brain taken with different echo train times



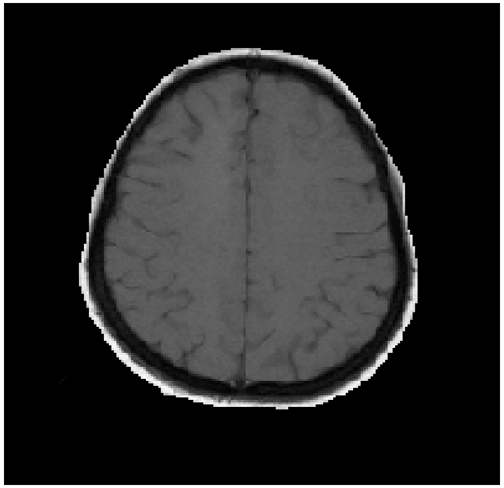
non-parametric image subtraction

Applications: volumetric analysis of lesions (statistical analysis of the difference image in a neighbourhood).

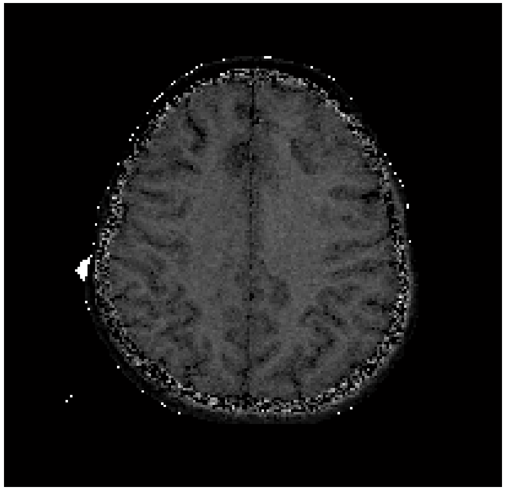
Image Subtraction (Magnetization Transfer Ratio Mapping)



Magnetization Transfer Off



Magnetization Transfer On



Magnetization Transfer Ratio Map

$$MTR = \frac{MT_{off} - MT_{on}}{MT_{off}}$$

Applications : detection of tape worm lesions and hemorrhages

Histogram Equalization

- Histogram of a digital image with gray values, r_k, in the range [0,L-1] is a discrete function.

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

  where r_k is the k^{th} gray value and n_k is the number of pixels of value r_k in the image.
- The '*n*' is total number of pixels in the image.
- $p(r_k)$ is the estimate of the probability of occurrence of gray level r_k .
- Histogram equalization enhances contrast of the image.

Histogram Equalization

$$s_k = T(r_k)$$

- $T(r_k)$ is single valued and monotonically increasing :

  – preserves the order of gray scale

- $0 \le T(r_k) \le 1$; for $0 \le r_k \le 1$: guarantees a consistent mapping in the allowed range

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n}$$

$$= \sum_{j=0}^{k} p(r_j)$$

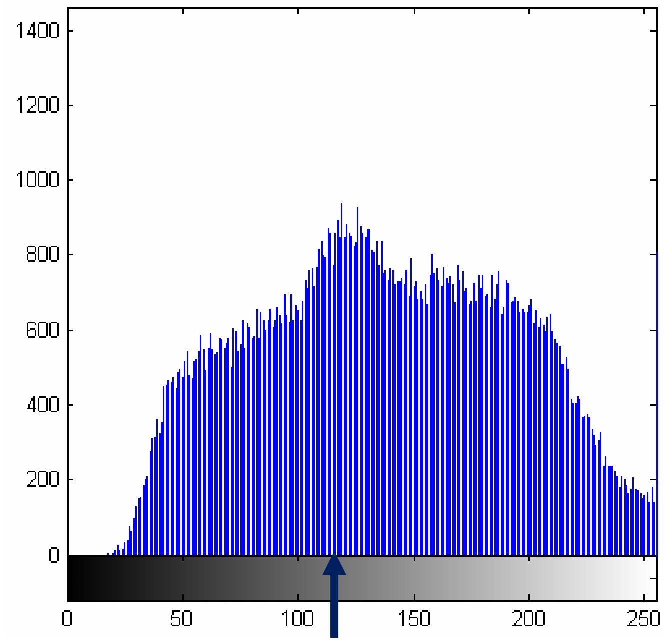
k = 0, 1, … L-1

Contd…

- In a gray level image the probabilities assigned to each gray level can be given by the relation:

$$p_r(r_k) = \frac{n_k}{N} \quad 0 \le \mathrm{r_k} \le 1\,,\, \mathrm{k} = 0,1,2 \ldots \mathrm{L-1}$$

- r_{k} - The normalized intensity value
- L - No. of gray levels in the image
- n_{k} - No. of pixels with gray level $\mathrm{r_k}$
- N - Total number of pixels



Histogram

➢ **The plot of $p_r(r_k)$ with respect to r_k is called Histogram of the image**

Histogram Specification

```
clear all
clc
I=imread('lena.tif');
figure, imshow(I), title('Original Gray Image')
%K=rgb2gray(I), figure, imshow(k); rgb image converted to gray
%title('Gray converted Original image’); title to gray converted image
figure, imhist(I), title('Histogram of Original image')
J=histeq(I,256);
figure, imshow(J),  title('Histogram Equalized image');
figure, imhist(J)
title('Histogram of equalized image');
```

Spatial Filters

- Two types of spatial filters
  - Smoothing filters
    - ✓ Neighborhood Averaging
    - ✓ Median filtering
  - Sharpening filters
    - ✓ High pass filter
    - ✓ High boost filter
    - ✓ Derivative filter

Median Filtering

- It is a Nonlinear filter
- When objective is noise reduction, not the smoothing, median filter is used
- Gray level of each pixel is replaced by the median of the gray levels in the neighborhood
- Highly effective for spike noise
- Arrange the matrix elements in ascending order

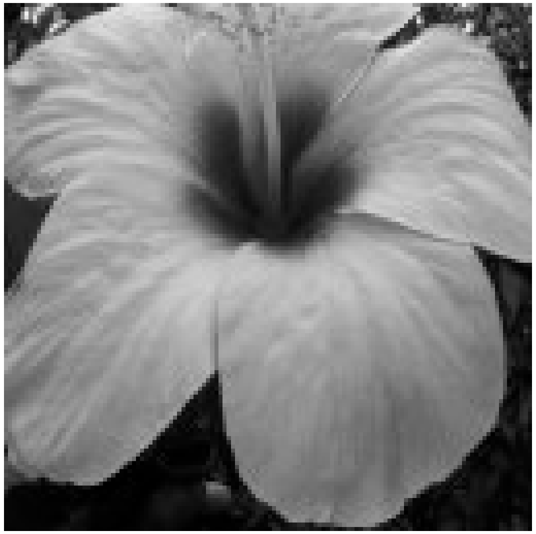
3	**6**	**8**
1	3	**2**
4	**7**	**5**

1 2 3 3 4 5 6 7 8

Median element (5th element in 3x3 mask)

- Replace the center element **'3'** by median element **'4'**

Median Filtering



Original

Median filtered
(3x3 neighbor)

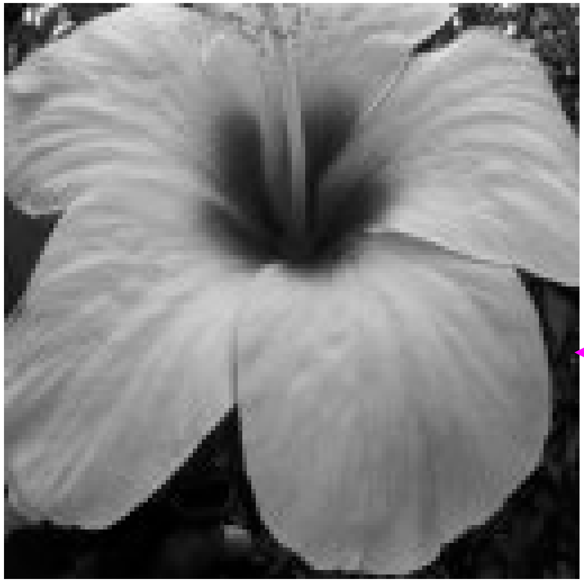
Median filtered
(7x7 neighbor)

Basic High Pass Filtering

- Positive coefficient at center and negative coefficients in the outer periphery
- Results in enhanced edges over a dark background

1/9 x

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



Original image

Basic high pass filtered image

High Boost Filtering

High pass = Original – Low pass

High boost = A (Original) – Low pass

= (A-1)(Original) + Original – Low pass

= (A -1)(Original) + High pass

- A=1 : standard High pass
- A > 1 : part of original added
- High boost looks more like original

High Boost Filtering

$$\frac{1}{9} \times \begin{array}{|c|c|c|} \hline -1 & -1 & -1 \\ \hline -1 & w & -1 \\ \hline -1 & -1 & -1 \\ \hline \end{array}$$

Mask for HBF
W = 9A -1

A=1.5

A=2.5

Derivative Filters

- Neighborhood averaging – smoothing effect
- Averaging is analogous to integration
- Differentiation is expected to have opposite effect
- For a continuous function *f(x,y)* the gradient of *f* at *(x,y)* is

$$\nabla \vec{f} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \qquad \nabla f = mag(\nabla \vec{f}) = \left[\left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2 \right]^{1/2}$$

Derivative Filters

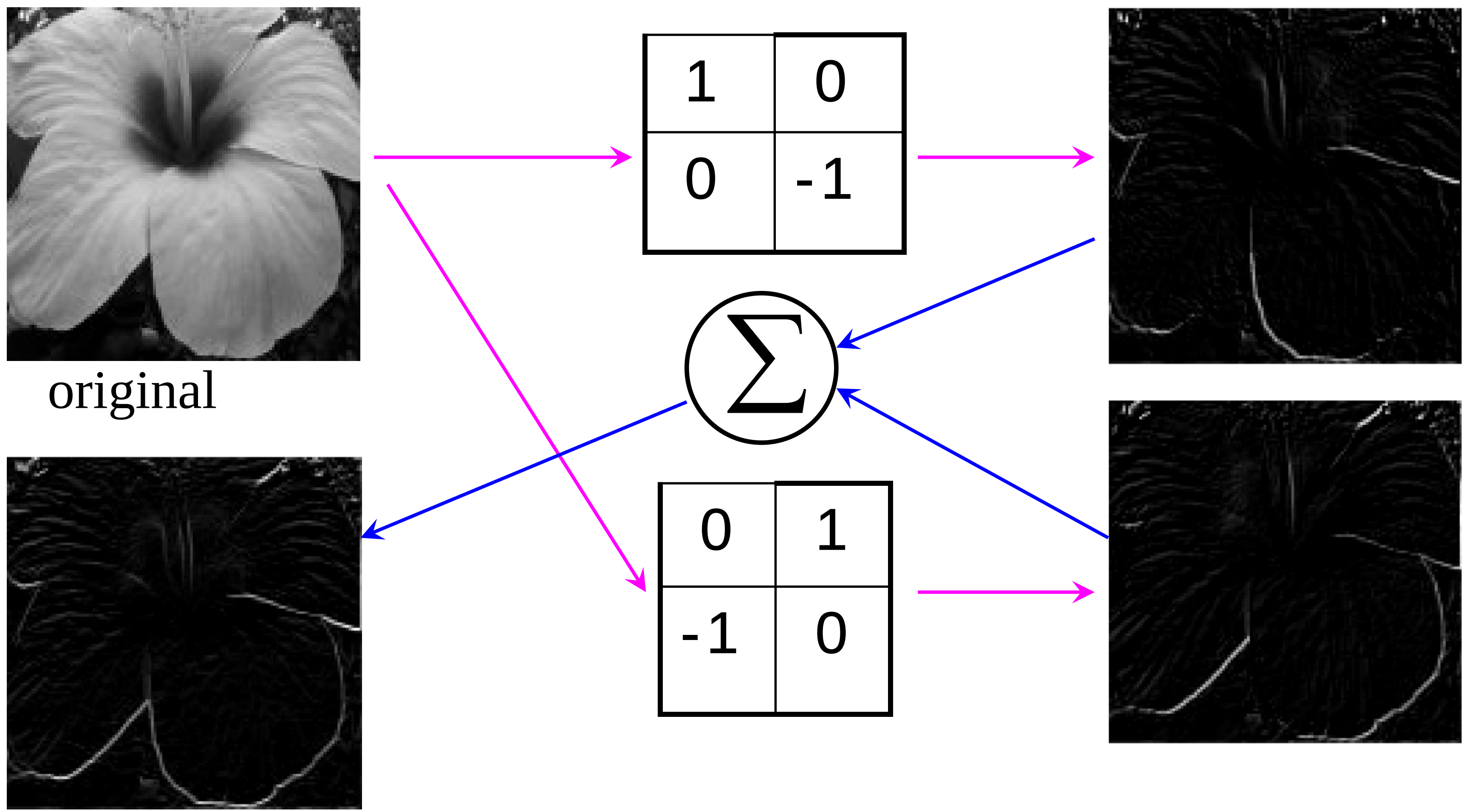
z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

$$\left.\begin{aligned}\nabla f &= \left[\left(z_5 - z_8\right)^2 + \left(z_5 - z_6\right)^2\right]^{1/2} \\ \nabla f &= \left[\left(z_5 - z_9\right)^2 + \left(z_6 - z_8\right)^2\right]^{1/2}\end{aligned}\right\} \text{Roberts operators}$$

}

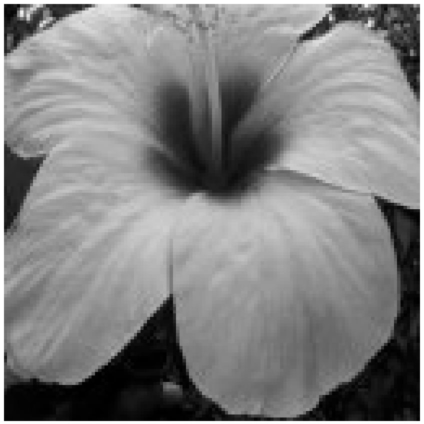
$$\left.\begin{aligned}\nabla f \approx & \left|(z_7 + z_8 + z_9) - (z_1 + z_2 + z_3)\right| \\ & + \left|(z_3 + z_6 + z_9) - (z_1 + z_4 + z_7)\right|\end{aligned}\right\} \text{Prewitt operator}$$

Roberts Filters



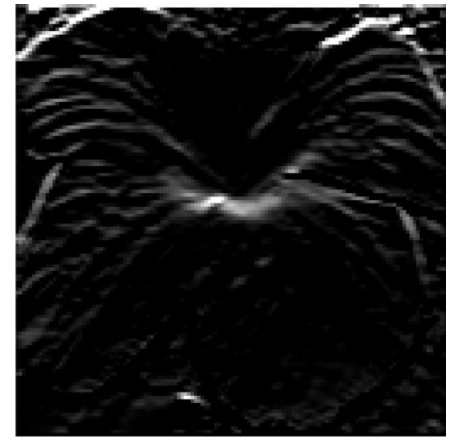
Output Image

Prewitt Filters

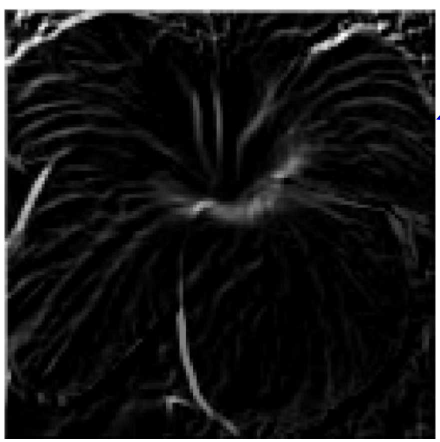


original

-1	-1	-1
0	0	0
1	1	1

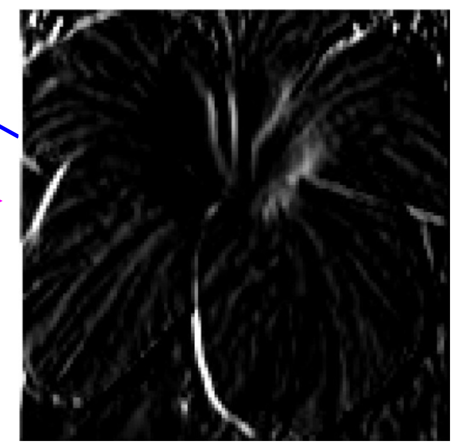


Σ



Output Image

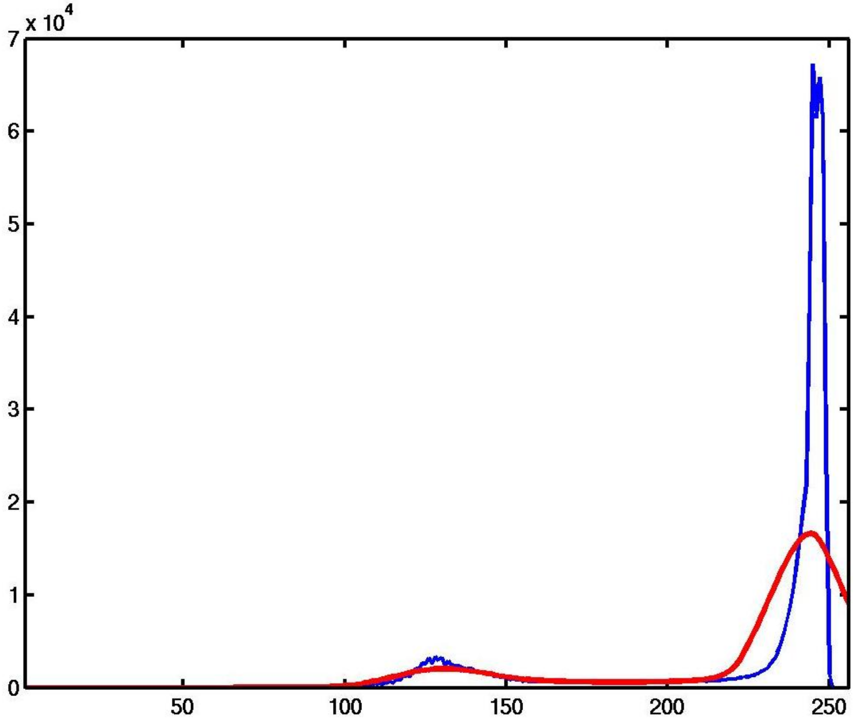
-1	0	1
-1	0	1
-1	0	1



Document Image Binarization

- Document Image is bimodal
- $N_1(\mu_1,\sigma_1)$, $N_2(\mu_2,\sigma_2)$ are modal parameters
- T is the threshold for binarization

$$T = \frac{\sigma_2\mu_1 + \sigma_1\mu_2}{\sigma_1 + \sigma_2}$$

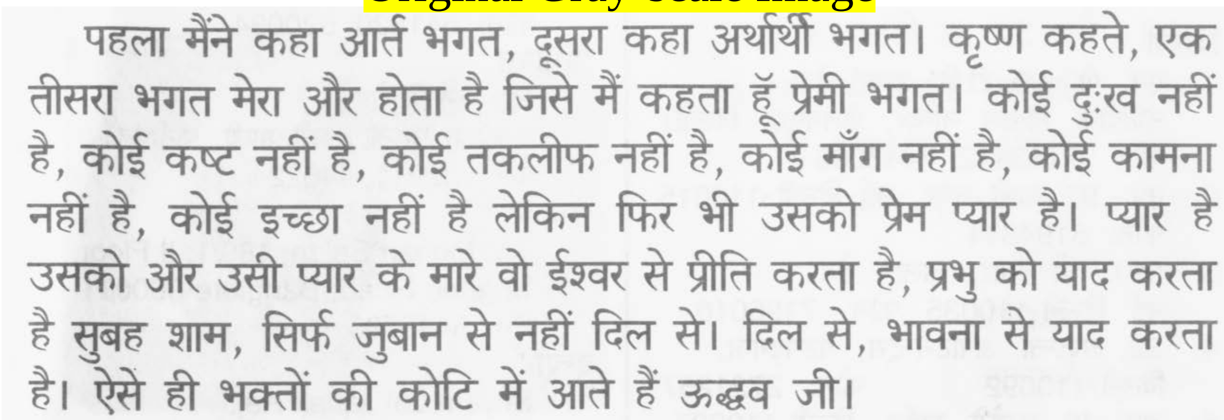


Matlab Program for Binarization

```
>>clear all
>>clc
>>I=imread('ocrr.png');
>>I1=rgb2gray(I);
>>imshow(I1), title('Original Gray-scale Image')
>>level1 = graythresh(I1);
>>BW = im2bw(I1,level1);
>>figure, imshow(BW),
>>title('Image after Gray-level Thresholding in Bi-Level')
```

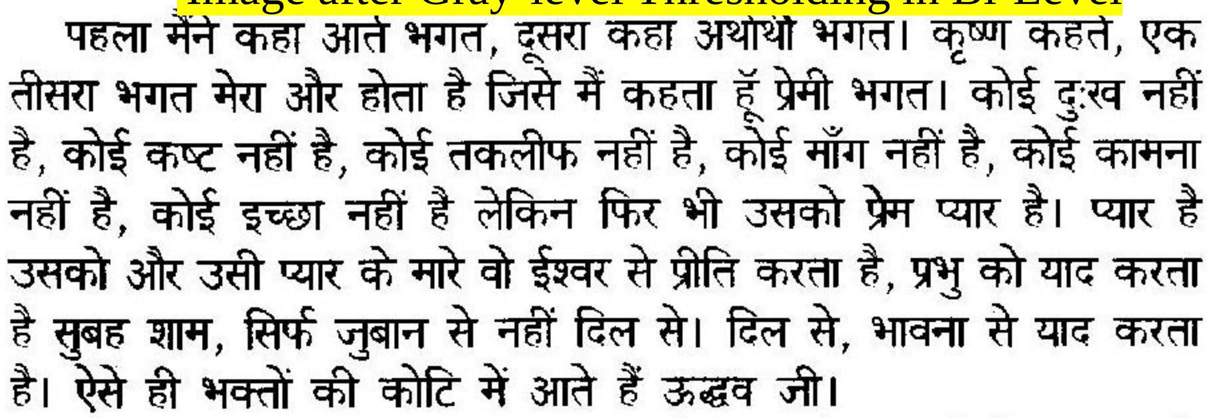
Document Image Binarization

Original Gray-scale Image

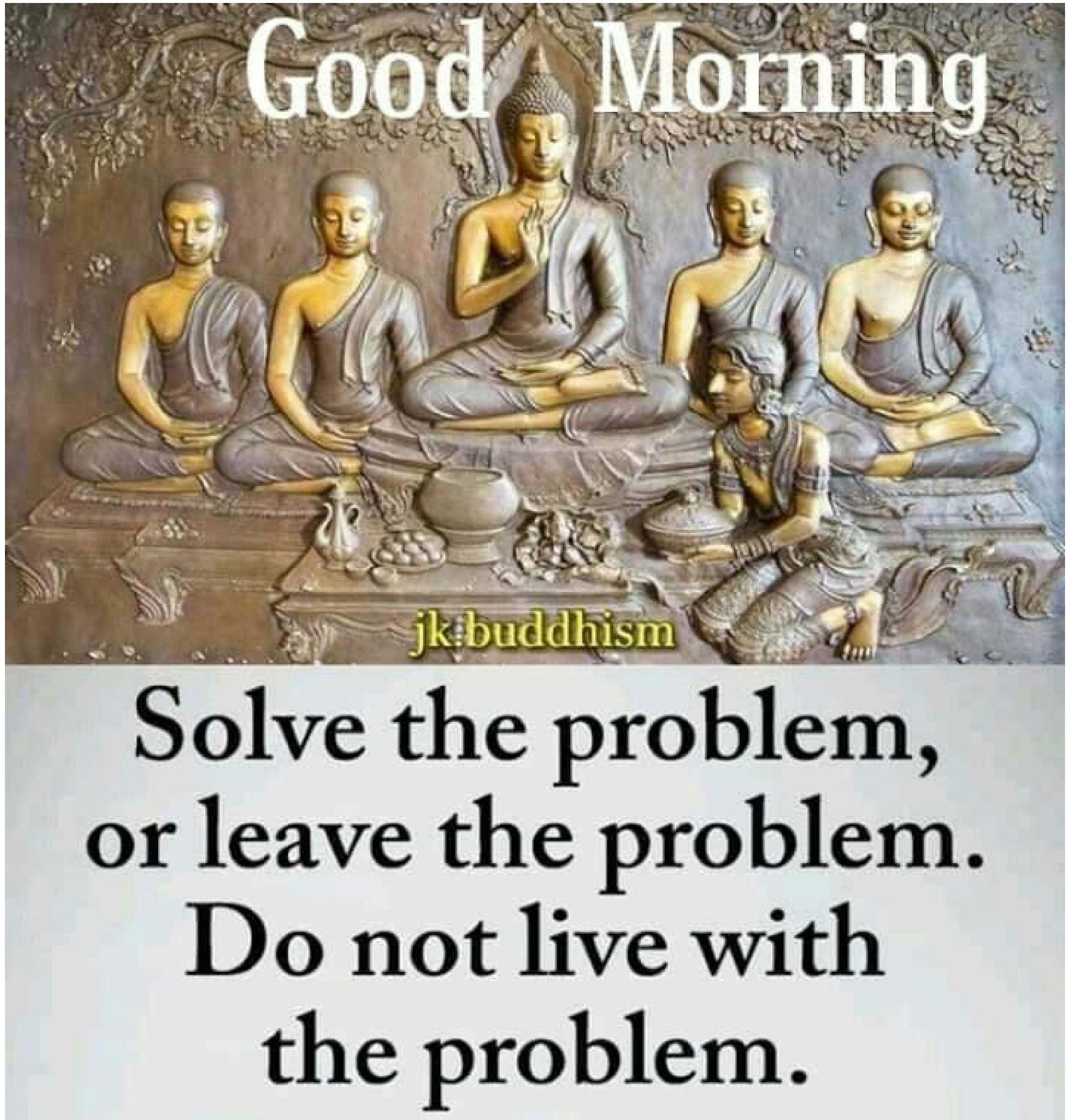


पहला मैंने कहा आर्त भगत, दूसरा कहा अर्थार्थी भगत। कृष्ण कहते, एक तीसरा भगत मेरा और होता है जिसे मैं कहता हूँ प्रेमी भगत। कोई दुःख नहीं है, कोई कष्ट नहीं है, कोई तकलीफ नहीं है, कोई माँग नहीं है, कोई कामना नहीं है, कोई इच्छा नहीं है लेकिन फिर भी उसको प्रेम प्यार है। प्यार है उसको और उसी प्यार के मारे वो ईश्वर से प्रीति करता है, प्रभु को याद करता है सुबह शाम, सिर्फ जुबान से नहीं दिल से। दिल से, भावना से याद करता है। ऐसे ही भक्तों की कोटि में आते हैं ऊद्धव जी।

'Image after Gray-level Thresholding in Bi-Level



पहला मैंने कहा आर्त भगत, दूसरा कहा अर्थार्थी भगत। कृष्ण कहते, एक तीसरा भगत मेरा और होता है जिसे मैं कहता हूँ प्रेमी भगत। कोई दुःख नहीं है, कोई कष्ट नहीं है, कोई तकलीफ नहीं है, कोई माँग नहीं है, कोई कामना नहीं है, कोई इच्छा नहीं है लेकिन फिर भी उसको प्रेम प्यार है। प्यार है उसको और उसी प्यार के मारे वो ईश्वर से प्रीति करता है, प्रभु को याद करता है सुबह शाम, सिर्फ जुबान से नहीं दिल से। दिल से, भावना से याद करता है। ऐसे ही भक्तों की कोटि में आते हैं ऊद्धव जी।


Good Morning
jk.buddhism
Solve the problem,
or leave the problem.
Do not live with
the problem.

Thanks!

Questions Please?