EE 562
Image Processing

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Contents

- Introduction
- Digital image fundamentals
- **Intensity transformations and spatial filtering**
- Filtering in the frequency domain
- Image restoration and reconstruction
- Color image processing
- Image compression
- Morphological image processing
- Image segmentation

Intensity Transformations

Tell me and I forget.

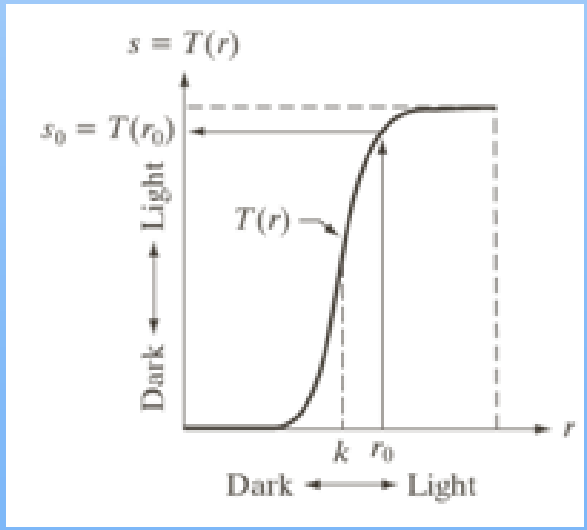
Show me and I remember.

Let me do and I understand.

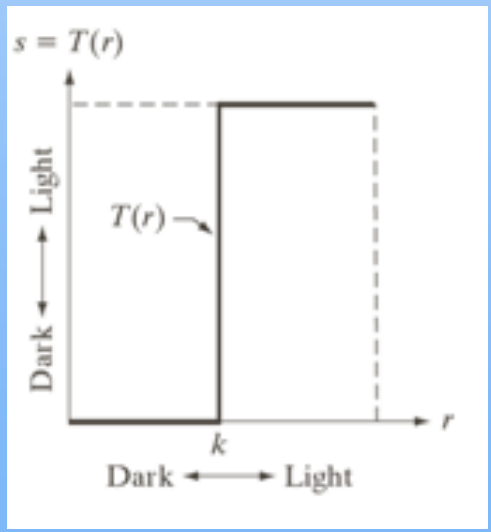
Intensity Transformations

Intensity transformation functions

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



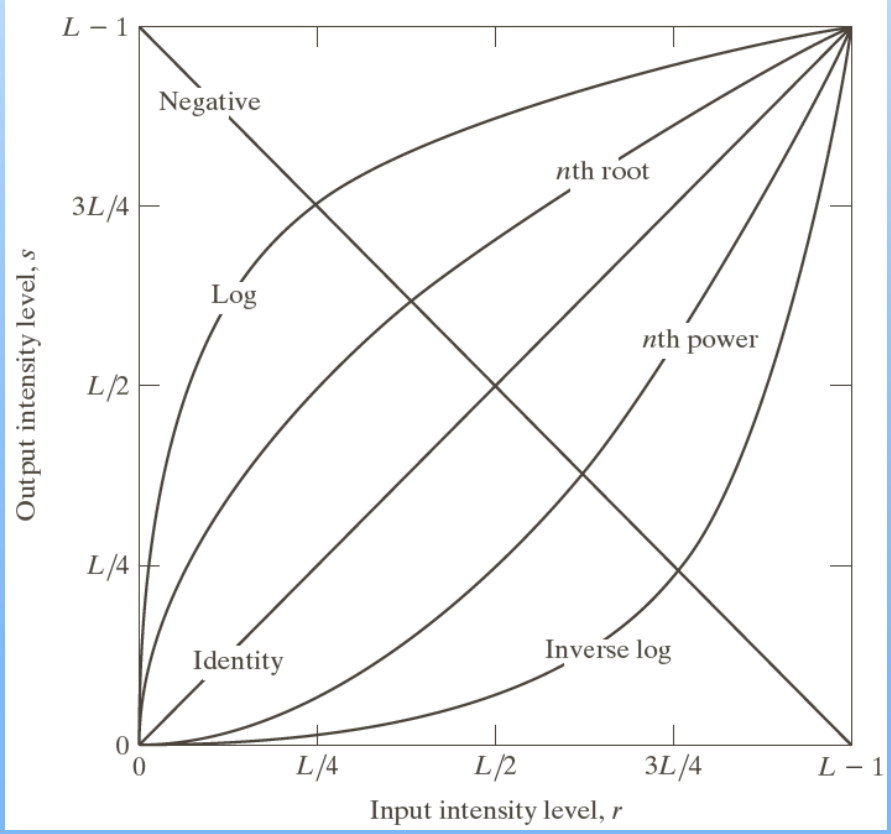
Contrast stretching



Thresholding

Intensity Transformations

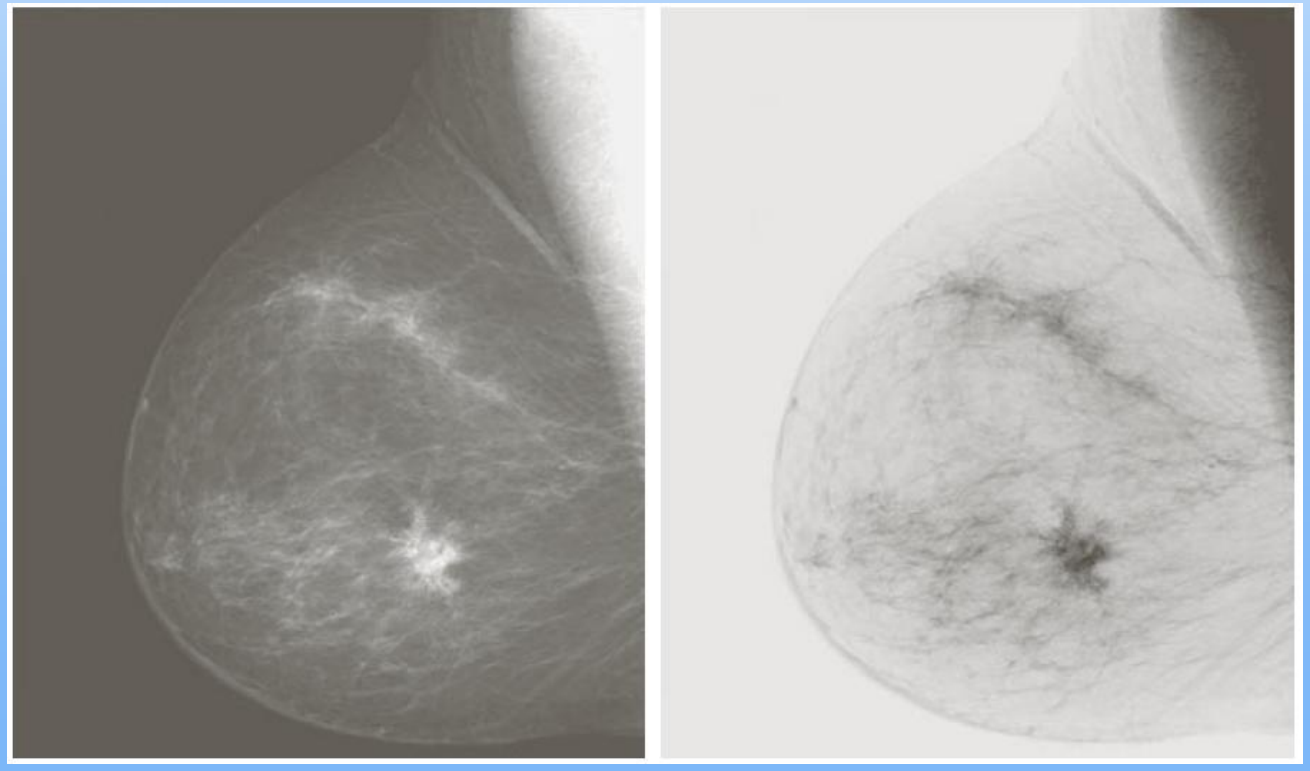
Intensity transformation functions



Some basic intensity functions

Intensity Transformations

Obtaining the Negative Image



Original mammogram and its negative

Intensity Transformations

Power Law (Gamma) Transformations

$$g(x,y) = cf^{\gamma}(x,y)$$

MRI

c=1, γ=0.6

c=1, γ=0.4

c=1, γ=0.3

Intensity Transformations

Power Law (Gamma) Transformations

$$g(x,y) = cf^{\gamma}(x,y)$$

Aerial image

c=1, γ=3

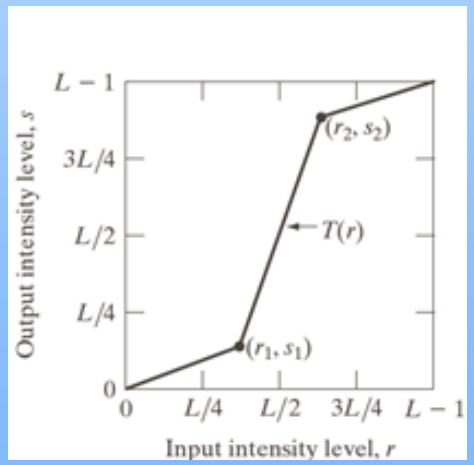
c=1, γ=4

c=1, γ=5

Intensity Transformations

Piecewise Linear Transformations

Low contrast image



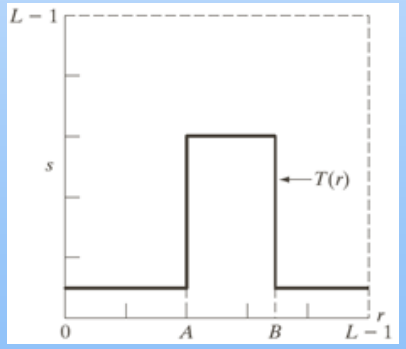
Transformation

Contrast stretched image

Intensity Transformations

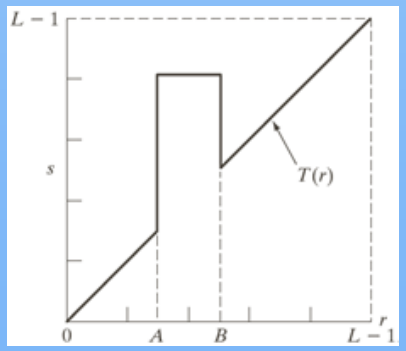
Thresholding and Slicing Transformations

Aortic angiogram



Transformation

Result

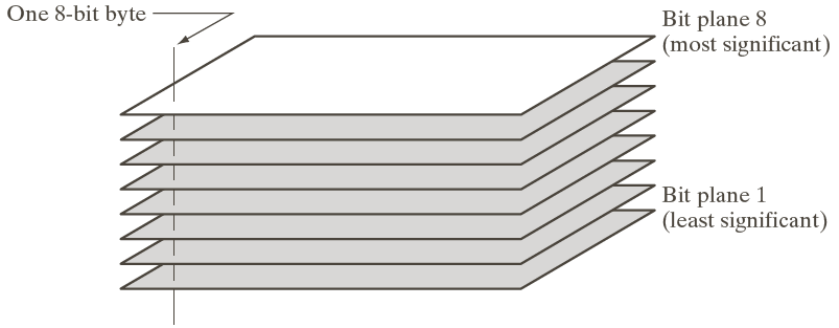


Transformation

Result

Intensity Transformations

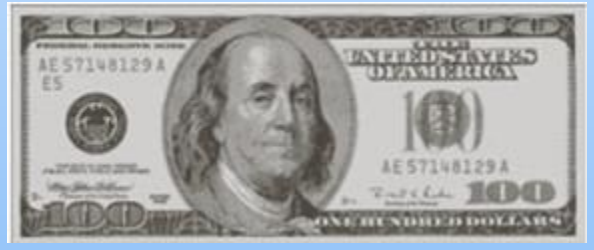
Bit Plane Representation



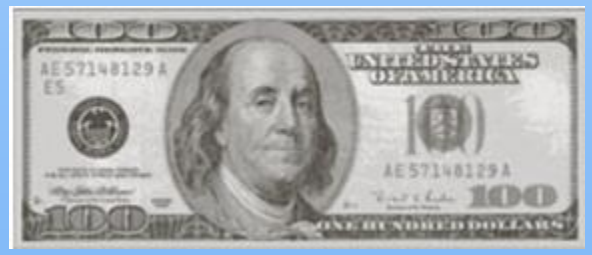
Bit planes of the dollar image

Intensity Transformations

Bit Plane Representation



Combining bit planes 7 and 8



Combining bit planes 6, 7, and 8

Combining bit planes 5, 6, 7 and 8

Intensity Transformations

Histogram based Intensity Transformation

What is a histogram?

- Histogram equalization
- Histogram specification
- Local enhancement

Intensity Transformations

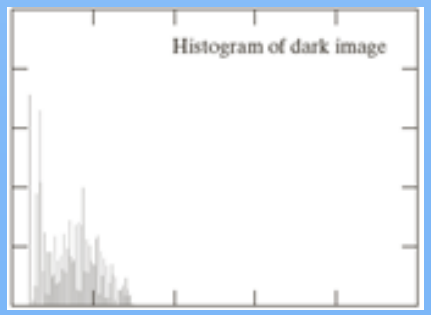
Histograms of Different Images

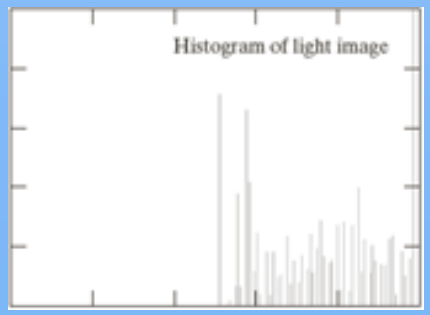
Dark image

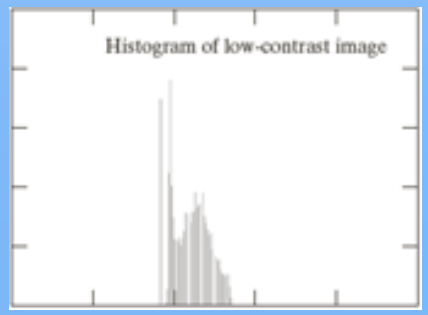
Light image

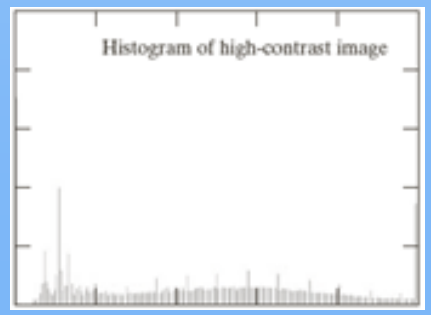
Low contrast image

High contrast image





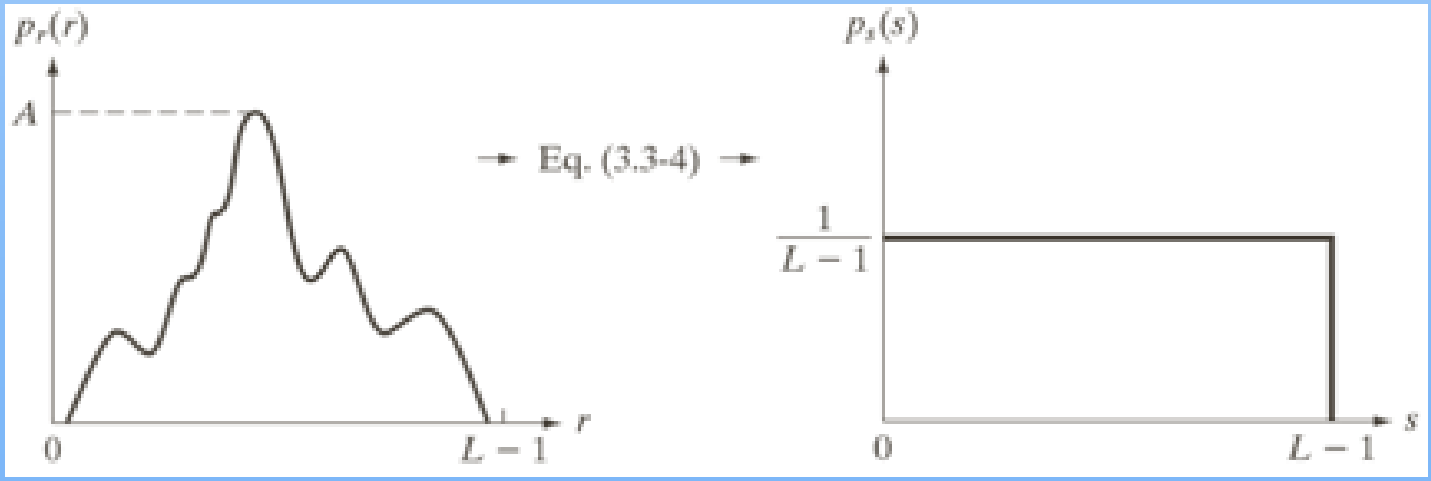




Intensity Transformations

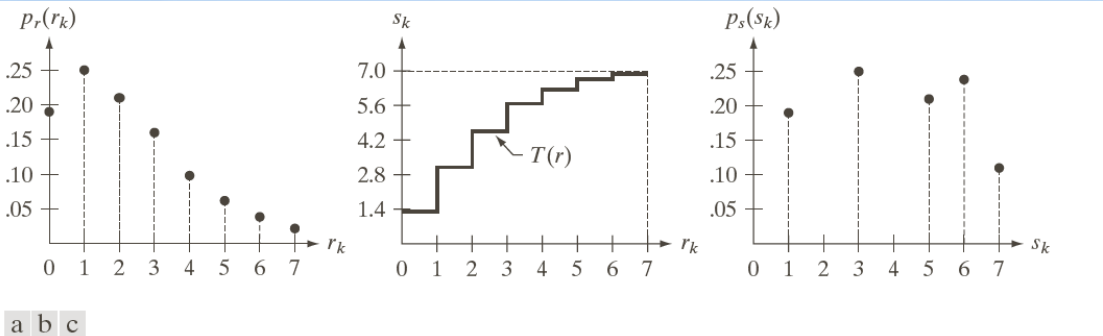
Histogram Equalization

$$s = T(r) = (L-1)\int_0^r p_r(w)dw$$



Obtaining a uniform pdf

Intensity Transformations

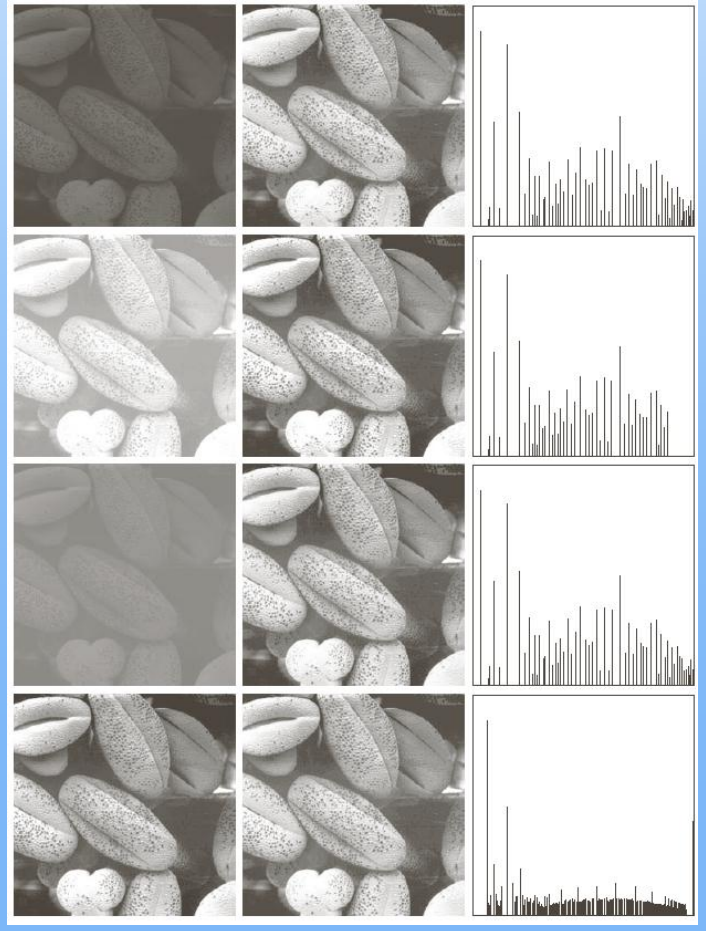


a b c

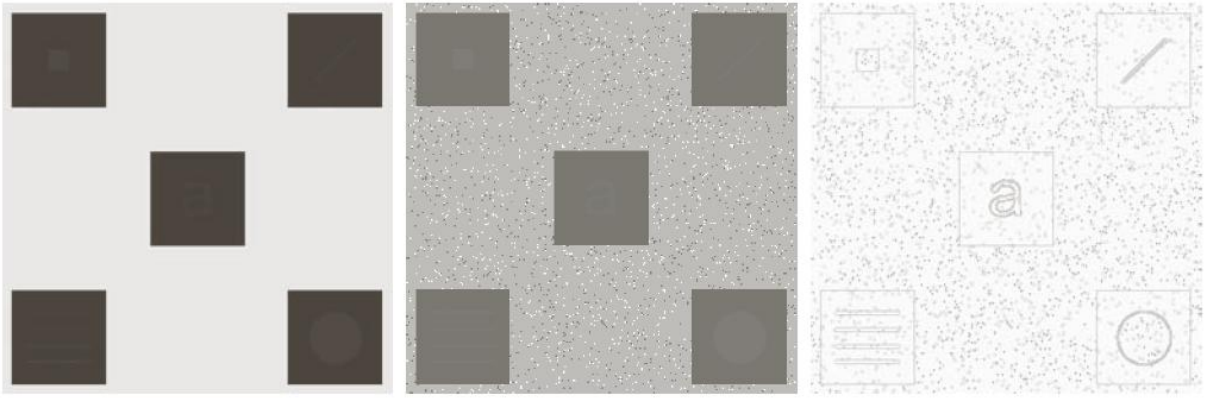
FIGURE 3.19 Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.

Intensity Transformations

Histogram Equalization



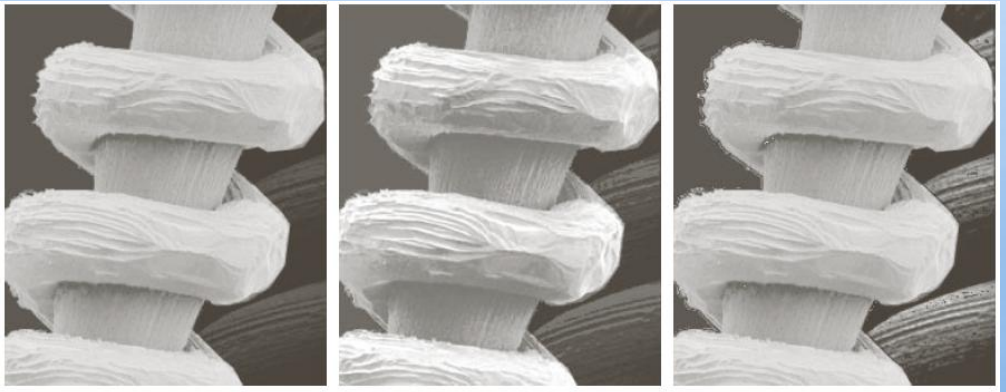
Intensity Transformations



a b c

FIGURE 3.26 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization applied to (a), using a neighborhood of size 3 × 3.

Intensity Transformations



a b c

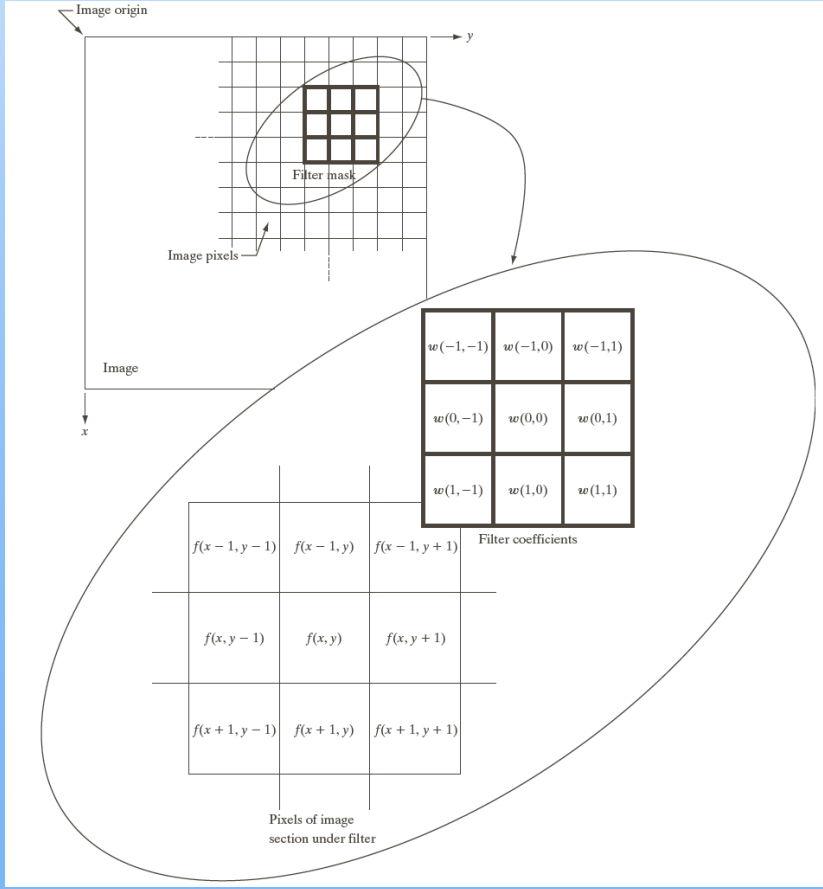
FIGURE 3.27 (a) SEM image of a tungsten filament magnified approximately 130×. (b) Result of global histogram equalization. (c) Image enhanced using local histogram statistics. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)

Spatial Filtering

Spatial Filter Types

- Smoothing filters
  - Lowpass
- Sharpening filters
  - Bandpass
  - Highpass
  - High-boost
- Derivative filters
- Fuzzy logic filters

Spatial Filtering Operation



Spatial Filtering

Linear Spatial Filter Masks

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

A general 3x3 mask

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

1	1	1
1	1	1
1	1	1

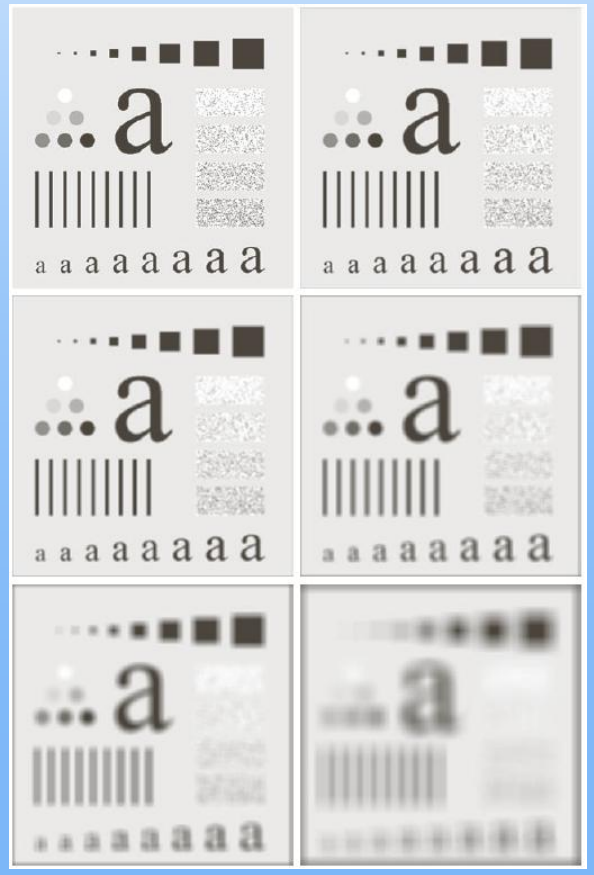
$\frac{1}{16} \times$

1	2	1
2	4	2
1	2	1

3x3 and 4x4 smoothing filter masks

Spatial Filtering

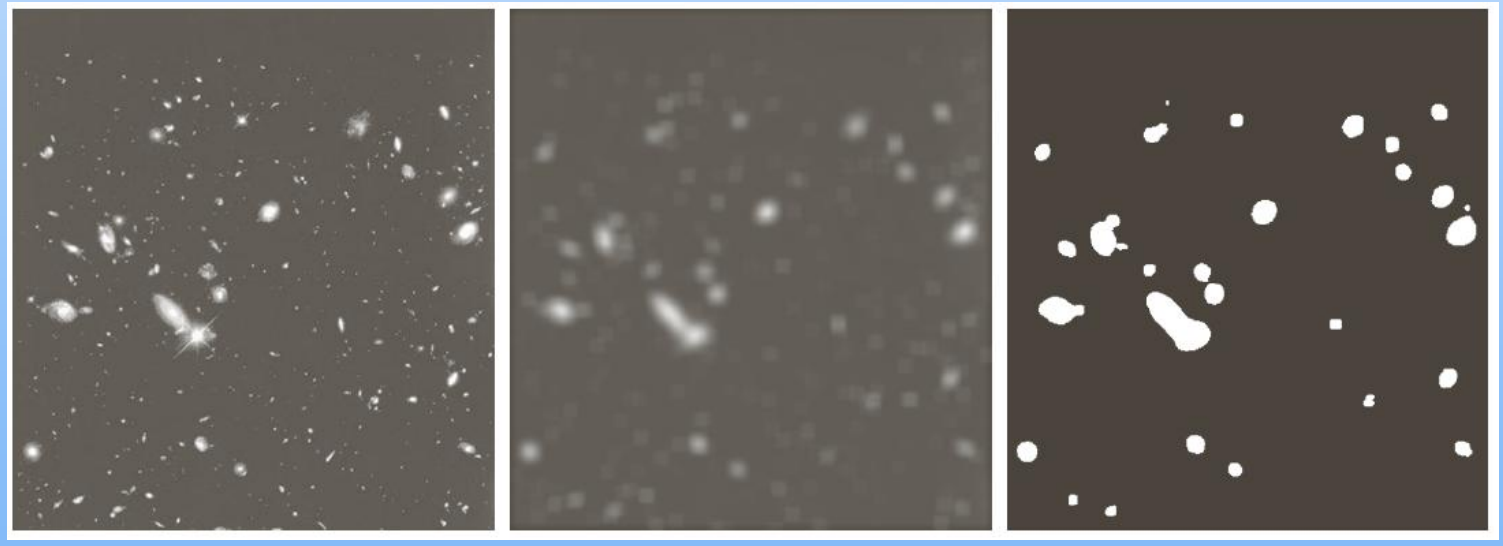
Smoothing Filters



Smoothing applied
at different levels

Spatial Filtering

Smoothing Filters



Hubble image | Smoothing applied | Thresholded

Spatial Filtering

Band Pass and High Pass Filtering

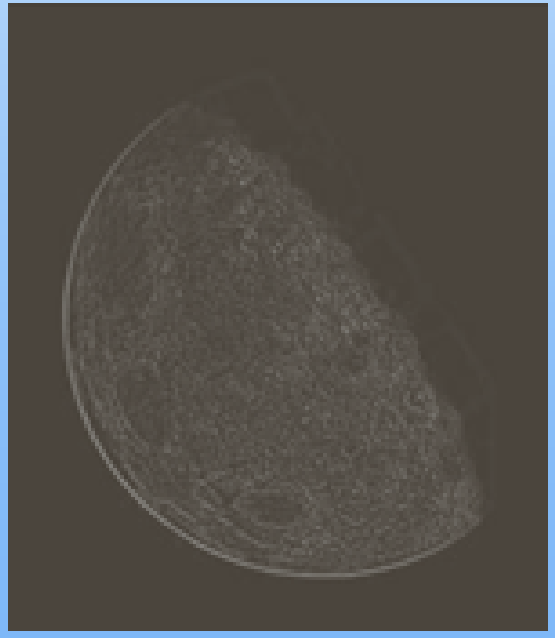
0	1	0	1	1	1
1	−4	1	1	−8	1
0	1	0	1	1	1
0	−1	0	−1	−1	−1
−1	4	−1	−1	8	−1
0	−1	0	−1	−1	−1

Sample (Laplacian) filter masks

Spatial Filtering

Image Sharpening by Filtering

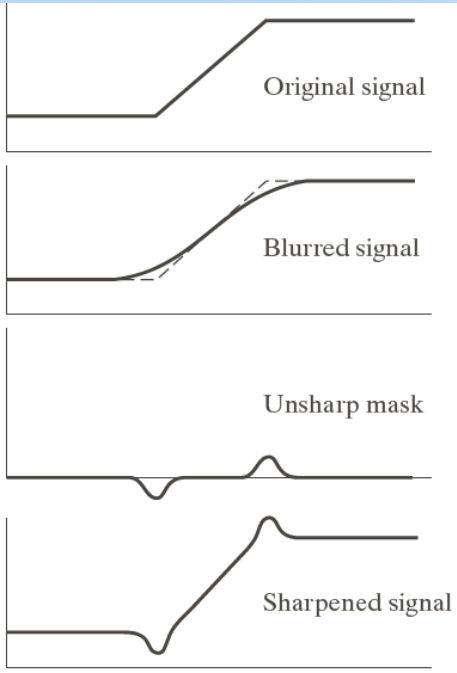
North pole of the moon



Laplacian image

Sharpened image

Spatial Filtering



a
b
c
d

FIGURE 3.39 1-D illustration of the mechanics of unsharp masking. (a) Original signal. (b) Blurred signal with original shown dashed for reference. (c) Unsharp mask. (d) Sharpened signal, obtained by adding (c) to (a).

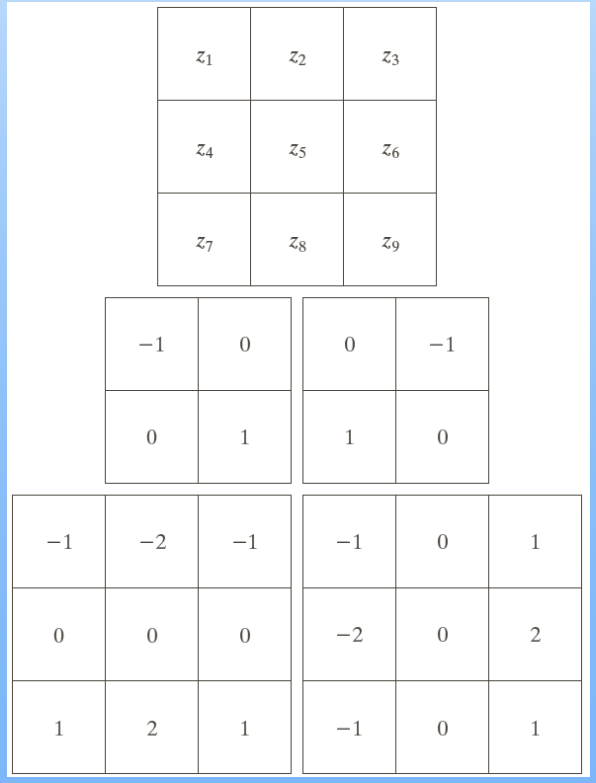
Spatial Filtering

a
b
c
d
e

FIGURE 3.40
(a) Original image.
(b) Result of blurring with a Gaussian filter.
(c) Unsharp mask. (d) Result of using unsharp masking.
(e) Result of using highboost filtering.

Spatial Filtering

Derivative Filters



z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

−1	0
0	1

0	−1
1	0

Roberts operators

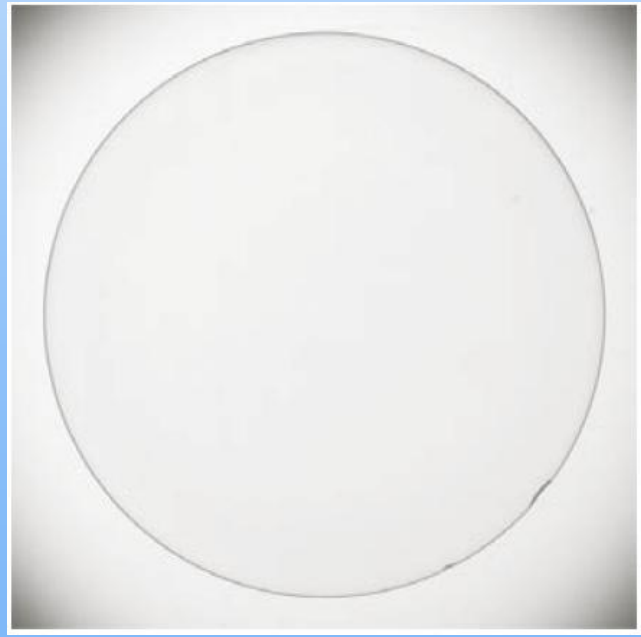
−1	−2	−1
0	0	0
1	2	1

−1	0	1
−2	0	2
−1	0	1

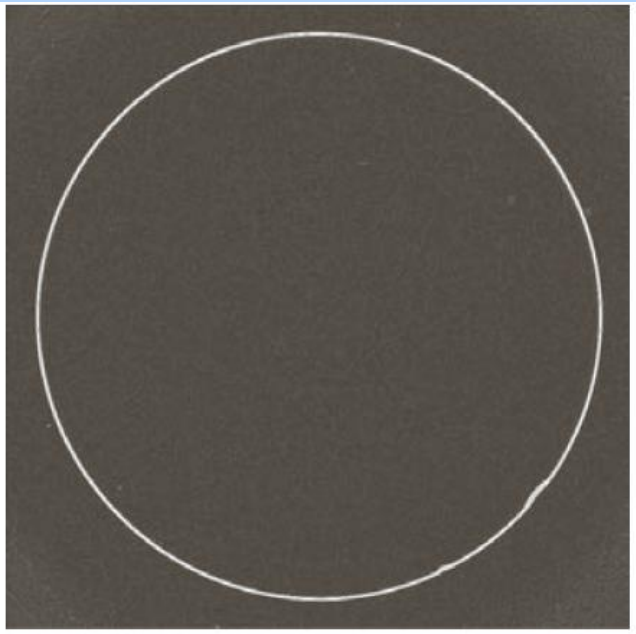
Sobel operators

Spatial Filtering

Derivative Filters



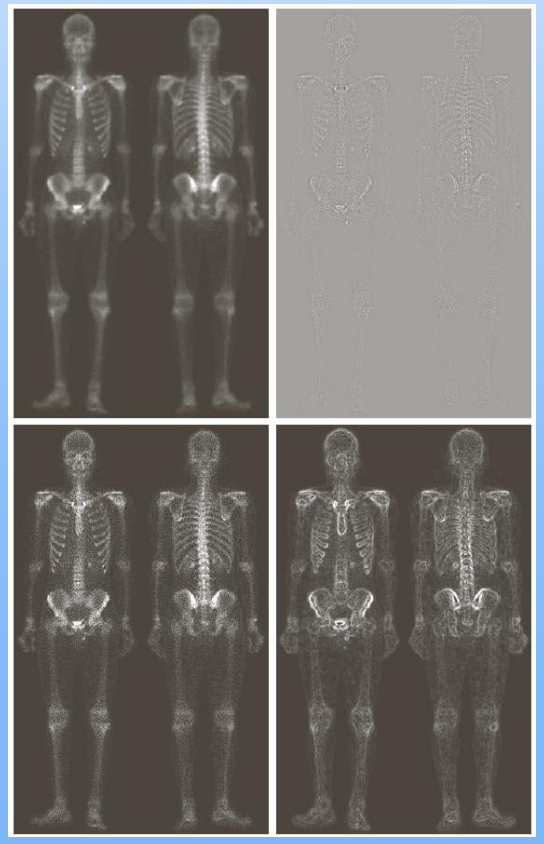
Original image



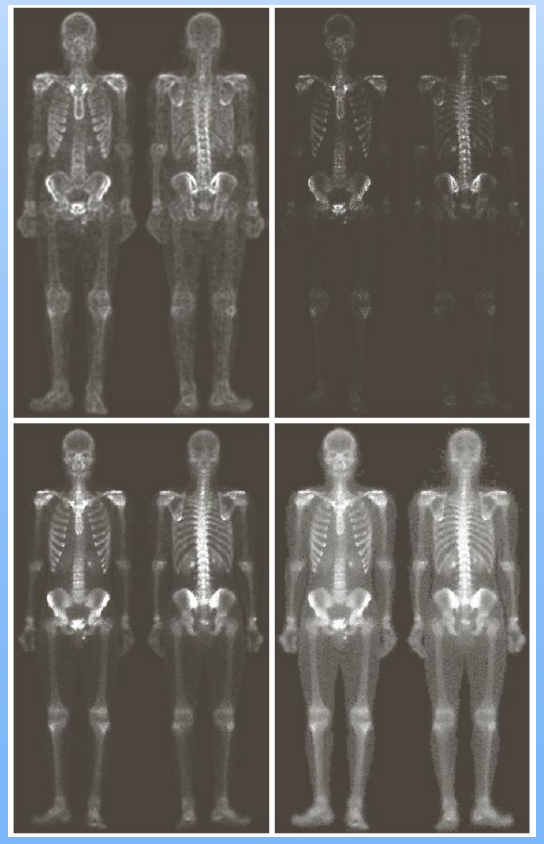
Sobel gradient

Spatial Filtering

Cascade Filtering



Original image; Laplacian; Sharpened; Sobel gradient



Sobel gradient and smoothing; mask image; sharpened image; power law transformed image

Spatial Filtering

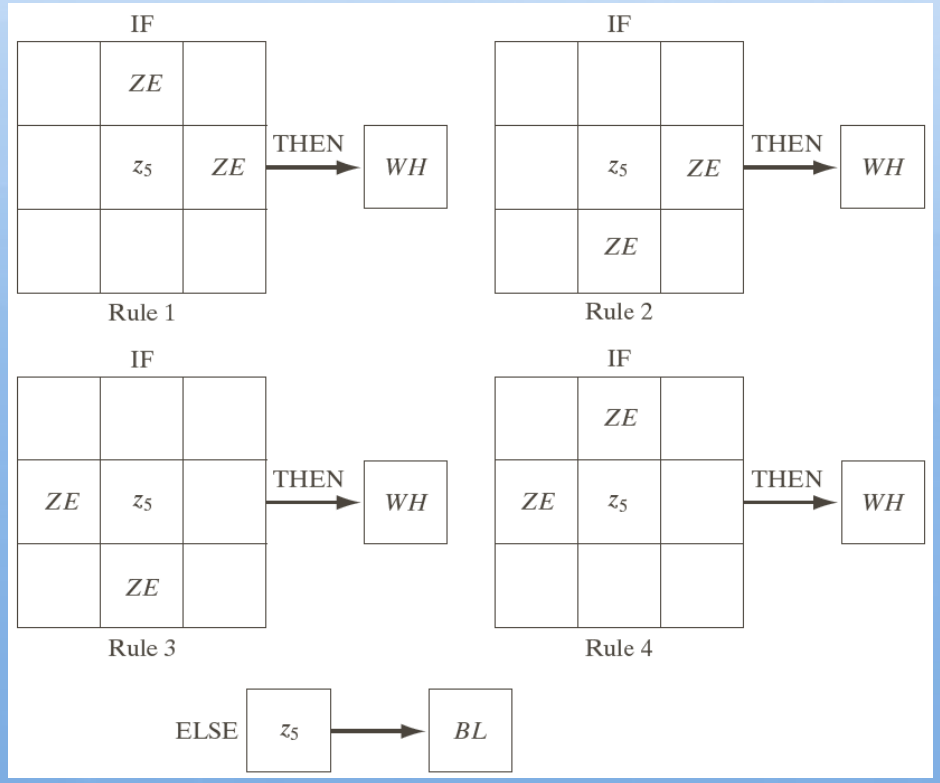


FIGURE 3.58 Fuzzy rules for boundary detection.

Spatial Filtering

a b c

FIGURE 3.59 (a) CT scan of a human head. (b) Result of fuzzy spatial filtering using the membership functions in Fig. 3.57 and the rules in Fig. 3.58. (c) Result after intensity scaling. The thin black picture borders in (b) and (c) were added for clarity; they are not part of the data. (Original image courtesy of Dr. David R. Pickens, Vanderbilt University.)