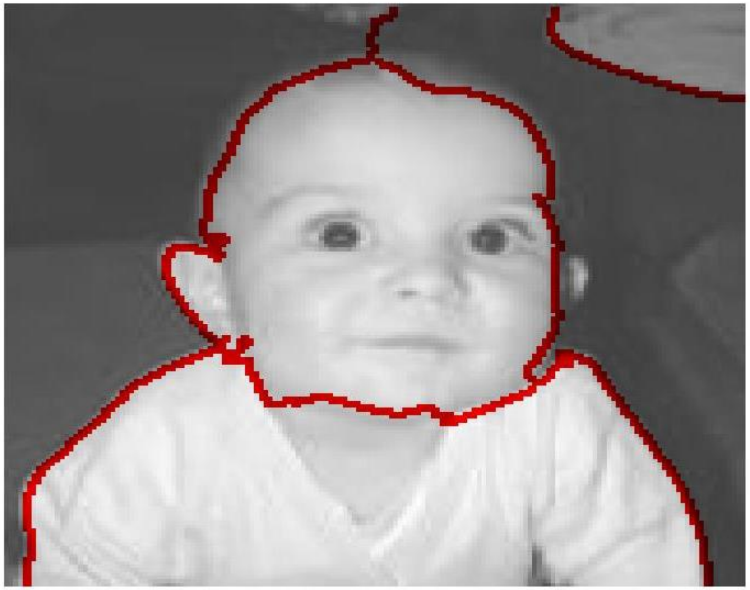
Digital Image Processing

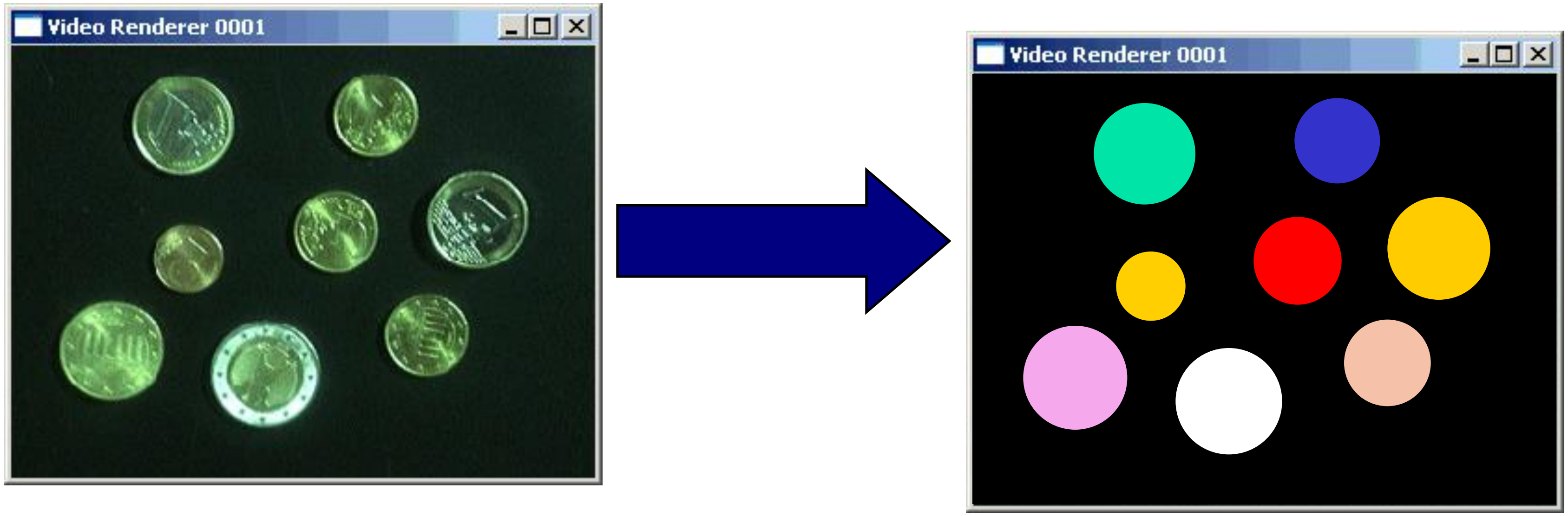




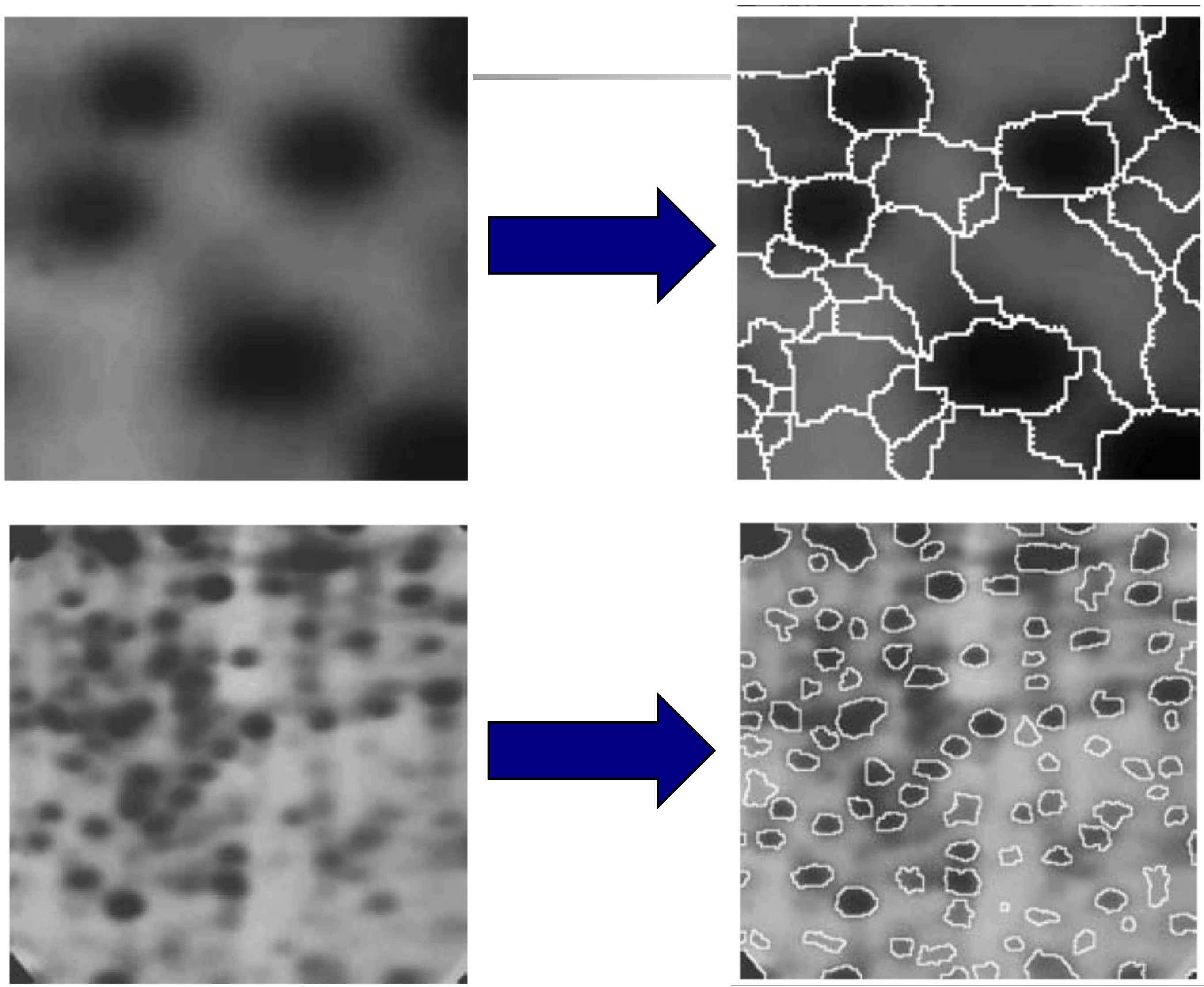
Lesson Links

- Point detection
- Line detection
- Edge detection

The Segmentation Problem



Segmentation Examples



Preview

- Segmentation is to subdivide an image into its component regions or objects.
- Segmentation should stop when the objects of interest in an application have been isolated.

EDGE DETECTION (CONTD….)

Detection of discontiuities:The Laplacian (based on second order derivative)

- Definition: $\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$

0	−1	0
−1	4	−1
0	−1	0

−1	−1	−1
−1	8	−1
−1	−1	−1

- Generally not used in its original form due to sensitivity to noise.
- Role of Laplacian in segmentation:
  - Zero-crossings
  - Tell whether a pixel is on the dark or light side of an edge.

Detection of Discontinuities
Gradient Operators

- Consider the function:

A Gaussian function

$$h(r) = -e^{-\frac{r^2}{2\sigma^2}} \quad \text{where} \quad r^2 = x^2 + y^2$$

and σ : the standard deviation

- The Laplacian of *h* is

$$\nabla^2 h(r) = -\left[\frac{r^2 - \sigma^2}{\sigma^4}\right] e^{-\frac{r^2}{2\sigma^2}}$$

The Laplacian of a Gaussian (LoG)

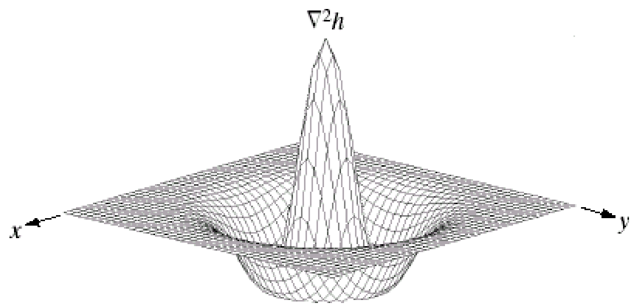
- The Laplacian of a Gaussian sometimes is called the Mexican hat function. It also can be computed by smoothing the image with the Gaussian smoothing mask, followed by application of the Laplacian mask.

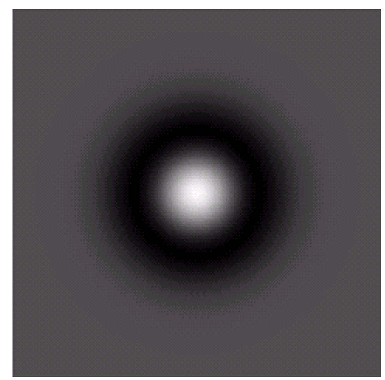
Laplacian of Gaussian

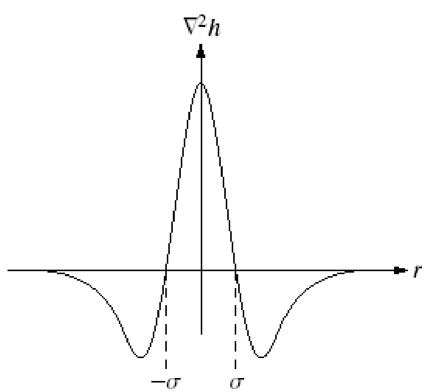
- Definition:

$$h(r) = -\exp(-r^2/2\sigma^2)$$

$$\nabla^2 h(r) = -\left[\frac{r^2-\sigma^2}{\sigma^4}\right]\exp(-r^2/2\sigma^2)$$







0	0	−1	0	0
0	−1	−2	−1	0
−1	−2	16	−2	−1
0	−1	−2	−1	0
0	0	−1	0	0

a	b
c	d

FIGURE 10.14 Laplacian of a Gaussian (LoG). (a) 3-D plot. (b) Image (black is negative, gray is the zero plane, and white is positive). (c) Cross section showing zero crossings. (d) 5 × 5 mask approximation to the shape of (a).

EDGE LINKING AND BOUNDARY DETECTION

Edge linking and Boundary detection

- Ideally, edge detection techniques yield pixels lying only on the boundaries between regions
- • In practice, this pixel set seldom characterizes a boundary completely because of
  - – noise
  - – breaks in the boundary due to non-uniform illumination
  - – other effects that introduce spurious discontinuities
- Thus, edge detection algorithms are usually followed by linking and other boundary detection procedures designed to assemble edge pixels into meaningful boundaries
- 3 types: local, regional and global processing.

Local processing

- • Basic idea:
  - Analyze the characteristics of pixels in a small neighborhood (3x3,5x5, etc) for every point (x,y) that has undergone edge detection
  - All points that are "similar" are linked, forming a boundary of pixels that share some common property
- Two principal properties for establishing similarity
  - The strength of the response of the gradient operator used to produce the edge pixels
  - The direction of the gradient

$$\alpha(x,y) = \tan^{-1}\left(\frac{G_y}{G_x}\right)$$

Edge linking: local processing (cont.)

- An edge pixel at (x',y') in the neighborhood centered at (x,y) is similar in magnitude to the pixel at (x,y) if

$$\left|\nabla f(x,y) - \nabla f(x',y')\right| \leq T$$

Where T is a predetermined threshold.

Edge linking: local processing (cont.)

- An edge pixel at (x',y') in the neighborhood centered at (x,y) is similar in angle to the pixel at (x,y) if

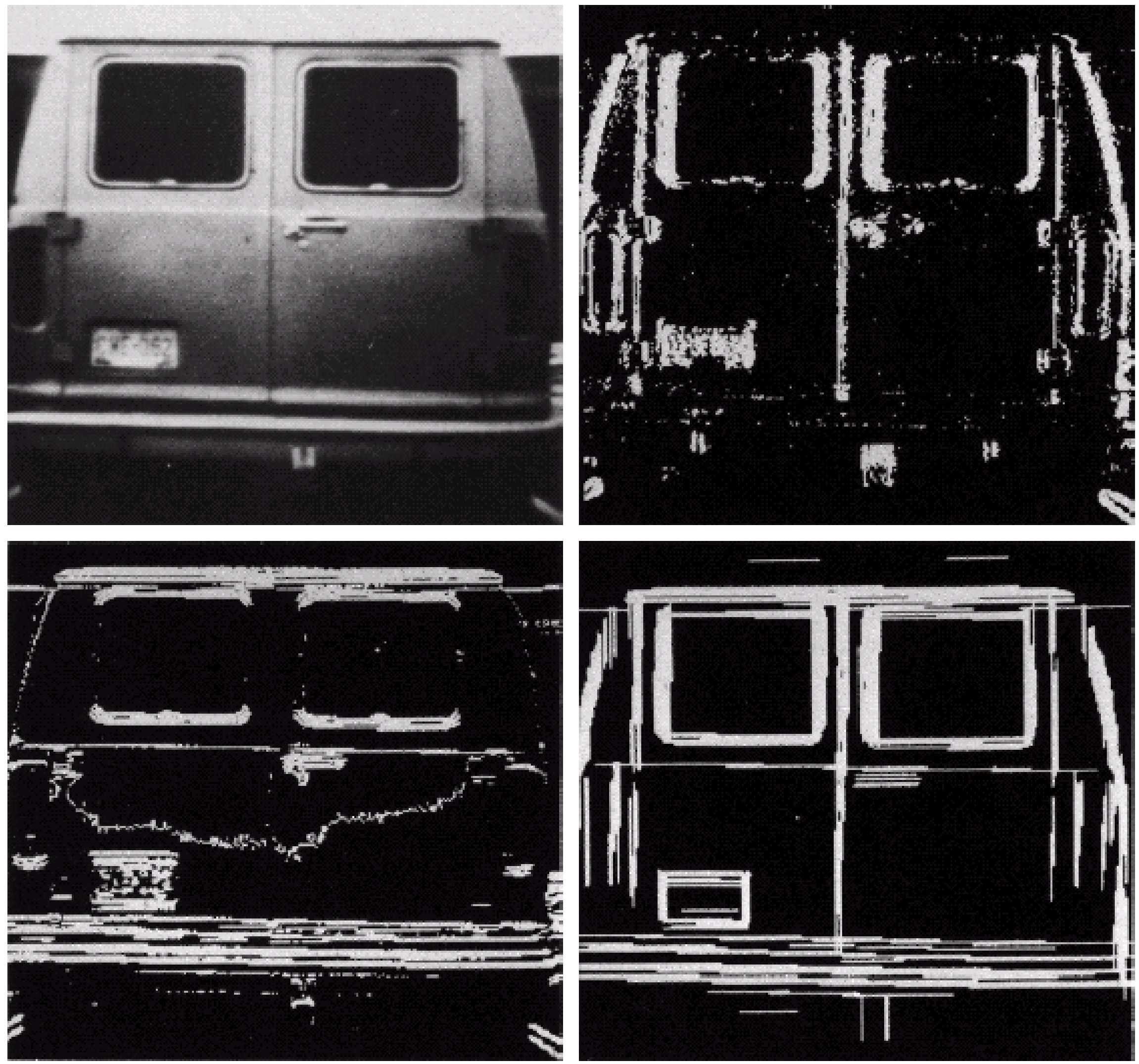
$$\left|\alpha(x,y)-\alpha(x',y')\right| \le A$$

Where A is a predetermined angle threshold.

Edge linking: local processing (cont.)

- A point in the neighborhood of (x,y) is linked to (x,y) if both magnitude and angle criteria are satisfied

Edge Linking and Boundary Detection Local Processing: Example



a b
c d

FIGURE 10.16
(a) Input image.
(b) G_y component of the gradient.
(c) G_x component of the gradient.
(d) Result of edge linking. (Courtesy of Perceptics Corporation.)

In this example, we can find the license plate candidate after edge linking process.

Need of Edge Linking

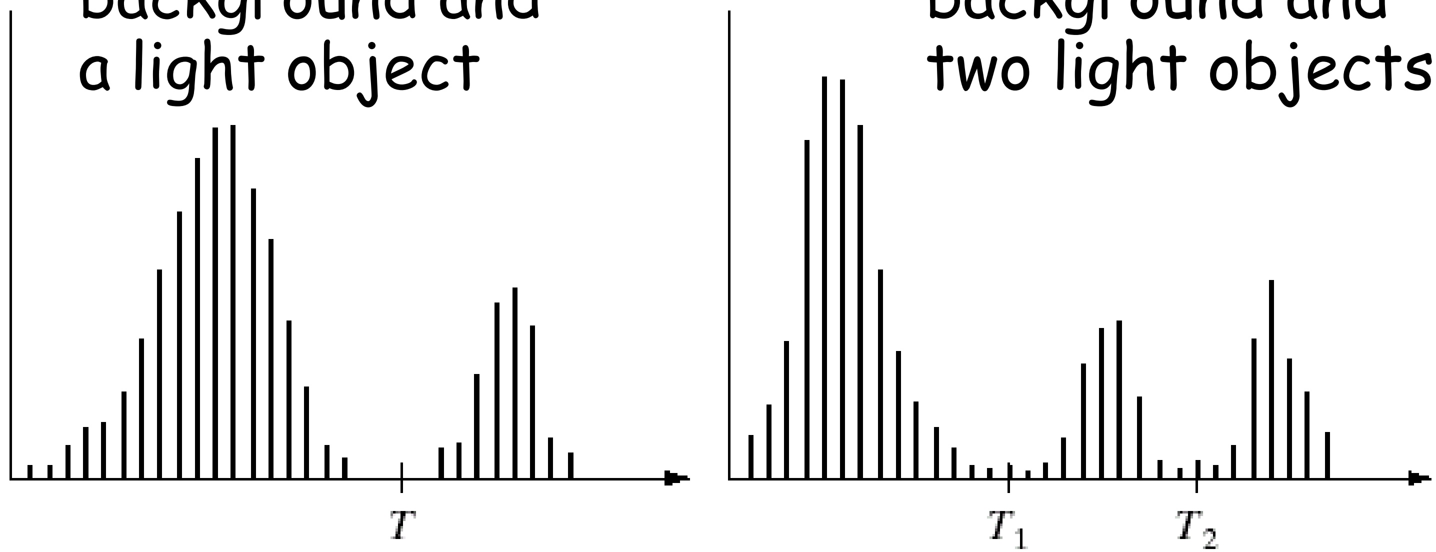
- The boundary is not complete in edge detection (bottom figure).

THRESHOLDING

Thresholding

image with dark background and a light object

image with dark background and two light objects



a b

FIGURE 10.26 (a) Gray-level histograms that can be partitioned by (a) a single threshold, and (b) multiple thresholds.

Multilevel thresholding

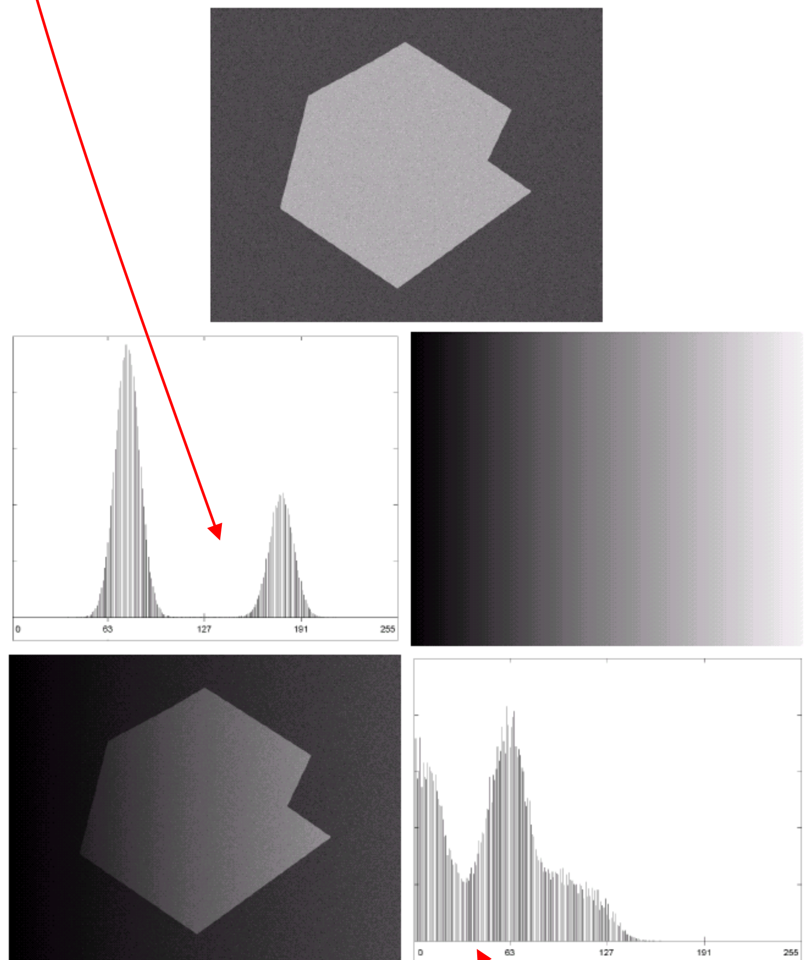
- a point (x,y) belongs to
  - to an object class if $T_1 < f(x,y) \leq T_2$
  - to another object class if $f(x,y) > T_2$
  - to background if $f(x,y) \leq T_1$
- T depends on
  - only f(x,y) : only on gray-level values ⇨ Global threshold
  - both f(x,y) and p(x,y) : on gray-level values and its neighbors ⇨ Local threshold

easily use global thresholding
object and background are separated

The Role of Illumination

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

a). computer generated reflectance function
b). histogram of reflectance function
c). computer generated illumination function (poor)
d). product of a). and c).
e). histogram of product image

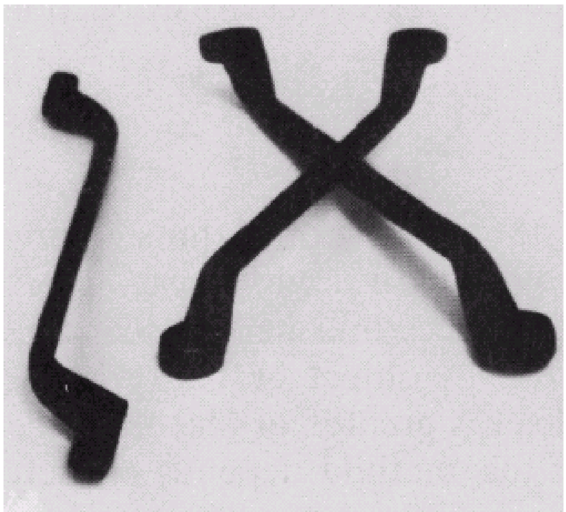


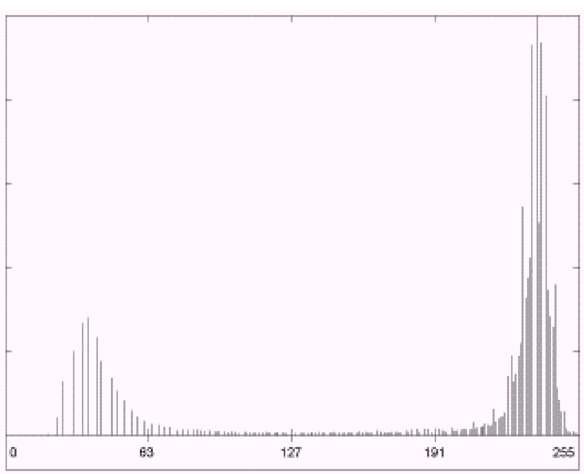
a
b c
d e

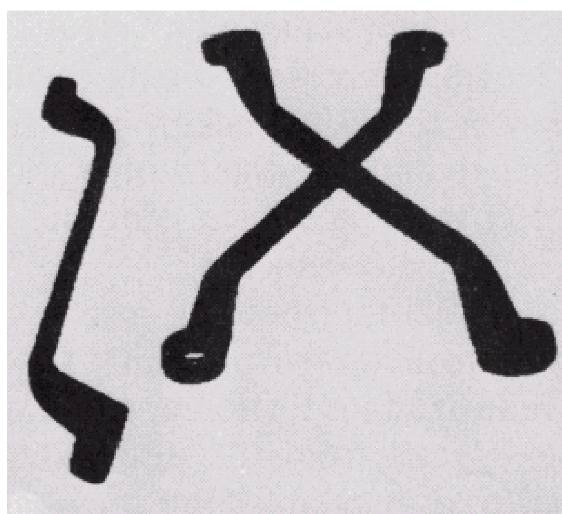
FIGURE 10.27 (a) Computer generated reflectance function. (b) Histogram of reflectance function. (c) Computer generated illumination function. (d) Product of (a) and (c). (e) Histogram of product image.

difficult to segment

Basic Global Thresholding







a
b c

FIGURE 10.28 (a) Original image. (b) Image histogram. (c) Result of global thresholding with *T* midway between the maximum and minimum gray levels.

use T midway between the max and min gray levels

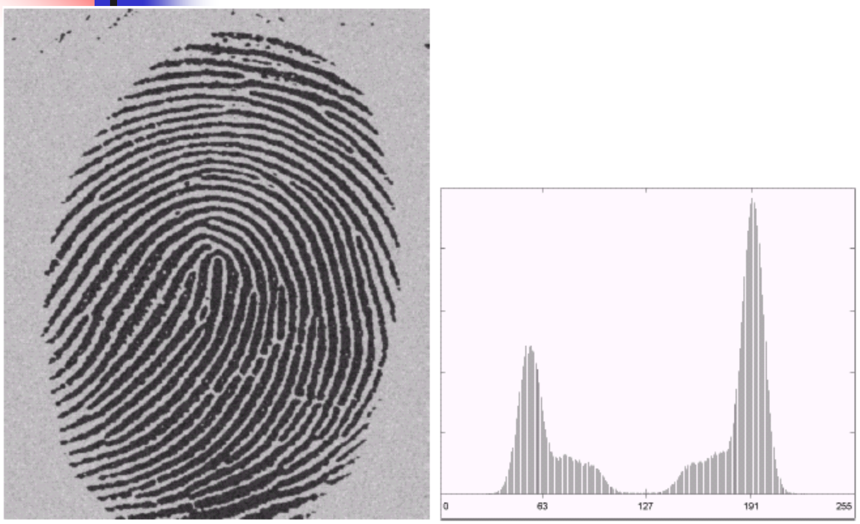
generate binary image

Basic Global Thresholding

- based on visual inspection of histogram

1. Select an initial estimate for T.
2. Segment the image using T. This will produce two groups of pixels: G_1 consisting of all pixels with gray level values > T and G_2 consisting of pixels with gray level values $\leq$ T
3. Compute the average gray level values μ_1 and μ_2 for the pixels in regions G_1 and G_2
4. Compute a new threshold value
5. $T = 0.5\ (\mu_1 + \mu_2)$
6. Repeat steps 2 through 4 until the difference in T in successive iterations is smaller than a predefined parameter T_o.

Example: Heuristic method



a b
c

FIGURE 10.29 (a) Original image. (b) Image histogram. (c) Result of segmentation with the threshold estimated by iteration. (Original courtesy of the National Institute of Standards and Technology.)

note: the clear valley of the histogram and the effective of the segmentation between object and background

$T_0 = 0$
3 iterations
with result T = 125

Basic Adaptive Thresholding

- subdivide original image into small areas.
- utilize a different threshold to segment each subimages.
- since the threshold used for each pixel depends on the location of the pixel in terms of the subimages, this type of thresholding is adaptive.

Example : Adaptive Thresholding

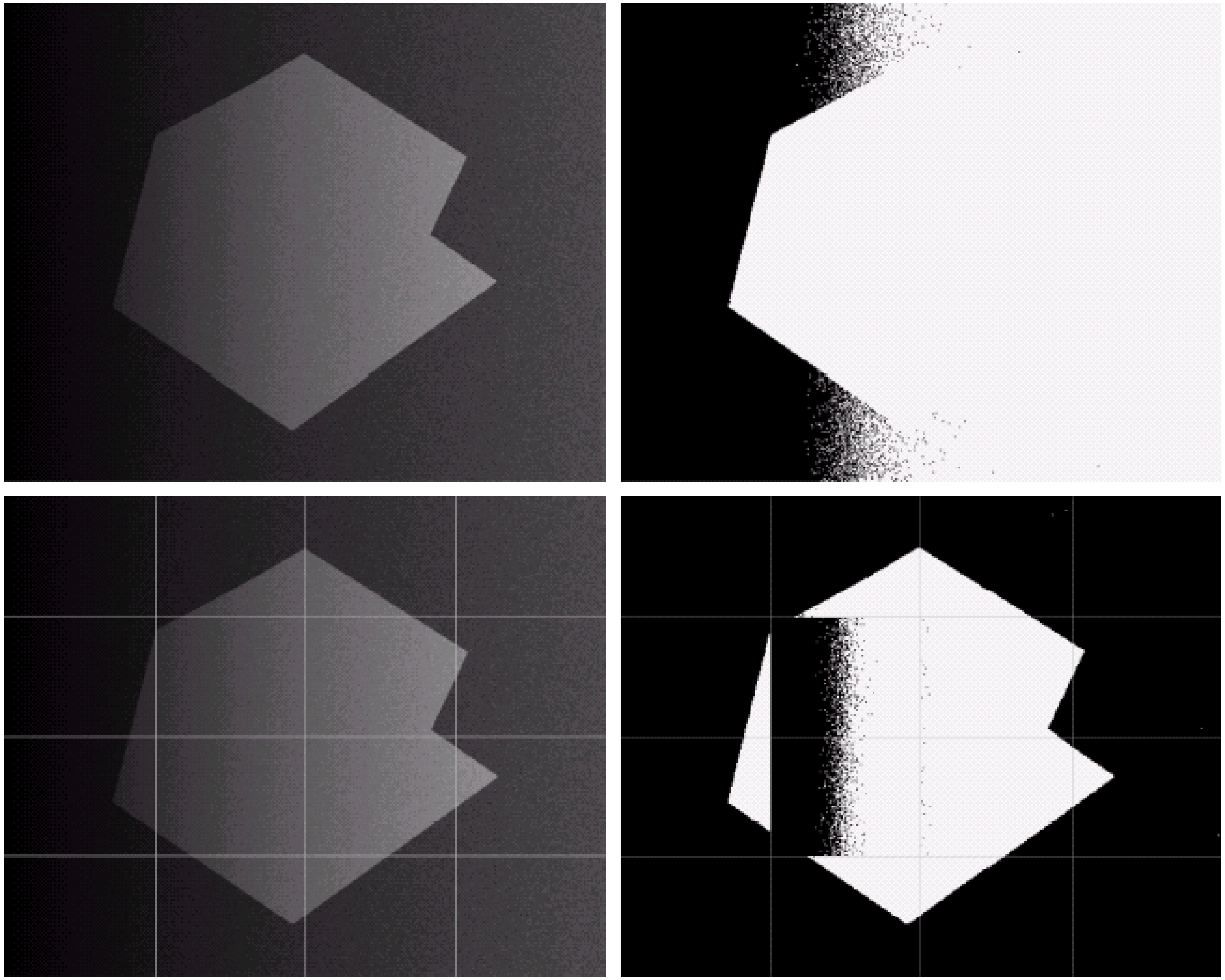
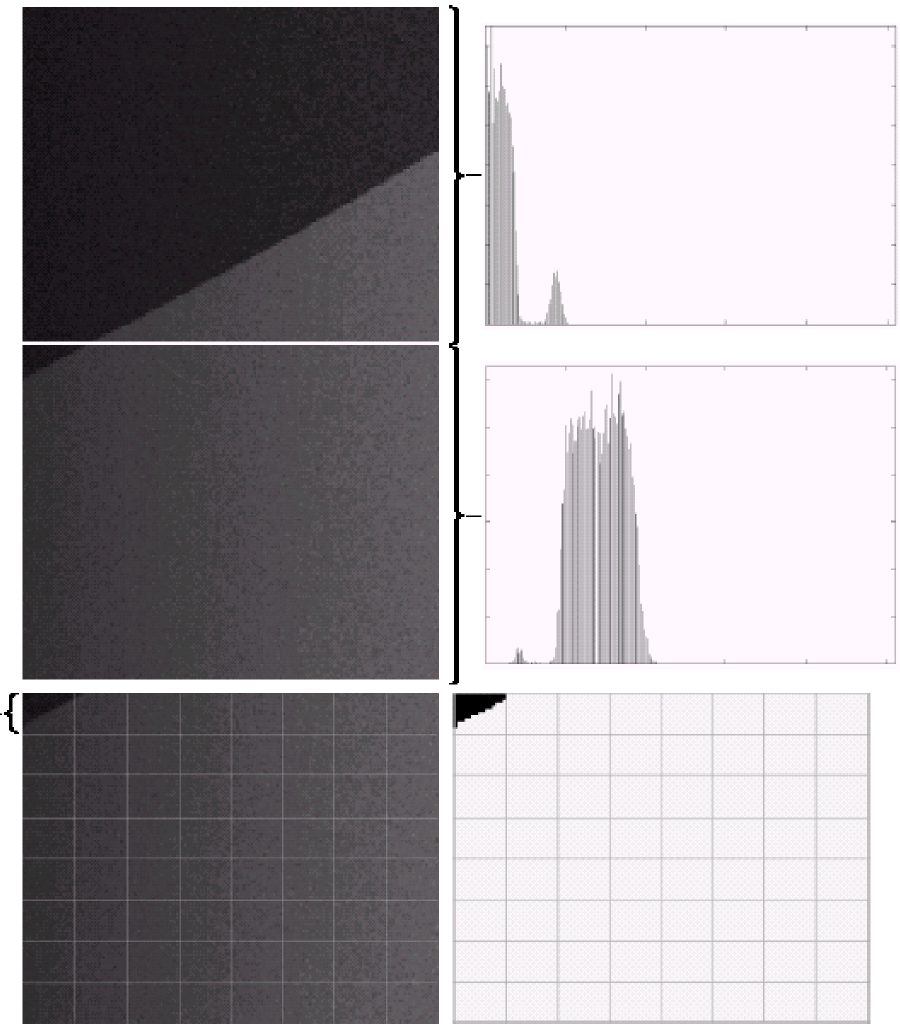
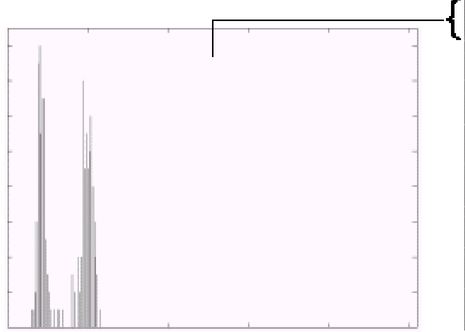


FIGURE 10.30 (a) Original image. (b) Result of global thresholding. (c) Image subdivided into individual subimages. (d) Result of adaptive thresholding.

Further subdivision

a). Properly and improperly segmented subimages from previous example
b)-c). corresponding histograms
d). further subdivision of the improperly segmented subimage.
e). histogram of small subimage at top
f). result of adaptively segmenting d).





Boundary Characteristic for Histogram Improvement and Local Thresholding

light object of dark background

$$s(x,y)=\begin{cases}0 & \text{if } \nabla f < T\\ + & \text{if } \nabla f \geq T \text{ and } \nabla^2 f \geq 0\\ - & \text{if } \nabla f \geq T \text{ and } \nabla^2 f < 0\end{cases}$$

- Gradient gives an indication of whether a pixel is on an edge
- Laplacian can yield information regarding whether a given pixel lies on the dark or light side of the edge
- all pixels that are not on an edge are labeled 0
- all pixels that are on the dark side of an edge are labeled +
- all pixels that are on the light side an edge are labeled -

Example

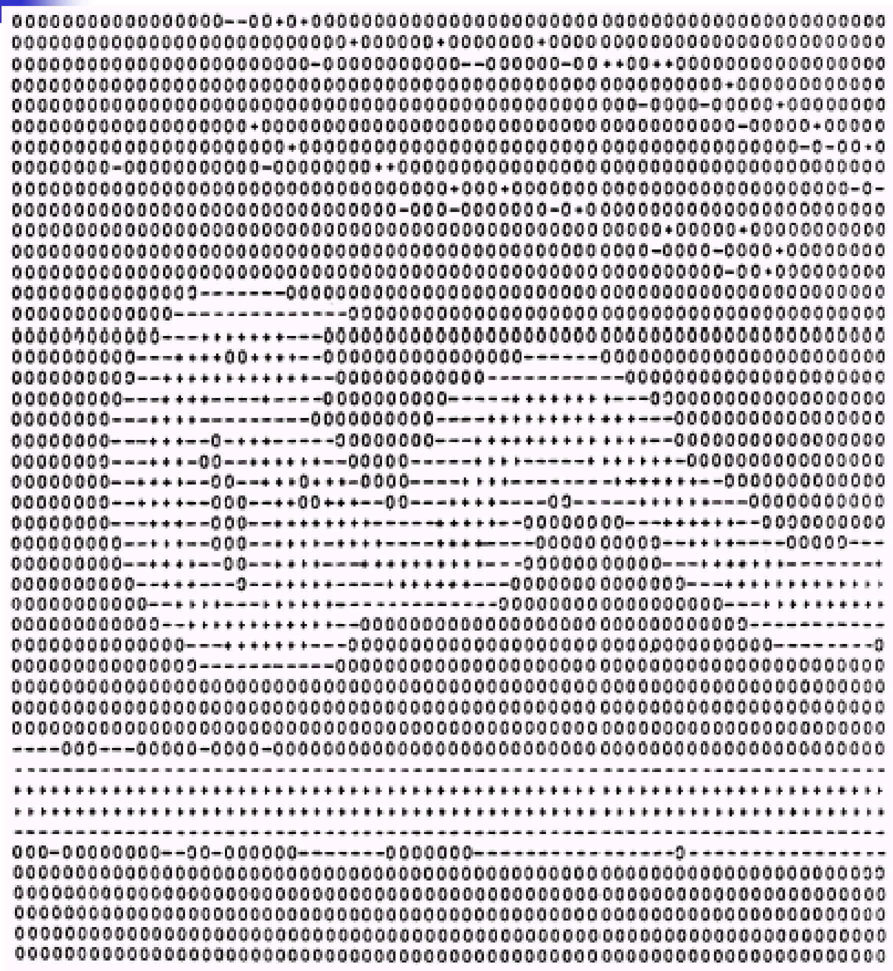
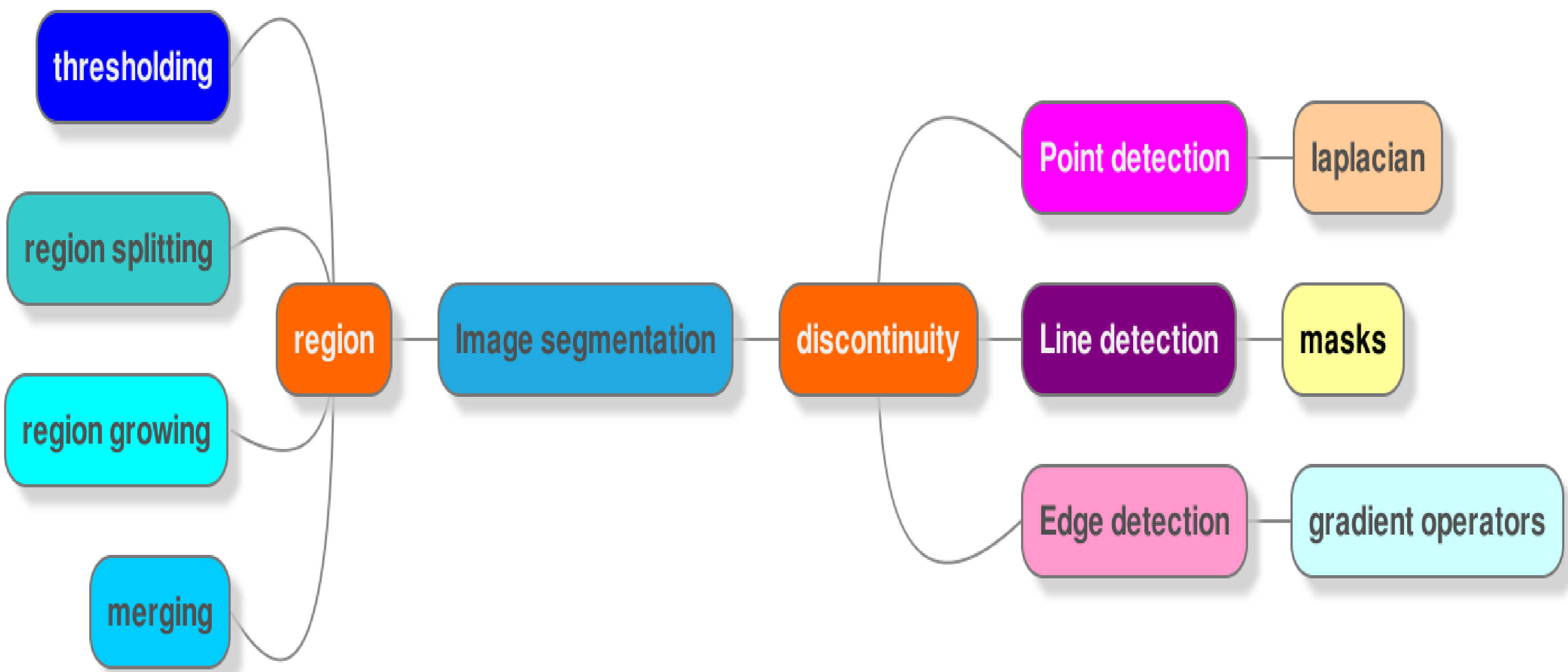


FIGURE 10.36 Image of a handwritten stroke coded by using Eq. (10.3-16). (Courtesy of IBM Corporation.)


Through the Wormhole

- 10 students appeared in an examination. How many ways results can be announced?

- Digital Image Processing by Gonzalez – 725-740


thresholding
region splitting
region growing
merging
region
Image segmentation
discontinuity
Point detection
laplacian
Line detection
masks
Edge detection
gradient operators

Assessment

- Give the techniques for edge linking.
- Define Hough transform.
- Specify steps for Hough transform based processing.


Thank
You!!!
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