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Object Segmentation

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Image Segmentation

- Segmentation divides an image into regions or objects (segments)
- The degree of segmentation is highly application dependent
- Segmentation typically based on either *similarity* or *discontinuity*
- All images from Digital Image Processing, Gonzalez and Woods

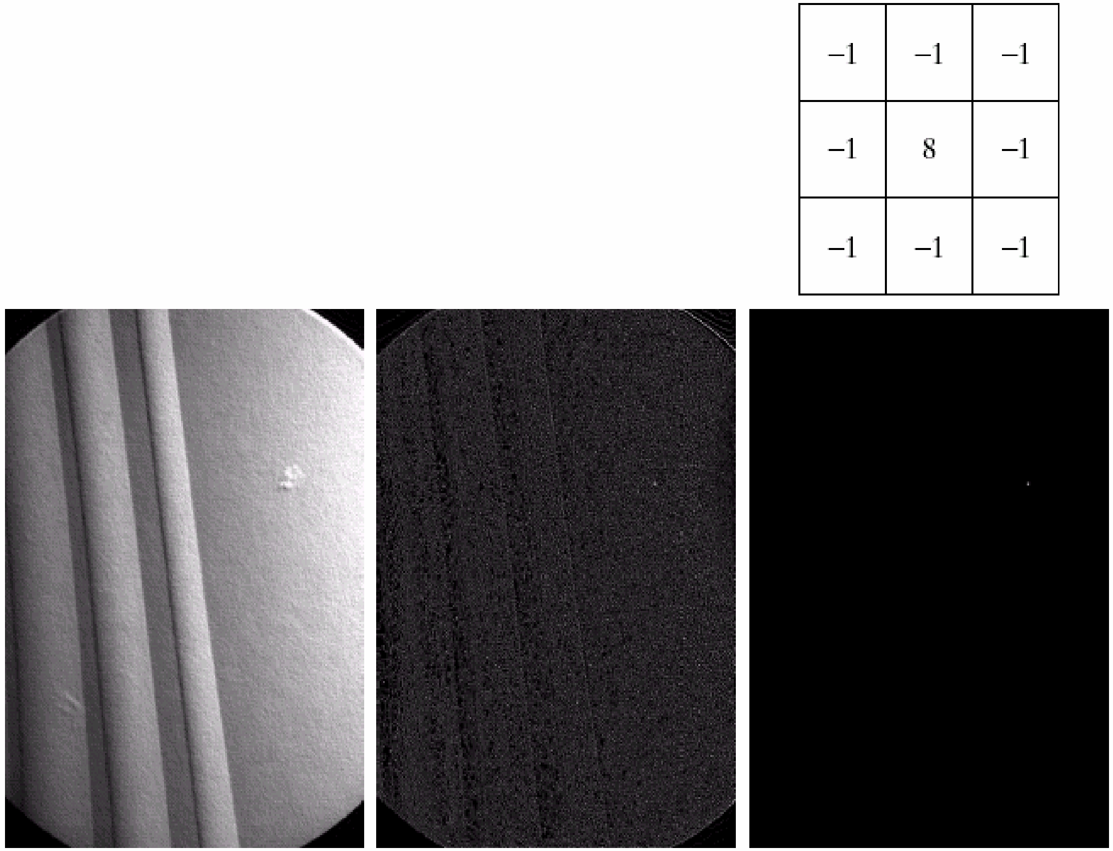
Detecting Discontinuities

- Assume grey level discontinuities
- Other discontinuities are possible
  - texture
  - curvature
  - any measurement of the image…
- A discontinuity is merely where the image or measurement changes quickly

Points

- An isolated discontinuity in which a single pixel differs greatly from its neighbors
- Use a “point mask”
- Measure the response and threshold
- Basic pattern matching

A Hole in a Jet Turbine



–1	–1	–1
–1	8	–1
–1	–1	–1

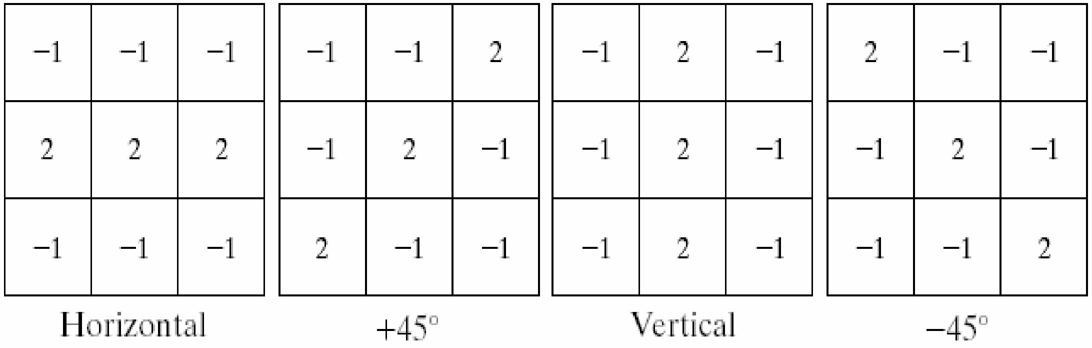
FIGURE 10.2 (a) Point detection mask. (b) X-ray image of a turbine blade with a porosity. (c) Result of point detection. (d) Result of using Eq. (10.1-2). (Original image courtesy of X-TEK Systems Ltd.)

Lines

- Lines are connected points
- Points on a line are similar to neighbors along the line, but different than neighbors off the line
- Use a “line mask”
- Need a separate mask for each direction

4 Line Masks

FIGURE 10.3 Line masks.



−1	−1	−1
2	2	2
−1	−1	−1

Horizontal

−1	−1	2
−1	2	−1
2	−1	−1

+45°

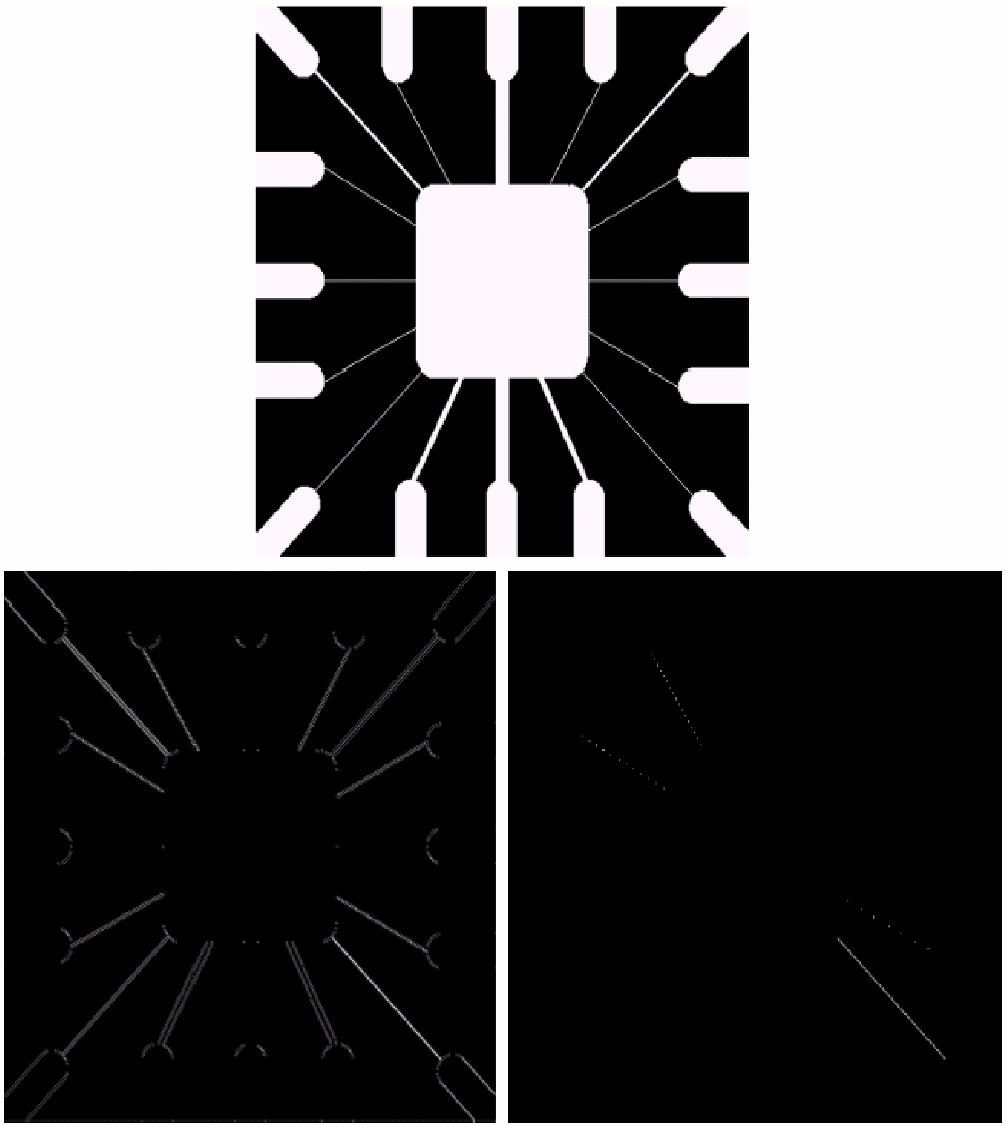
−1	2	−1
−1	2	−1
−1	2	−1

Vertical

2	−1	−1
−1	2	−1
−1	−1	2

−45°

Binary Wirebond Mask



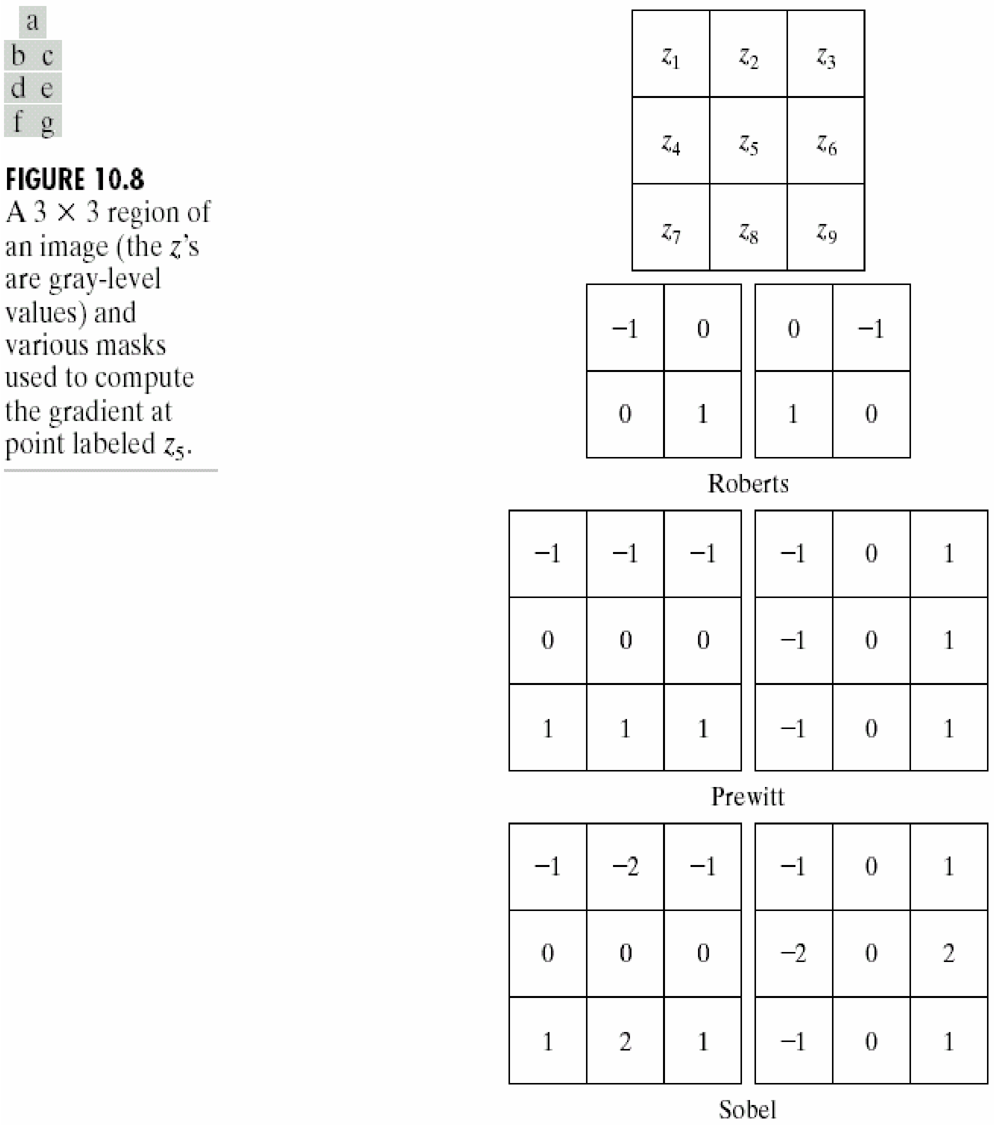
a
b c

FIGURE 10.4 Illustration of line detection. (a) Binary wirebond mask. (b) Absolute value of result after processing with −45° line detector. (c) Result of thresholding image (b).

Edge Detection

- Edge represents the discontinuity between two regions
- Typically between an “object” and its “background” although objects can also share an edge
- Realistically, an edge represents a gradual discontinuity

Edge Masks



a
b c
d e
f g

FIGURE 10.8 A 3 × 3 region of an image (the z's are gray-level values) and various masks used to compute the gradient at point labeled z_5.

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

−1	−1	−1
0	0	0
1	1	1

−1	0	1
−1	0	1
−1	0	1

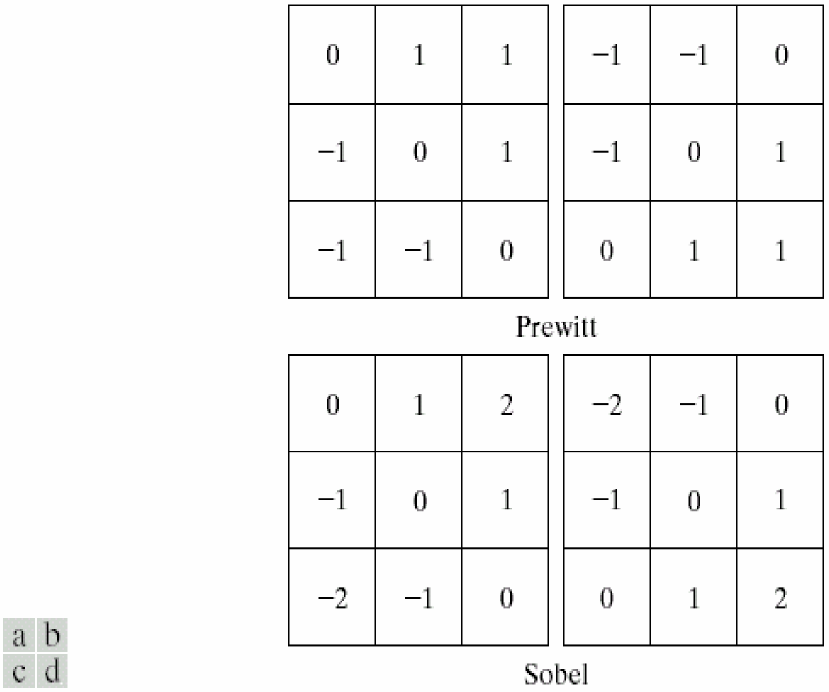
Prewitt

−1	−2	−1
0	0	0
1	2	1

−1	0	1
−2	0	2
−1	0	1

Sobel

Diagonal Masks



0	1	1
−1	0	1
−1	−1	0

−1	−1	0
−1	0	1
0	1	1

Prewitt

0	1	2
−1	0	1
−2	−1	0

−2	−1	0
−1	0	1
0	1	2

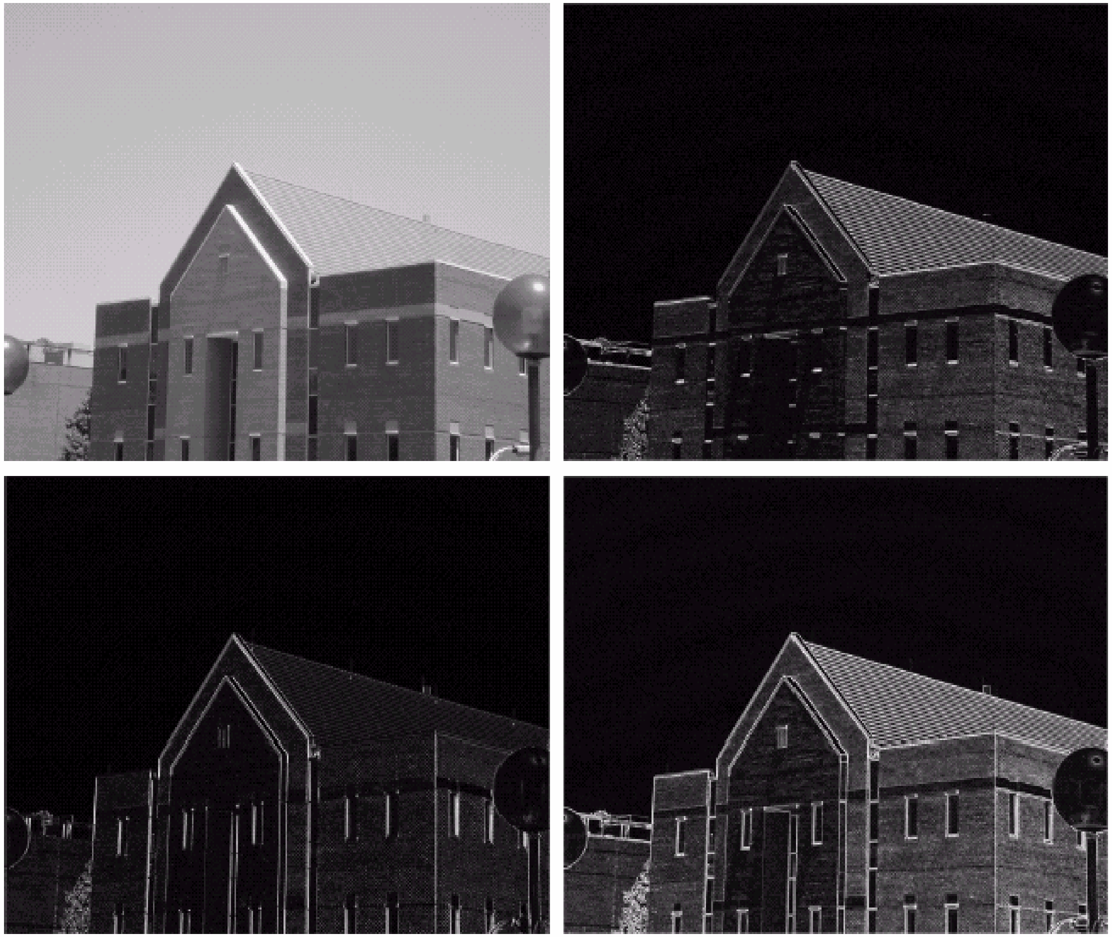
Sobel

FIGURE 10.9 Prewitt and Sobel masks for detecting diagonal edges.

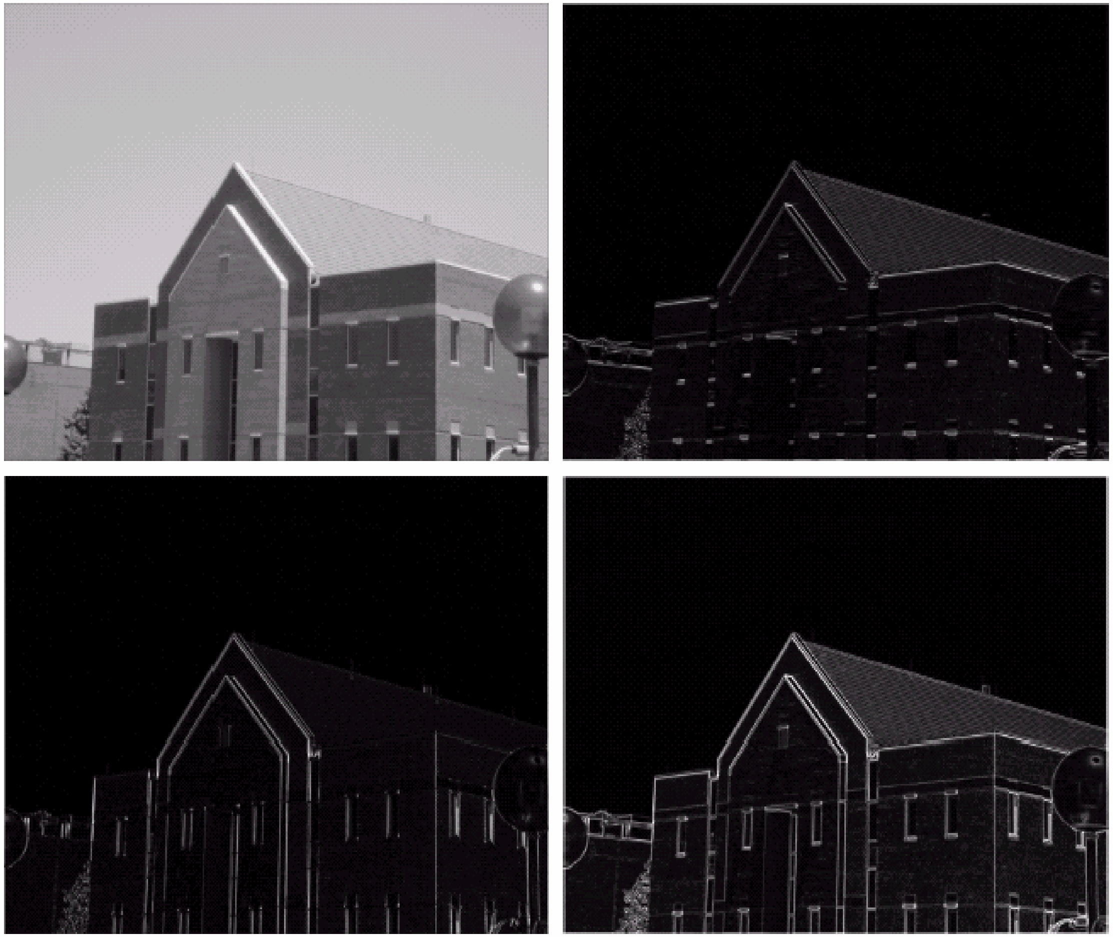
Application of Gradient

a b
c d

FIGURE 10.10 (a) Original image. (b) $|G_x|$, component of the gradient in the x-direction. (c) $|G_y|$, component in the y-direction. (d) Gradient image, $|G_x| + |G_y|$.



Smoothed Gradient



a b
c d

FIGURE 10.11 Same sequence as in Fig. 10.10, but with the original image smoothed with a 5 × 5 averaging filter.

Edge Linking

- Look at each edge pixel
  - strength of gradient response
  - direction of gradient
- If the difference for both these criteria is small in neighboring edge pixels, the pixels are part of the same edge
- Keep track of all linked edges

Thresholding

- Simple and intuitive to apply
- May be binary (object and background) or multilevel
- May be
  - global (depends only on intensity)
  - local (also depends on other quantities)
  - adaptive (also depends on pixel position)

Histogram

- Histograms provide a good visual idea of why thresholding works
- Separate the image based on intensities that fall in the valley(s) of the histogram

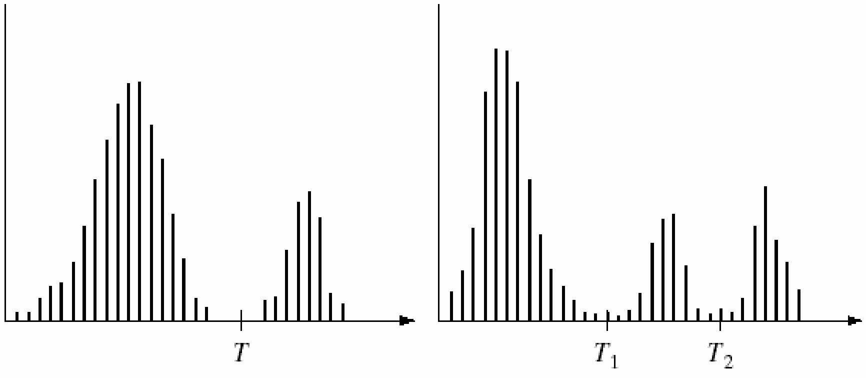


FIGURE 10.26 (a) Gray-level histograms that can be partitioned by (a) a single threshold, and (b) multiple thresholds.

Global Thresholding

- Uses a single global threshold to separate object from background
- Threshold may be known *a priori* or estimated
  - average grey level of image (when object and background are the same size)
  - midway between minimum and maximum grey level
  - iteratively calculated from an initial guess

Basic Segmentation

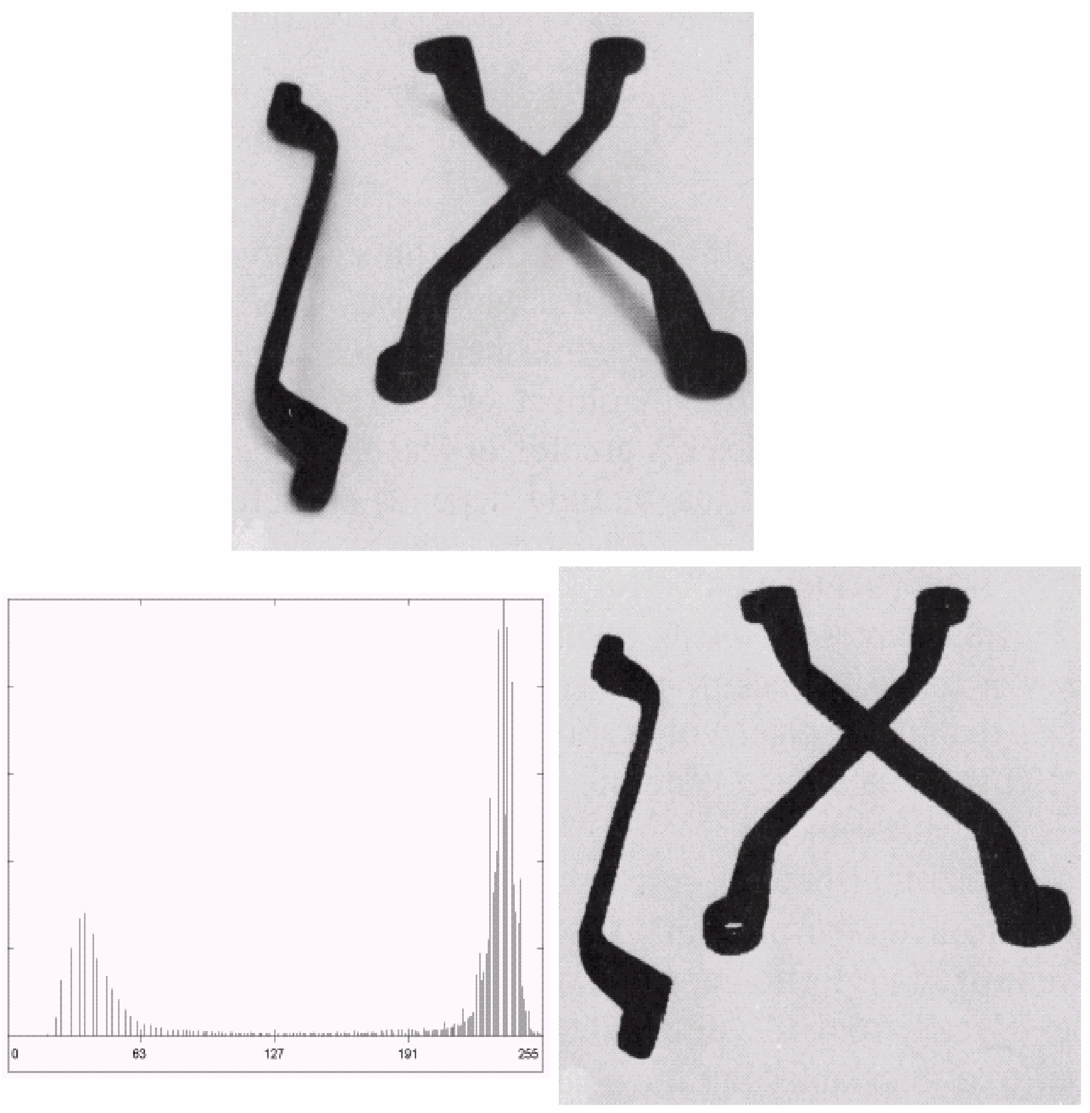
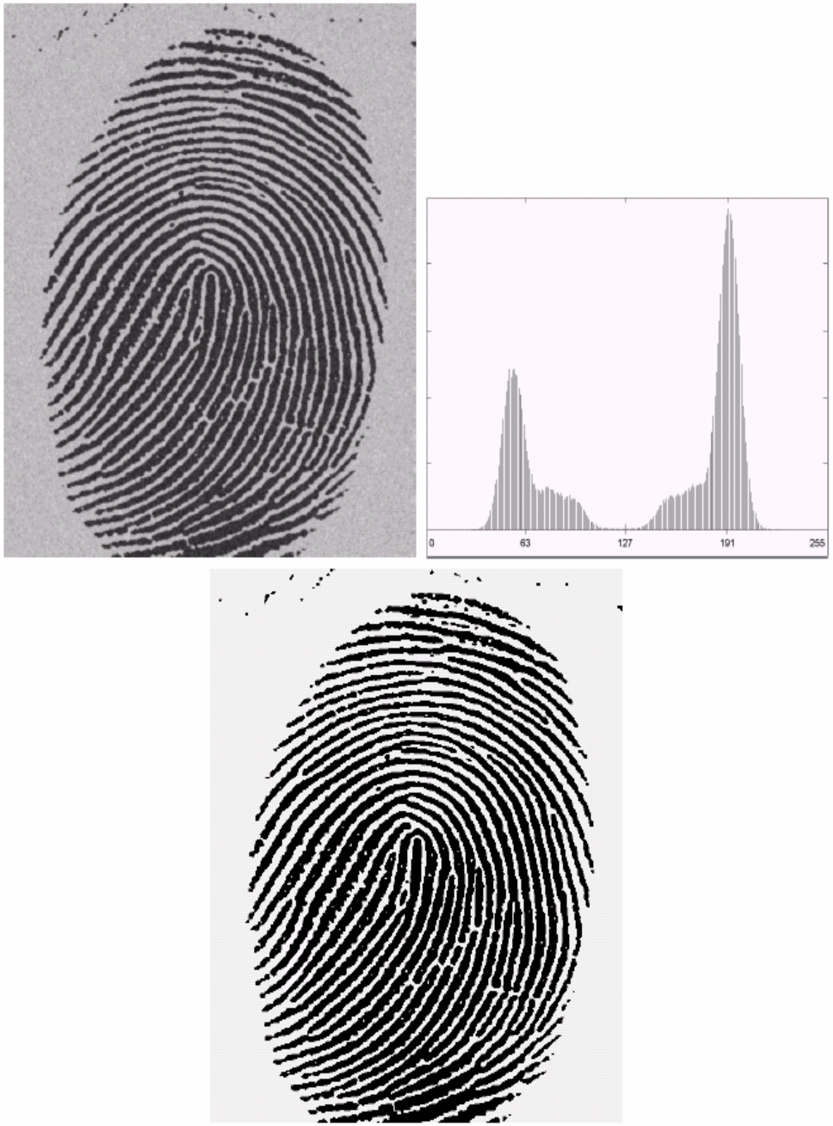


FIGURE 10.28 (a) Original image. (b) Image histogram. (c) Result of global thresholding with *T* midway between the maximum and minimum gray levels.

Iterating a Threshold

- Start with an initial guess
- Segment the image
- Compute the average grey levels of the segmented regions
- Compute a new threshold as the average of the average grey levels
- Segment the image…
- Stop when the threshold stops changing

Iterated Threshold



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.)

Multispectral Threshholding

- If more than one variable for each pixel is available, threshold on multiple values
  - – MRI
  - – Color (RGB, HIS)
  - – Color and IR
- Use a cluster analysis to find “clumps” in the multidimensional histogram

RGB Threshholding

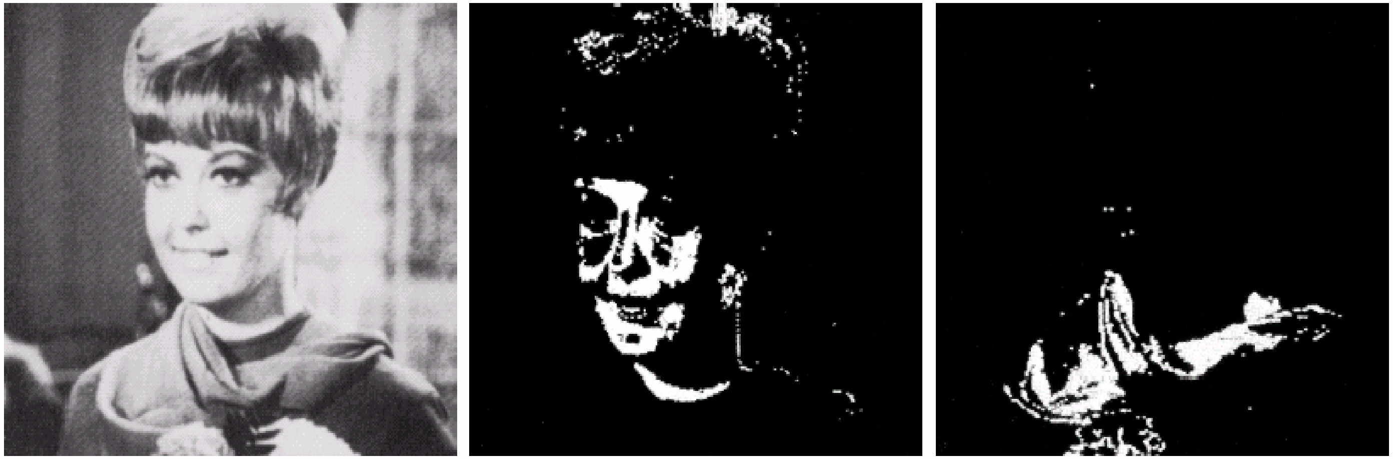


FIGURE 10.39 (a) Original color image shown as a monochrome picture. (b) Segmentation of pixels with colors close to facial tones. (c) Segmentation of red components.

Region-Based Segmentation

- Use notions of logic and set theory to break the image into regions
  - All pixels must be classified
  - Regions must be connected
  - Regions must be disjoint
  - All pixels in the same region share a property that pixels in different regions do not share
- Grow or split regions until these conditions are satisfied

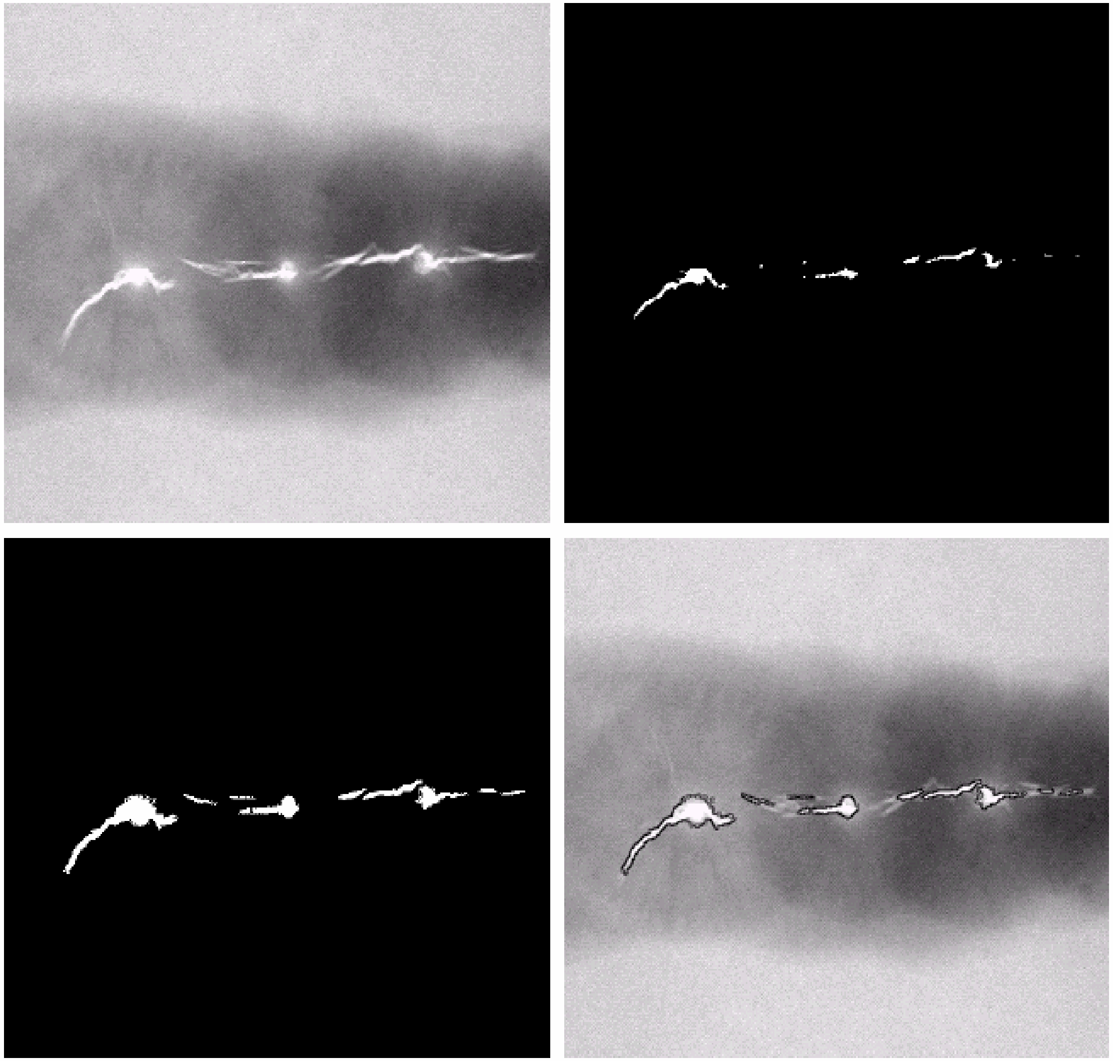
Region Growing

- Start with seed pixels
- Grow each seed into a region of “similar” pixels, keeping connectivity
- Keep growing regions until no more pixels can be added
- Requires a good selection of seed points to identify all regions
- Regions may be merged

Defective Welds

a b
c d

FIGURE 10.40 (a) Image showing defective welds. (b) Seed points. (c) Result of region growing. (d) Boundaries of segmented defective welds (in black). (Original image courtesy of X-TEK Systems, Ltd.).



Welding Histogram

- Histogram used to determine the similarity criterion
- Connectivity provided the needed improvement over simple thresholding

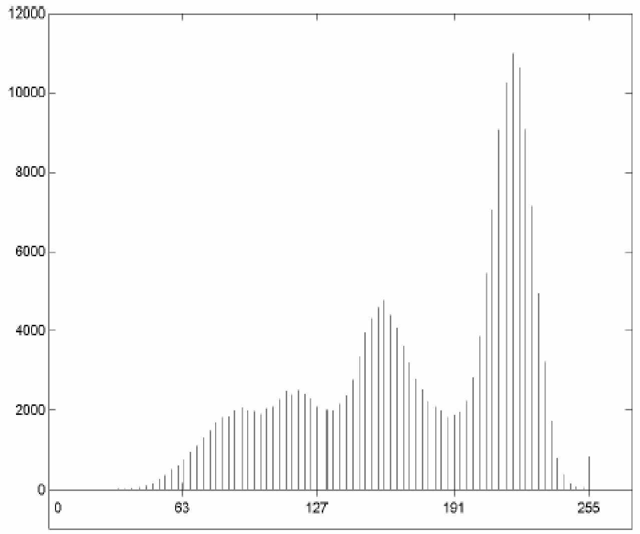
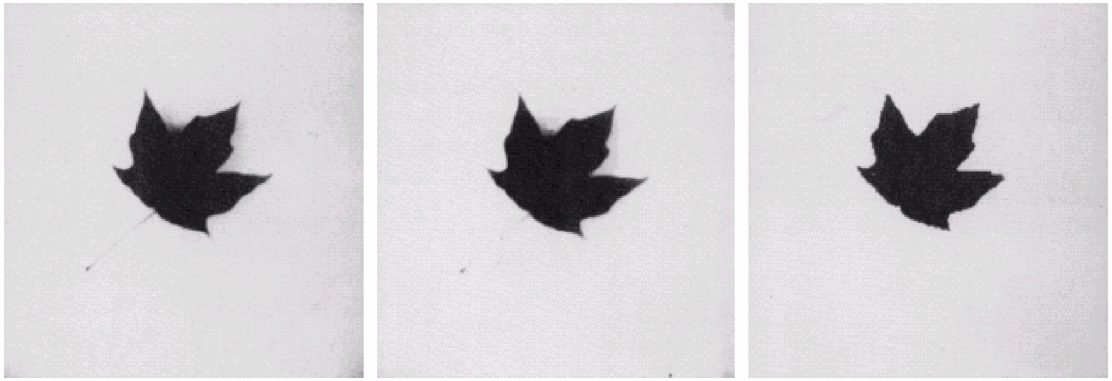


FIGURE 10.41 Histogram of Fig. 10.40(a).

Region Splitting and Merging

- Subdivide the image into smaller and smaller regions until the regions are all “self-similar”, then join any regions that share the same “similarity”
- Use a quadtree data structure to manage the blocks
- “Predefined” square regions on which to investigate similarity

Segmented Leaf



a b c

FIGURE 10.43 (a) Original image. (b) Result of split and merge procedure. (c) Result of thresholding (a).