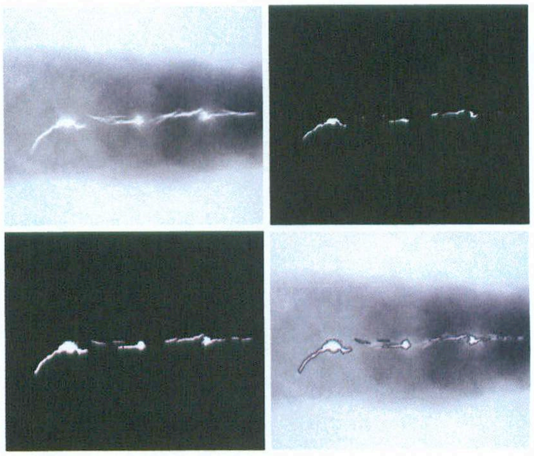
Chapter 10
Image Segmentation

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.).



select as seed points all points with intensity = 255

to be added to region
1. seed(255) − p(x,y) < 64
2. 8-connected to region

boundaries superimposed on original image

Chapter 10
Image Segmentation

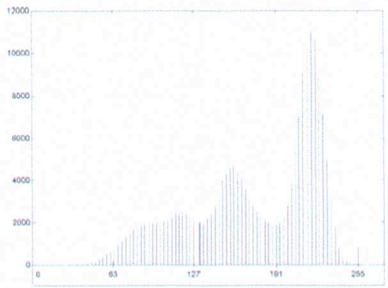
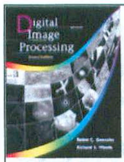


FIGURE 10.41 Histogram of Fig. 10.40(a).

Histogram of weld image
Could not be segmented without using connectivity



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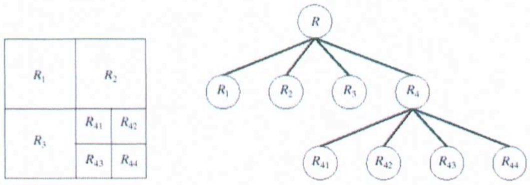
a b

FIGURE 10.42
(a) Partitioned image.
(b) Corresponding quadtree.



split-merge

split image into quadrants

for each quadrant which is not homogeneous

    split into sub-quadrants

repeat until every quadrant is homogeneous

Merge any adjacent regions which are similar

repeat split and merge until there are no changes.

Chapter 10
Image Segmentation

a b c

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

original image

result of split-merge

thresholded result of split-merge

Use mean and standard deviation

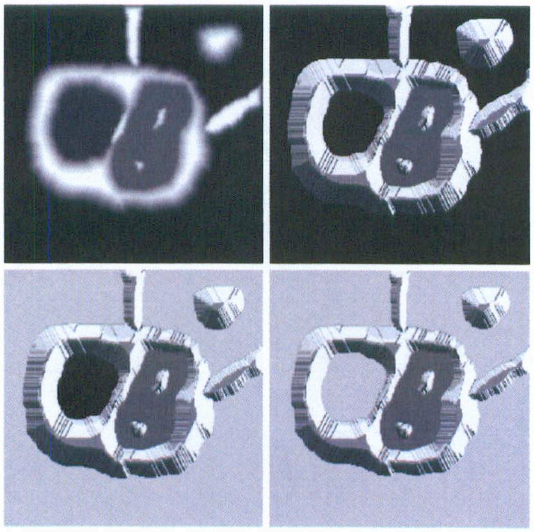
(Quadrant) Region is uniform if $|z_j - m_i| \leq 2\sigma_i$

set all pixels in region i to m_i

Chapter 10
Image Segmentation

a b
c d

FIGURE 10.44 (a) Original image. (b) Topographic view. (c)–(d) Two stages of flooding.



original gray scale image

topographic view

punch holes in bottom of each region minimum

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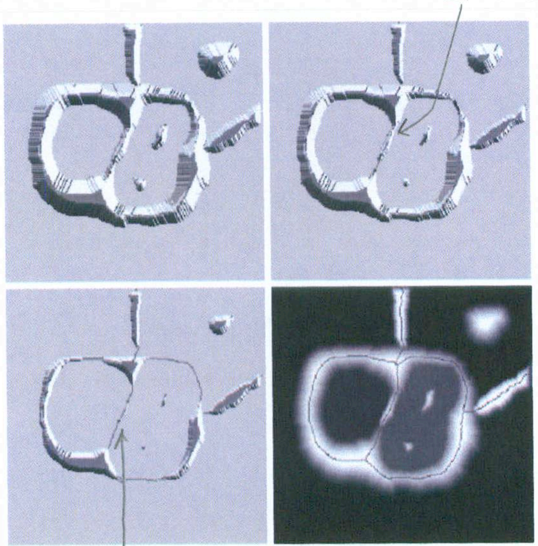
Image Segmentation

start building dam



e f
g h

FIGURE 10.44 *(Continued)* (e) Result of further flooding. (f) Beginning of merging of water from two catchment basins (a short dam was built between them). (g) Longer dams. (h) Final watershed (segmentation) lines. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

final watershed

longer dams

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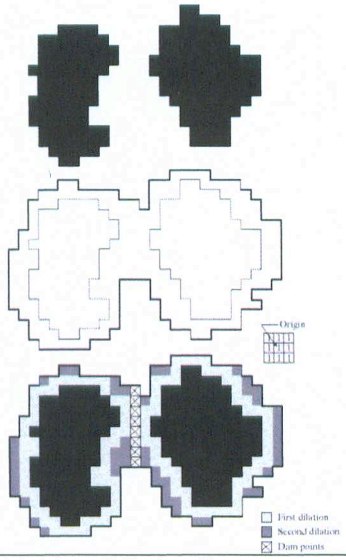
Image Segmentation



a
b c
d

FIGURE 10.45 (a) Two partially flooded catchment basins at stage $n-1$ of flooding. (b) Flooding at stage n, showing that water has spilled between basins (for clarity, water is shown in white rather than black). (c) Structuring element used for dilation. (d) Result of dilation and dam construction.

start at lowest points

dam construction occurs when dilations overlap.

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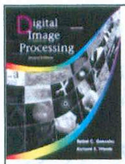
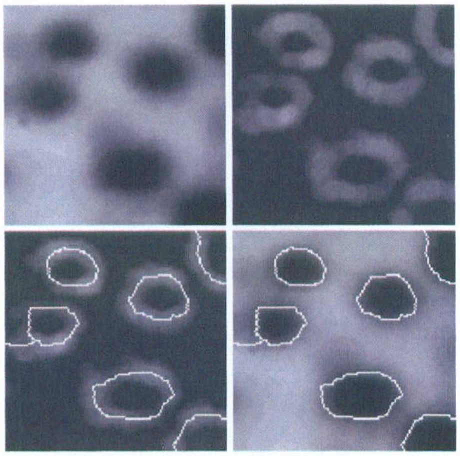
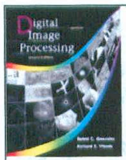
Image Segmentation





a b
c d

FIGURE 10.46 (a) Image of blobs. (b) Image gradient. (c) Watershed lines. (d) Watershed lines superimposed on original image. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)



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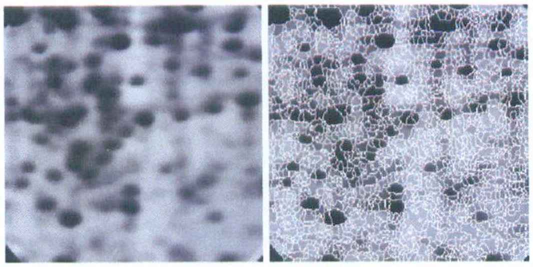

a b

FIGURE 10.47 (a) Electrophoresis image. (b) Result of applying the watershed segmentation algorithm to the gradient image. Oversegmentation is evident. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

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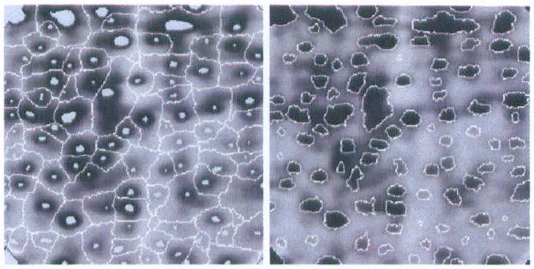
Image Segmentation



a b

FIGURE 10.48 (a) Image showing internal markers (light gray regions) and external markers (watershed lines). (b) Result of segmentation. Note the improvement over Fig. 10.47(b). (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

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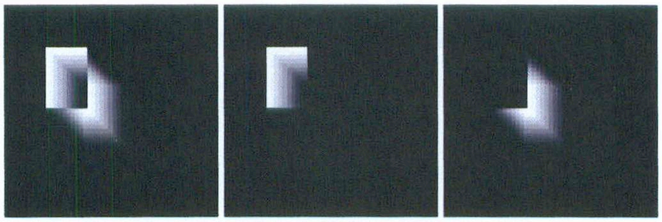

a b c

FIGURE 10.49 ADIs of a rectangular object moving in a southeasterly direction. (a) Absolute ADI. (b) Positive ADI. (c) Negative ADI.

ADI - accumulative difference image

$$A_k(x,y) = \begin{cases} A_{k-1}(x,y)+1 & \text{if } |R(x,y) - f(x,y,k)| > T \\ A_{k-1}(x,y) & \text{otherwise} \end{cases}$$

increase the accumulator if the absolute difference between the reference [$R(x,y)$ is usually $f(x,y,t_0)$] image and each successive image $f(x,y,k) = f(x,y,t_k)$

You can also do positive and negative accumulator images

$$P_k(x,y) = \begin{cases} P_{k-1}(x,y)+1 & \text{if } [R(x,y) - f(x,y,t_k)] > T \\ P_{k-1}(x,y) & \text{otherwise} \end{cases}$$

$$N_k(x,y) = \begin{cases} N_{k-1}(x,y)+1 & \text{if } [R(x,y) - f(x,y,t_k)] < -T \\ N_{k-1}(x,y) & \text{otherwise} \end{cases}$$

Chapter 10
Image Segmentation

a b c

FIGURE 10.50 Building a static reference image. (a) and (b) Two frames in a sequence. (c) Eastbound automobile subtracted from (a) and the background restored from the corresponding area in (b). (Jain and Jain.)

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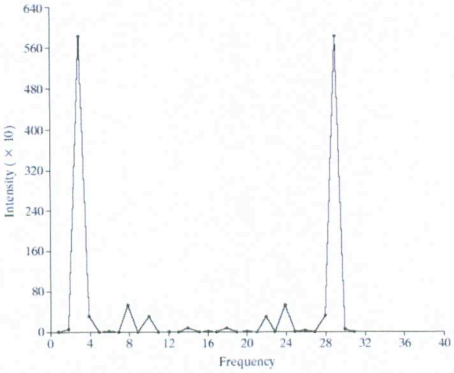

FIGURE 10.53 Spectrum of Eq. (10.6-8) showing a peak at $u_1 = 3$. (Rajala, Riddle, and Snyder.)

$a_1 = 6$

peak at $u_1 = 3$

$\therefore\ V_1 = \frac{u_1}{a_1} = \frac{3}{6} = 0.5$ pixel/frame

Assume images are $M \times N$

x-axis projection $\quad g_x(t, a_1) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y,t)\, e^{+j2\pi a_1 x \Delta t} \qquad t = 0, 1, \ldots, K-1$

y-axis projection $\quad g_y(t, a_2) = \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} f(x,y,t)\, e^{j2\pi a_2 y \Delta t} \qquad t = 0, 1, \ldots, K-1$

Fourier transform these projections

$$G_x(u_1, a_1) = \frac{1}{K} \sum_{t=0}^{K-1} g_x(t, a_1)\, e^{-j2\pi \frac{u_1 t}{K}} \qquad u_1 = 0, 1, \ldots, K-1$$

$$G_y(u_2, a_2) = \frac{1}{K} \sum_{t=0}^{K-1} g_y(t, a_2)\, e^{-j2\pi \frac{u_2 t}{K}} \qquad u_2 = 0, 1, \ldots, K-1$$

peak at frequency $u_1 = a_1 V_1 \leftarrow$ x-component velocity

peak at frequency $u_2 = a_2 V_2 \leftarrow$ y-component velocity

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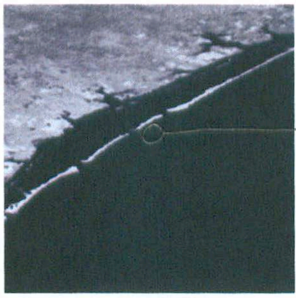
FIGURE 10.51 LANDSAT frame. (Cowart, Snyder, and Ruedger.)



— somewhere near here.

There is actually a small moving object with a 9 pixel Gaussian distribution moving with $v_x = 0.5$ pixel/frame and $v_y = 1$ pixel/frame.

Basic concept:
- single 1-pixel object moving, background = 0 at t = 0
  project onto x-axis, i.e. sum columns
  multiply components of array by
  $$e^{j2\pi a_1 x \Delta t} \qquad x = 0, 1, 2, \ldots$$
  (a_1 ↑ a positive integer; Δt ↑ time interval between planes)
- at t = 1 do same thing except object has moved to $x'+1$
- if constant velocity result is
  $$e^{j2\pi a_1 (x'+t)\Delta t} = \cos[2\pi a_1 (x'+t)\Delta t] + j\sin[2\pi a_1 (x'+t)\Delta t]$$

i.e. projections of moving objects give single frequency sinusoids (for constant velocity)

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Image Segmentation

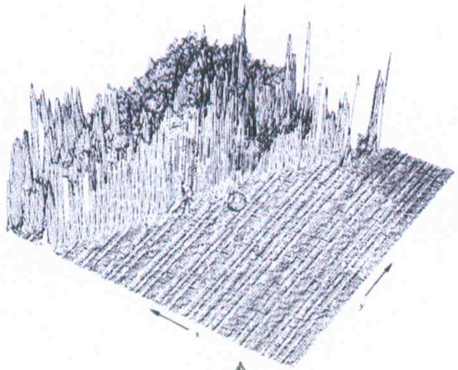

FIGURE 10.52 Intensity plot of the image in Fig. 10.51, with the target circled. (Rajala, Riddle, and Snyder.)

↑ moving target is in circle

intensity plot of image

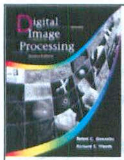

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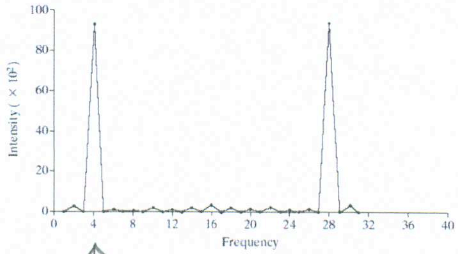
FIGURE 10.54 Spectrum of Eq. (10.6-9) showing a peak at $u_2 = 4$. (Rajala, Riddle, and Snyder.)



$a_2 = 4$

↑ $u_2 = 4$

$$\therefore \; v_2 = \frac{u_2}{a_2} = \frac{4}{4} = 1 \text{ pixel/frame.}$$

Representing a region:

- external representation – boundary

  – the boundary can be described by features such as length, orientation of the straight line connecting its extreme points, and the number of concavities in the boundary

  – chosen when the focus is on shape

- internal representation – pixels comprising the region

  – color and texture

  – chosen when the primary focus is on regional properties

want features to be insensitive to size, translation and rotation

Representing a region:

- external representation – boundary

  – the boundary can be described by features such as length, orientation of the straight line connecting its extreme points, and the number of concavities in the boundary

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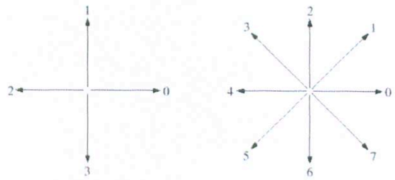
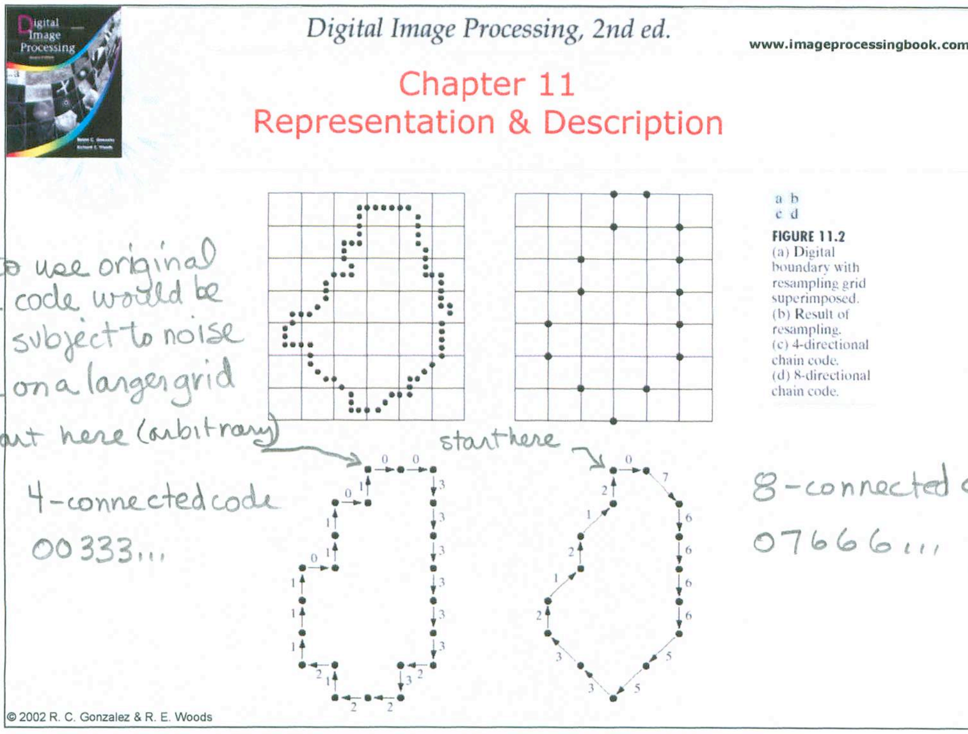
Chapter 11
Representation & Description



a b

FIGURE 11.1 Direction numbers for (a) 4-directional chain code, and (b) 8-directional chain code.

don't want to use original pixels since code would be too long and subject to noise — resample on a larger grid



start here (arbitrary)

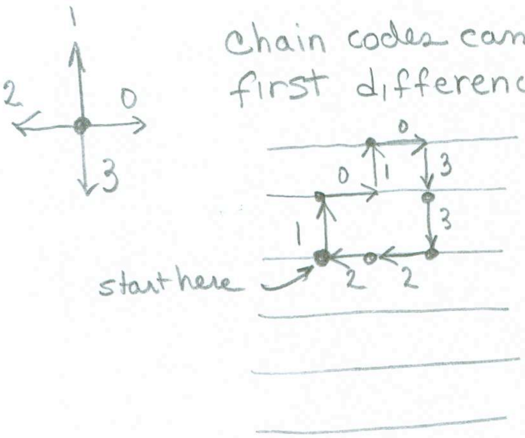
4-connected code 00333...

start here

8-connected code - 07666...

chain codes represent a boundary as a connected sequence of straight-line segments of specified length and direction

chain codes can be normalized for rotation by using first difference



1 0 1 0 3 3 2 2 chain code representation

first difference normalizes for rotation

go in counter clockwise direction, count # of $\frac{\pi}{2}$ (or $\frac{\pi}{4}$)

1→0 3 turns

0→1 1

1→0 3

0→3 3

3→3 0

3→2 3

2→2 0

2→1 3 put at beginning

3 3 1 3 3 0 3 0

only rotation invariant if the digitizations are insensitive to rotation

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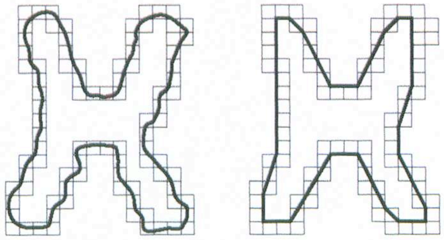
Representation & Description



a b
FIGURE 11.3 (a) Object boundary enclosed by cells. (b) Minimum perimeter polygon.

grid of cells which "walls" in boundary

let boundary be a "rubber band"

MINIMUM PERIMETER POLYGONS

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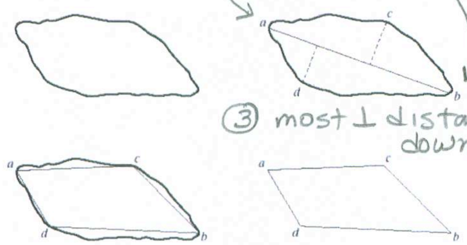
Representation & Description

① two most distant points joined by ab

② most ⊥ distance up from ab

③ most ⊥ distance down



a b
c d

FIGURE 11.4 (a) Original boundary. (b) Boundary divided into segments based on extreme points. (c) Joining of vertices. (d) Resulting polygon.

boundary segment splitting – subdivide a segment successively until a specified criterion is satisfied

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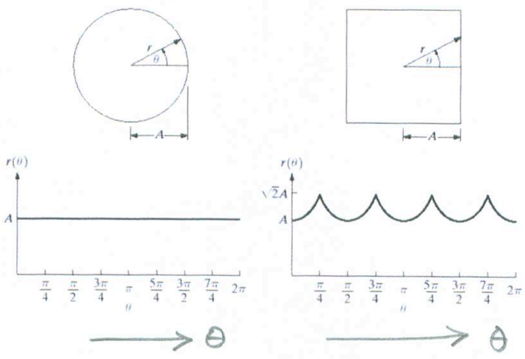
Representation & Description

a b

FIGURE 11.5 Distance-versus-angle signatures. In (a) $r(\theta)$ is constant. In (b), the signature consists of repetitions of the pattern $r(\theta) = A \sec\theta$ for $0 \le \theta \le \pi/4$ and $r(\theta) = A \csc\theta$ for $\pi/4 < \theta \le \pi/2$.



signature - 1-D representation of a boundary

These are invariant to translation but
sensitive to rotation and scale (size)

Methods of selecting starting point can make signatures
independent of rotation
- select point farthest from centroid
- select point farthest from centroid along eigenaxis
- use a chain code

Many other types of signatures
ψ - s (i.e. plot the tangent)

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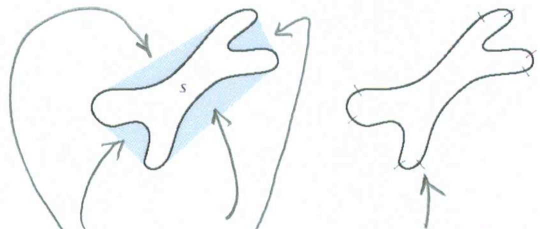
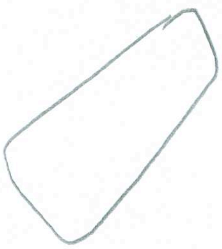


a b

FIGURE 11.6 (a) A region, S, and its convex deficiency (shaded). (b) Partitioned boundary.

convex deficiency

code boundary by points where boundary passes in and out of a convex deficiency



H is the convex hull of S

H - S is the convex defeciency.

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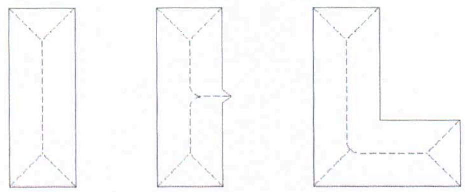
Representation & Description



a b c
FIGURE 11.7 Medial axes (dashed) of three simple regions.

reduce the structure of a shape to a skeleton

morphology will not necessarily keep a skeleton connected

median axis transformation (MAT) algorithm

MAT of a region R with border B
for each point p in R find its closest neighbor on B
if p has more that one "closest" neighbor it belongs
to the medial axis (skeleton) of B

closest is defined using Euclidian distance

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p_9	p_2	p_3
p_8	p_1	p_4
p_7	p_6	p_5

FIGURE 11.8 Neighborhood arrangement used by the thinning algorithm.

0	0	1
1	p_1	0
1	0	1

$N(p_1) = 4$

$T(p_1) = 3$

Algorithm for thinning binary images.

contour point is any pixel with value 1 and at least one 8-neighbor valued 0

Step 1: mark for deletion any contour point p_1 which has

(a) $2 \leq N(p_1) \leq 6$ — # of non-zero neighbors is between 2 and 6 — don't delete if end point or inside region

(b) $T(p_1) = 1$ — # of 0-1 transitions in sequence $p_2\, p_3\, p_4\, p_5\, p_6\, p_7\, p_8\, p_9\, p_2$ — prevents breaking connected lines

(c) $p_2\, p_4\, p_6 = 0$ — east or south boundary pt.

(d) $p_4\, p_6\, p_8 = 0$ — northwest corner

(c) and (d) says that either p_4 and $p_6 = 0$ or p_2 and $p_8 = 0$

Step 2: mark for deletion if

(a) $2 \leq N(p_1) \leq 6$

(b) $T(p_1) = 1$

(c') $p_2\, p_4\, p_8 = 0$

(d') $p_4\, p_6\, p_8 = 0$

(c') and (d') says that p_2 and $p_4 = 0$ or p_6 and $p_8 = 0$

Iterate by applying step 1 to all border points; deleting marked points; apply step 2 to all remaining border points; and deleting marked points. Repeat until no further points deleted.

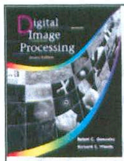

FIGURE 11.9 Illustration of conditions (a) and (b) in Eq. (11.1-1). In this case $N(p_1) = 4$ and $T(p_1) = 3$.

0	0	1
1	p_1	0
1	0	1

$N(p_1) = 4$

$T(p_1) = 3$

$P_2 P_4 P_6 = 0$

$P_4 P_6 P_8 = 0$

$P_2 P_4 P_8 = 0$

$P_2 P_6 P_8 = 0$

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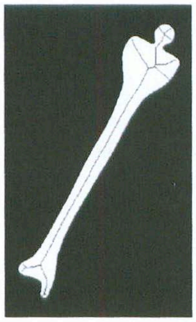

FIGURE 11.10 Human leg bone and skeleton of the region shown superimposed.