Image Segmentation

Point Detection, Line Detection, Edge Detection, Hough Transform, Thresholding, Region Based Segmentation

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Image Segmentation

- Segmentation subdivides an image into its constituent regions or objects.
- The level to which subdivision is carried out depends on the problem being solved.
- Most of the segmentation algorithms in this chapter are based on one of two basic properties of image intensity values: discontinuity and similarity.
- Discontinuity: The approach is to partition an image into regions based on abrupt changes in intensity, such as edges.
- Similarity: The approach is to partition an image into regions that are similar according to a set of predefined criteria.

Detection of Discontinuity

- Several techniques for detecting the three gray levels of discontinuities in digital images: points, lines, and edges
- The most common method is to run a musk through the image.
- The procedure involves computing the sum of the product of the coefficients with the grey levels contained in the region encompassed by the mask.

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

Response of the mask

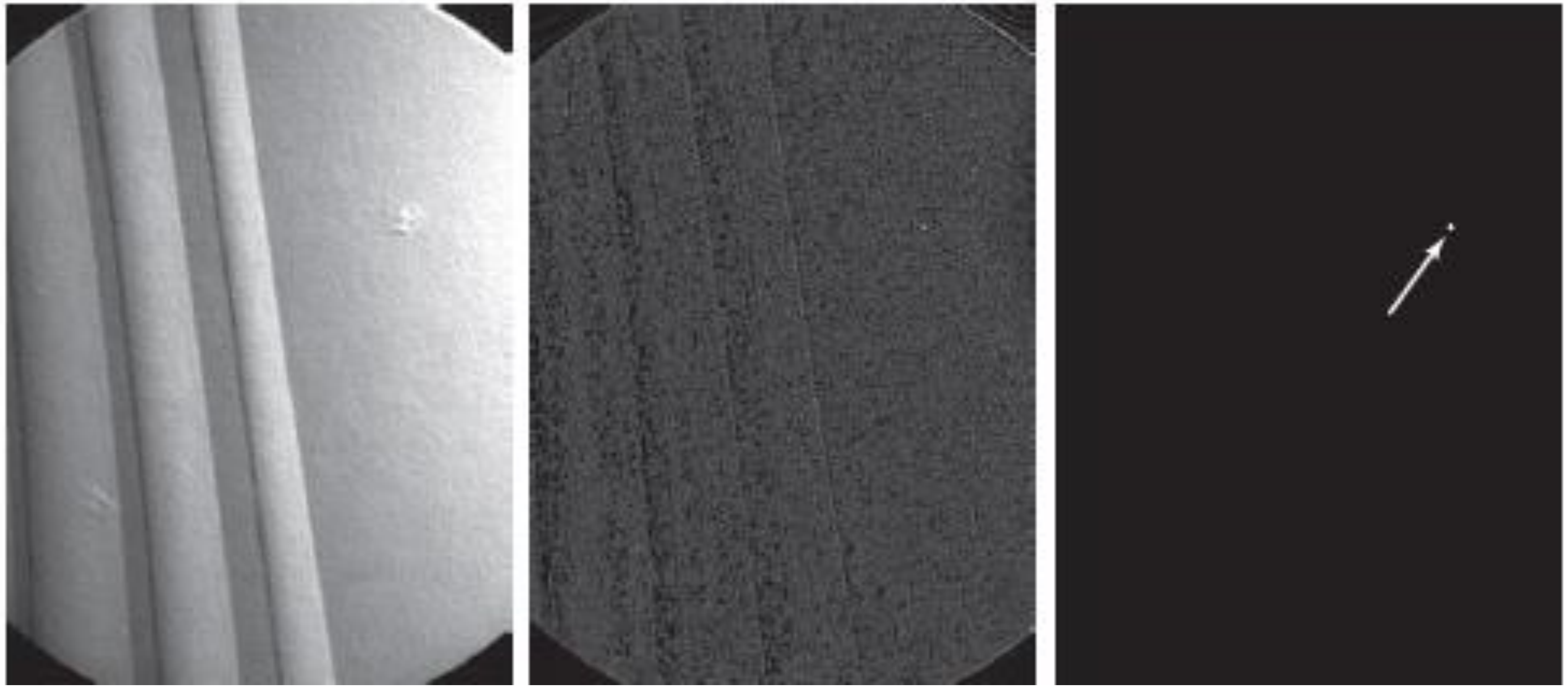
$$R = \sum_{i=1} w_i z_i$$

Point Detection

- An isolated point is a point whose grey level is significantly different from its background in a homogeneous area.
- To identify the availability of isolated points, we have to select a threshold value and the threshold value is denoted as T.
- Using the mask, we say that a point has been detected at the location on which the mask is centered if $|R| \geq T$, where T is an nonnegative integer.

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

Point Detection



a b c (a) X-ray image of a turbine blade with a porosity manifested by a single black pixel. (b) Result of convolving the kernel with the image. (c) Result of using point detection equation was a single point (shown enlarged at the tip of the arrow).

Line Detection

- In line detection four types of masks are used to get the response i.e. $R_1, R_2, R_3, and\ R_4$ for the vertical, horizontal, $+45°$, and $-45°$ respectively.

-1	-1	-1
2	2	2
-1	-1	-1

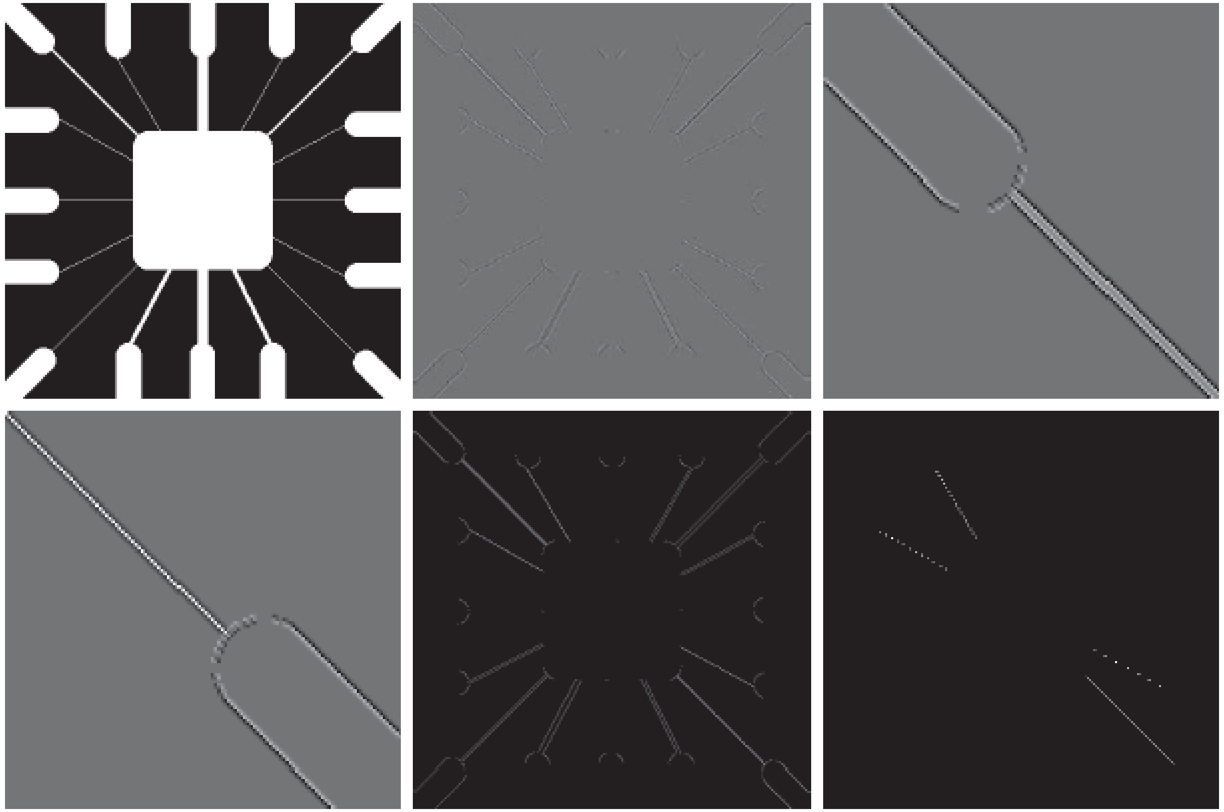
-1	2	-1
-1	2	-1
-1	2	-1

-1	-1	2
-1	2	-1
2	-1	-1

2	-1	-1
-1	2	-1
-1	-1	2

- If the first mask were moved around the image, it would respond more strongly to lines oriented horizontally.

Line Detection



a b c
d e f

FIGURE 10.7 (a) Image of a wire-bond template. (b) Result of processing with the +45° line detector kernel in Fig. 10.6. (c) Zoomed view of the top left region of (b). (d) Zoomed view of the bottom right region of (b). (e) The image in (b) with all negative values set to zero. (f) All points (in white) whose values satisfied the condition $g > T$, where g is the image in (e) and $T = 254$ (the maximum pixel value in the image minus 1). (The points in (f) were enlarged to make them easier to see.)

Edge Detection

- An edge is a set of connected pixels that lies on the boundary between two regions which differ in grey value. Pixel on edge is known as edge points.
- Edge provides an outline of the object
- In physical plane, edge corresponds to the discontinuity in depth, surface orientation, change in material properties, light variations etc.
- It locates sharp changes in the intensities

Edge Detection

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

Roberts

-1	0
0	1

0	-1
1	0

Prewitt

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

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

Sobel

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

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

Edge Linking and Boundary Detection

- Edge detection yield sets of pixels lying only on edges.
- In practice, these pixels seldom characterize edges completely because of noise, breaks in the edges caused by nonuniform illumination, and other effects that introduce discontinuities in intensity values.
- Therefore, edge detection typically is followed by linking algorithms designed to assemble edge pixels into meaningful edges and/or region boundaries.
- Local Processing requires the knowledge about edge points in a local region (e.g., a 3 × 3 neighborhood)
- Global Processing works with an entire edge map.

Local Processing

- Analyze the characteristics of pixels in a small neighborhood S_{xy} (say 3X3 or 5X5), about every edge pixels (x, y) in an image that have undergone the edge detection.
- All points that share some common properties are linked together. These are

➢ Strength/ magnitude of the gradient

➢ Direction of the gradient

Local Processing

- Pixels (s, t) and (x, y) are similar and linked if
- $|M(s,t) - M(x,y)| \leq E$, where E is positive threshold
- $|\alpha(s,t) - \alpha(x,y)| \leq A$, where A is positive threshold

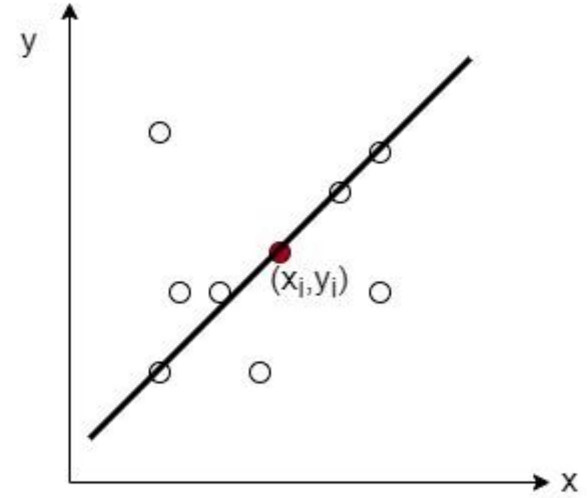
- The magnitude of the gradient
- $M(x,y) = mag(\nabla f) = \sqrt{G_x^2 + G_y^2} = \sqrt{(\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2)}$
- The direction of the gradient vector $\alpha(x,y) = \tan^{-1}\frac{G_y}{G_x}$

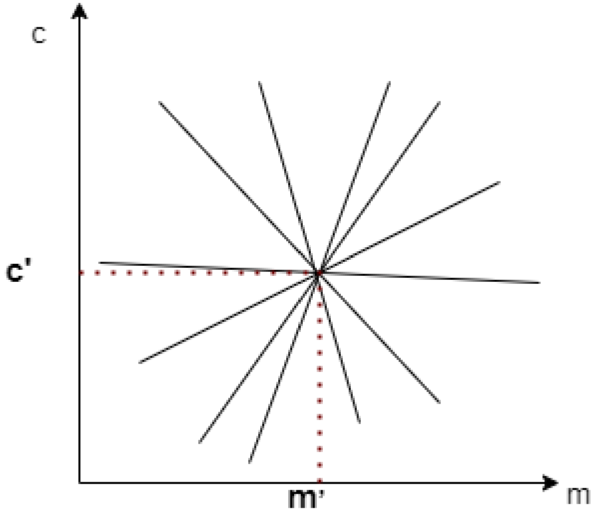
Global Processing via Hough Transform

- One powerful global method for detecting edges is called the Hough transform
- Let us suppose that we are looking for straight lines in an image
- If we take a point $(x1, y1)$ in the image , all lines which pass through that pixels have the form $y1 = mx1 + c$, for varying values of m and c
- However this equation can also be written as $c = -mx1 + y1$
- This is a straight line on a graph of c against m.
- Each different line through the point $(x1, y1)$ corresponds to one of the points on the line (m, c) space.

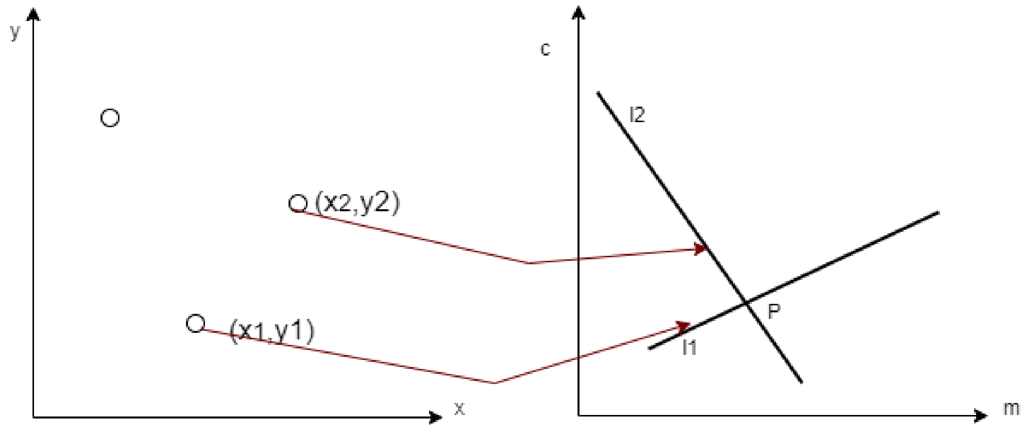
Hough Transform

- All pixels which lie on the same line in (x, y) space are represented by the lines which all pass through a single point in (m, c)
- The single point through which they all pass gives the values of m and c in the equation of the line $y = mx + c$, find (m, c)
- Consider the point (x_i, y_i)
- $y_i = mx_i + c \; or \; c = -mx_i + y_i$
- Parameter space (m, c) also called Hough space





Hough Transform



- The points (x_1, y_1) and (x_2, y_2) are mapped to lines l_1 and l_2 respectively in $m - c$ space.
- l_1 and l_2 will intersect at a point P representing the (m, c) values of the line joining (x_1, y_1)
- The intersection of multiple lines in the mc values of lines in the edge image plane.

Hough Transform

- Quantize Parameter space (m, c)
- Create Accumulator Array $A(m, c)$
- Set $A(m, c) = 0 \quad \forall m, c$
- For each image (x_i, y_i) increment:
- $A(m, c) = A(m, c) + 1$
- If (m, c) lies on the line: $c = -x_i m + y_i$
- Find local maxima in $A(m, c)$

Thresholding

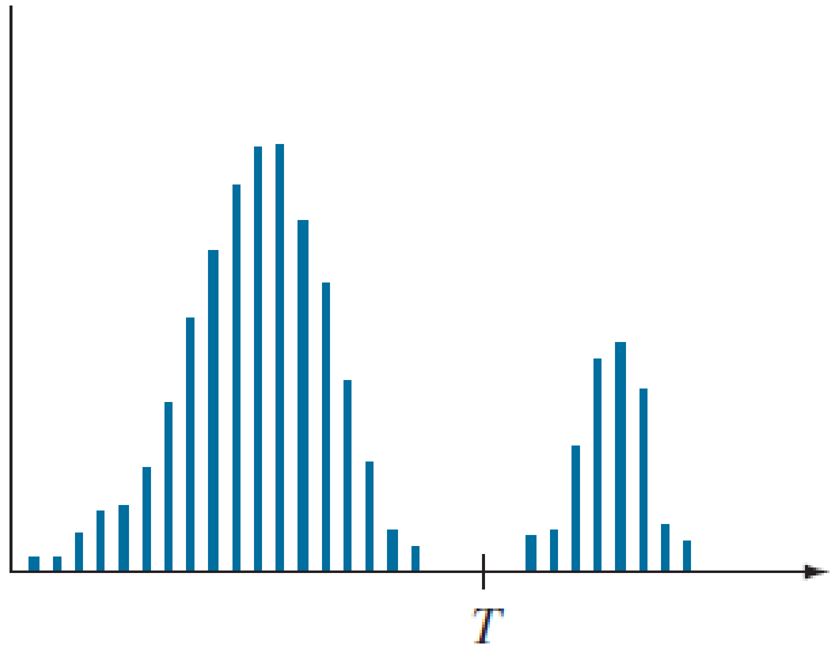
- Thresholding produces uniform regions based segmentation on the thresholding criterion, T
- Key parameter of thresholding process is the choice of threshold value
- Global Thresholding: if thresholding operations depends only on grey scale value, it is called Global thresholding
- Local Thresholding: in case neighborhood properties are also taken into account, the method is known as local thresholding
- If T depends on pixel coordinates also, it is known as dynamic or adaptive thresholding.
- Thresholding operation can be expressed as $Th = T[x, y, f(x, y), p(x, y)]$

Histogram and Thresholding

- the quality of thresholding algorithm depends on the selection of a suitable threshold
- Tools that help us to find the threshold is histogram.
- Types of Histogram:
  A. Unimodal histogram
  B. Bimodal histogram
  C. Multimodal histogram

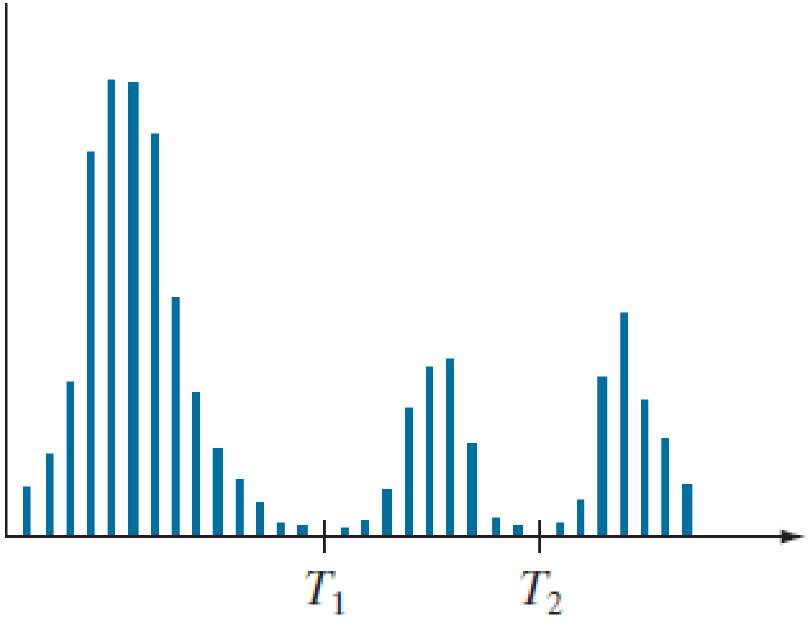
Histogram and Thresholding

- Single level thresholding:



$$g(x,y) = \begin{cases} 1 & \text{if } f(x,y) > T \\ 0 & \text{if } f(x,y) \le T \end{cases}$$

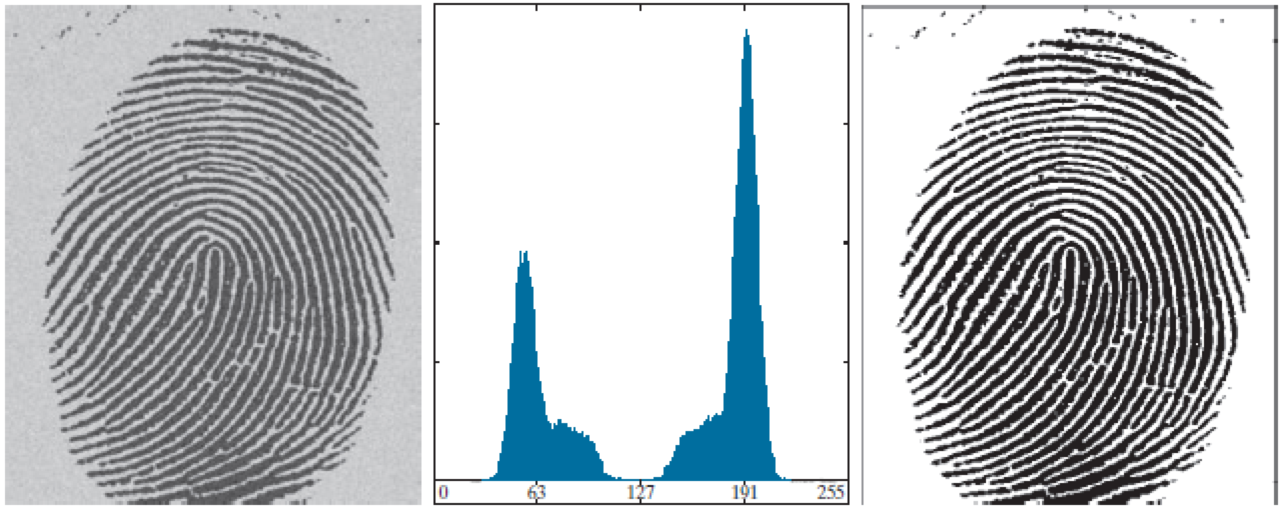
Multi-level Thresholding



$$g(x,y) = \begin{cases} a & \text{if } f(x,y) > T_2 \\ b & \text{if } T_1 < f(x,y) \le T_2 \\ c & \text{if } f(x,y) \le T_1 \end{cases}$$

Global Thresholding

- When the intensity distributions of objects and background pixels are sufficiently distinct, it is possible to use a single (global) threshold applicable over the entire image.



a b c

FIGURE 10.35 (a) Noisy fingerprint. (b) Histogram. (c) Segmented result using a global threshold (thin image border added for clarity). (Original image courtesy of the National Institute of Standards and Technology.).

Global Thresholding

Global Thresholding

1. Select an initial estimate for the global threshold, T.
2. Segment the image using T. This will produce two groups of pixels: $G1$, consisting of pixels with intensity values $> T$; and $G2$, consisting of pixels with values$\leq T$.
3. Compute the average (mean) intensity values $m1$ and $m2$ for the pixels in $G1$ and $G2$, respectively.
4. Compute a new threshold value midway between $m1$ and $m2$:

$$T = \frac{1}{2}(m1 + m2)$$

1. Repeat Steps 2 through 4 until the difference between values of T in successive iterations is smaller than a predefined value ΔT,

Region Based Segmentation

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- The objective of segmentation is to partition an image into regions.
- First we find boundaries between regions based on discontinuities in intensity levels
- Next, segmentation was accomplished via thresholds based on the distribution of pixel properties, such as intensity values or color.
- Region based segmentation techniques that find the regions directly.

Basic Formulation

- Let R represent the entire spatial region occupied by an image. We may view the image segmentation as a process that partitions R into n subregions, $R_1, R_2, \ldots, R_n$ such that
- $\cup_{i=1}^{n} R_i = R$
- $R_i \ for \ i = 1,2,3,$ …is connected set
- $R_i \cap R_j = \emptyset$
- $Q(R_i) = TRUE$ for $i = 1,2,3 \ldots$
- $Q\left(R_i \cup R_j\right) = FALSE$ for any adjacent region R_i and R_j

Region Growing

- Region growing is a procedure that groups pixels or subregions into larger regions based on predefined criteria for growth.
- The basic approach is to start with a set of “seed” points, and from these grow regions by appending to each seed those neighboring pixels that have predefined properties similar to the seed (such as ranges of intensity or color).
- Selecting a set of one or more starting points can often be based on the nature of the problem.

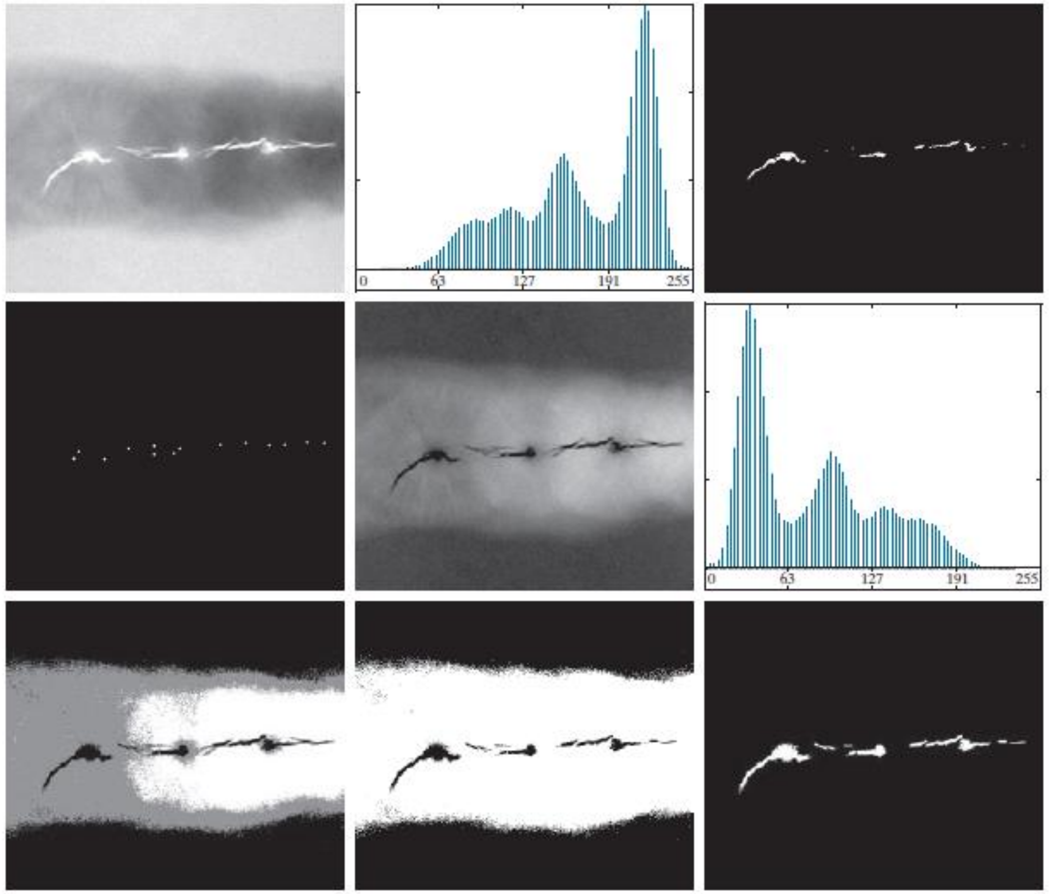
Region Growing

- When a priori information is not available, the procedure is to compute at every pixel the same set of properties that ultimately will be used to assign pixels to regions during the growing process.
- If the result of these computations shows clusters of values, the pixels whose properties place them near the centroid of these clusters can be used as seeds.
- The selection of similarity criteria depends not only on the problem under consideration, but also on the type of image data available.

Region Growing

- Let: $f(x, y)$ denote an input image; $S(x, y)$ denote a seed array containing 1's at the locations of seed points and 0's elsewhere; and Q denote a predicate to be applied at each location (x, y). Arrays f and S are assumed to be of the same size. A basic region-growing algorithm based on 8-connectivity may be stated as follows.
- Find all connected components in $S(x, y)$ and reduce each connected component to one pixel; label all such pixels found as 1. All other pixels in S are labeled 0.
- Form an image f_Q such that, at each point (x, y), $f_Q(x, y) = 1$ if the input image satisfies a given predicate, Q, at those coordinates, and $f_Q(x, y) = 0$, otherwise.
- Let g be an image formed by appending to each seed point in S all the 1-valued points in f_Q that are 8-connected to that seed point.
- Label each connected component in g with a different region label (e.g.,integers or letters). This is the segmented image obtained by region growing.

Region Growing

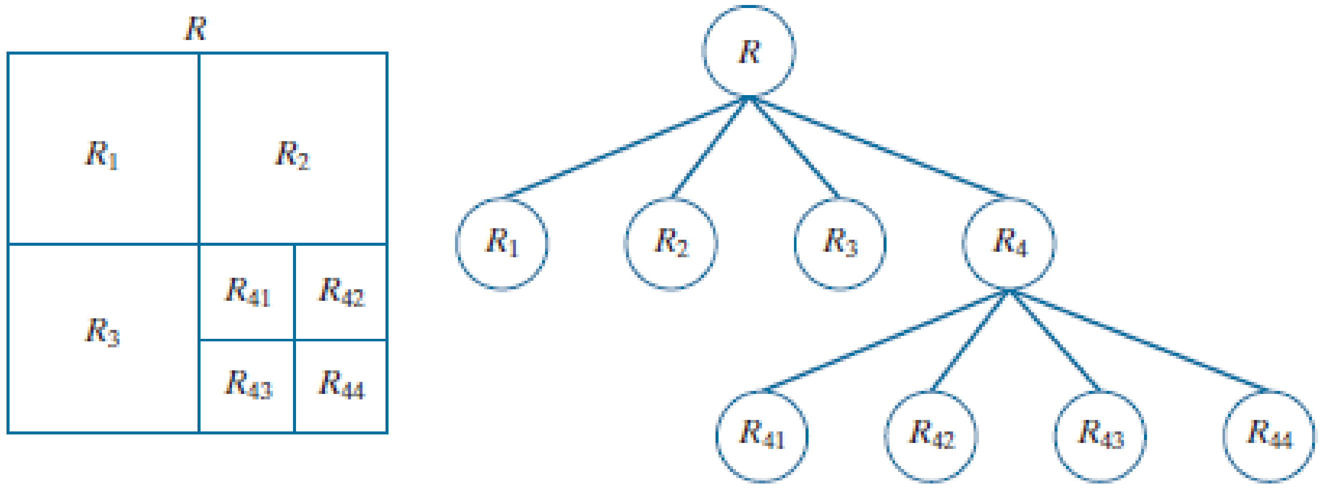


Region Splitting and Merging

- Subdivide an image initially into a set of disjoint regions and then merge and/or split the regions in an attempt to satisfy the conditions of segmentation stated
- Let R represent the entire image region and select a predicate Q.
- One approach for segmenting R is to subdivide it successively into smaller and smaller quadrant regions so that, for any region Ri ,Q(Ri) = TRUE. We start with the entire region, R.
- If Q(R) = FALSE, we divide the image into quadrants. If Q is FALSE for any quadrant, we subdivide that quadrant into sub-quadrants, and so on.

Region Splitting and Merging

- This splitting technique has a convenient representation in the form of so-called quadtrees; that is, trees in which each node has exactly four descendants, as Figure shows.



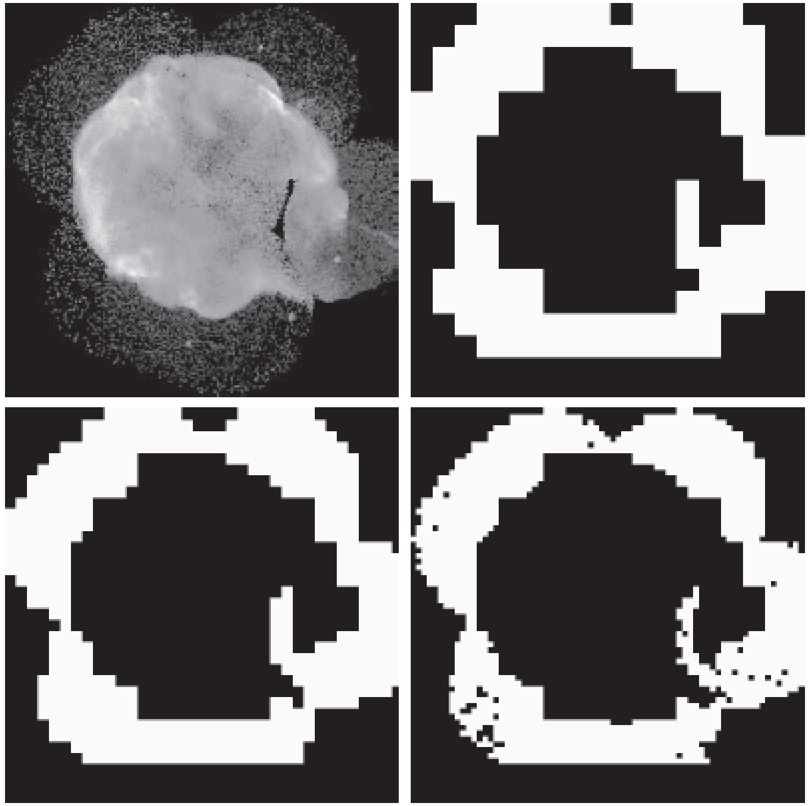
Region Splitting and Merging

- If only splitting is used, the final partition normally contains adjacent regions with identical properties.
- This drawback can be remedied by allowing merging as well as splitting.
- Satisfying the constraints of segmentation requires merging only adjacent regions whose combined pixels satisfy the predicate Q.
- That is, two adjacent regions R_j and R_k are merged only if $Q(R_i \cup R_k) = TRUE$.

Region Splitting and Merging

1. Split into four disjoint quadrants any region R_i for which $Q(R_i) = FALSE$.
2. When no further splitting is possible, merge any adjacent regions R_j and R_k for which $Q(R_i \cup R_k) = TRUE$.
3. Stop when no further merging is possible.

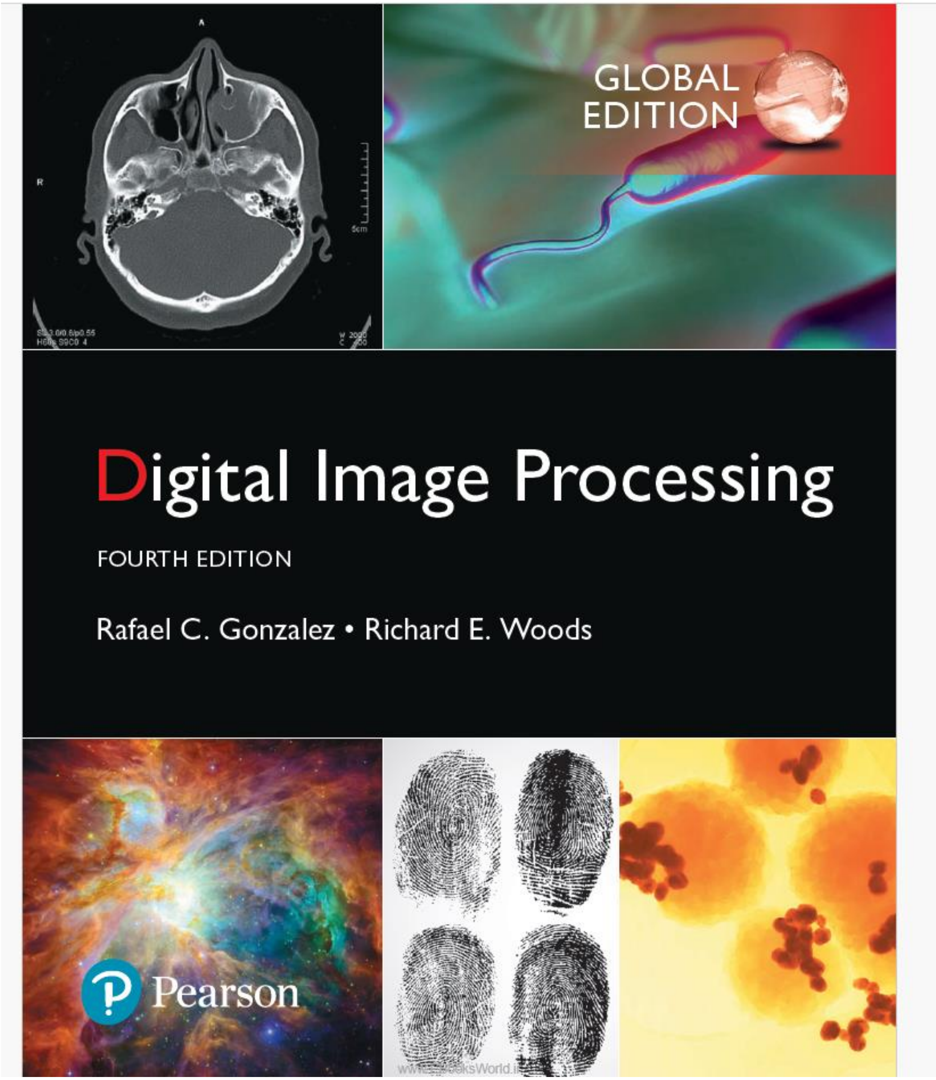
Region Splitting and Merging



a b
c d

FIGURE 10.48 (a) Image of the Cygnus Loop supernova, taken in the X-ray band by NASA's Hubble Telescope. (b) through (d) Results of limiting the smallest allowed quadregion to be of sizes of 32×32, 16×16, and 8×8 pixels, respectively. (Original image courtesy of NASA.)

Reference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