P-600

Image Segmentation

Segmentation

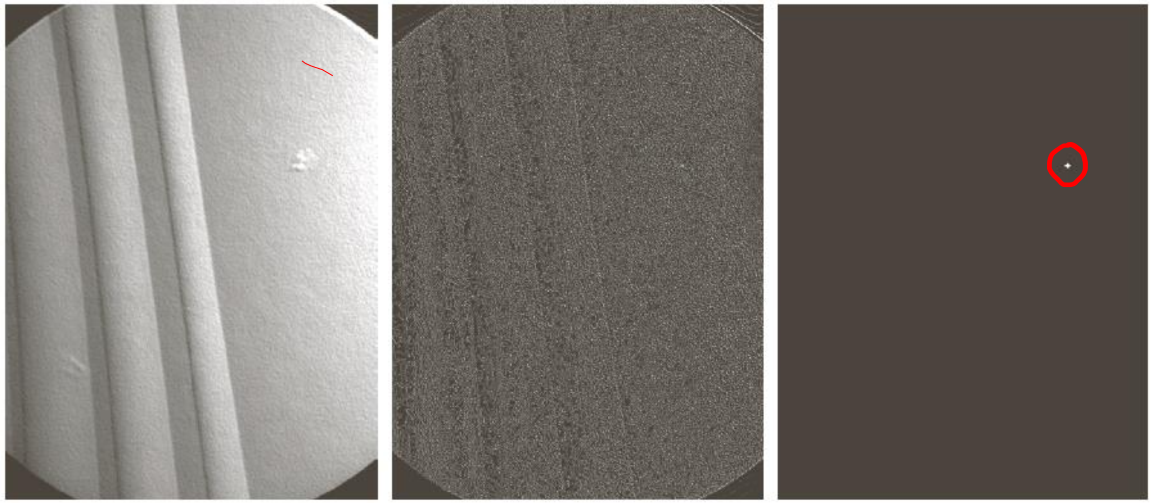
- A process of subdividing an image into its constituent parts.
- Level of subdivision is application dependent.
- It can be of mainly two types
  - Discontinuity based approach
  - Similarity based approach
- Discontinuity based: segmentation is carried out based on abrupt changes in intensity level in image
  - Main objective is to identify i) isolated points, ii) lines, iii) edges
- Similarity based: objective is to find the pixels which are similar in some sense
  - Thresholding is the main technique

Point Detection

- Convolving the image with a mask.

$|R| > T$

1	1	1
1	−8	1
1	1	1



a
b c d

FIGURE 10.4 (a) Point detection (Laplacian) mask. (b) X-ray image of turbine blade with a porosity. The porosity contains a single black pixel. (c) Result of convolving the mask with the image. (d) Result of using Eq. (10.2-8) showing a single point (the point was enlarged to make it easier to see). (Original image courtesy of X-TEK Systems, Ltd.)

Line Detection

−1	−1	−1
2	2	2
−1	−1	−1

Horizontal

2	−1	−1
−1	2	−1
−1	−1	2

+45° −45

−1	2	−1
−1	2	−1
−1	2	−1

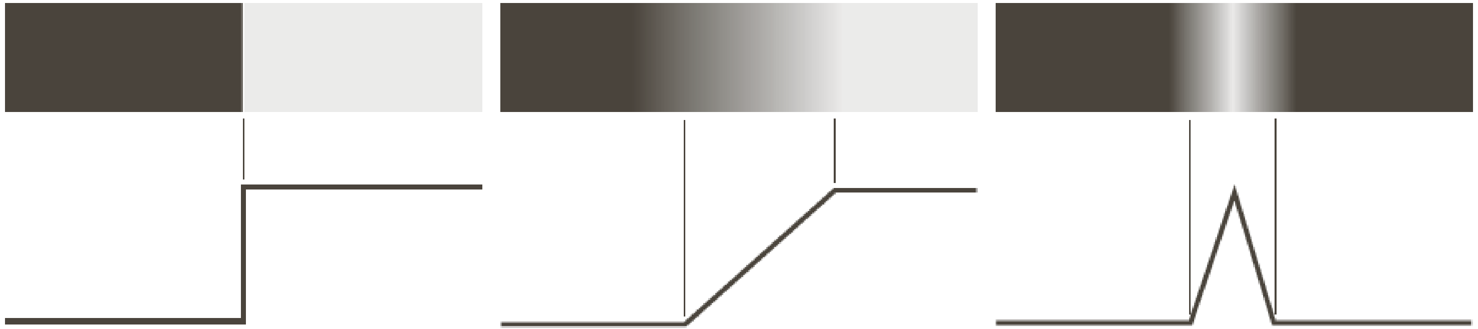
Vertical

−1	−1	2
−1	2	−1
2	−1	−1

−45° +45°

- Apply i^{th} mask compute $|G_i|$
- Apply j^{th} mask to compute $|G_j|$
- If $|G_i|>|G_j|$ the corresponding point is more likely to be associated with a line in the direction of mask i.

Edge Detection



a b c

FIGURE 10.8 From left to right, models (ideal representations) of a step, a ramp, and a roof edge, and their corresponding intensity profiles.

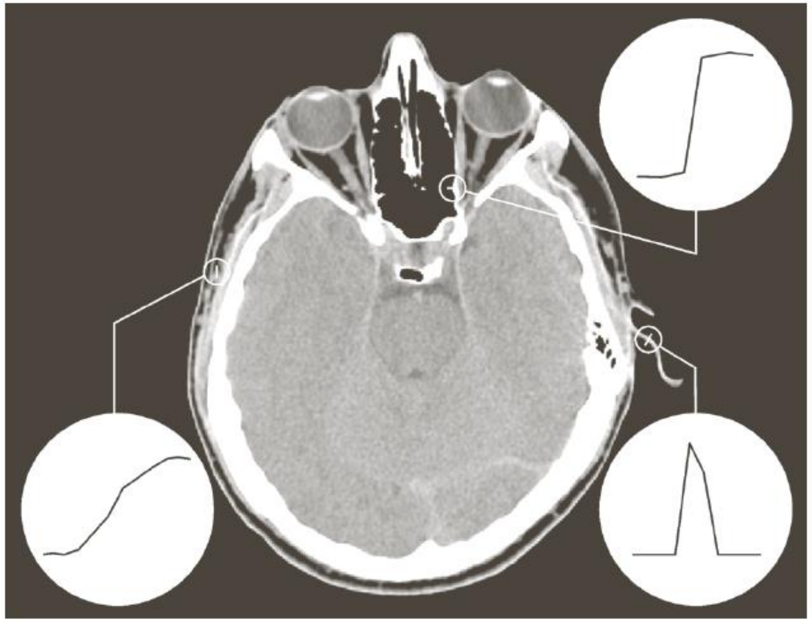
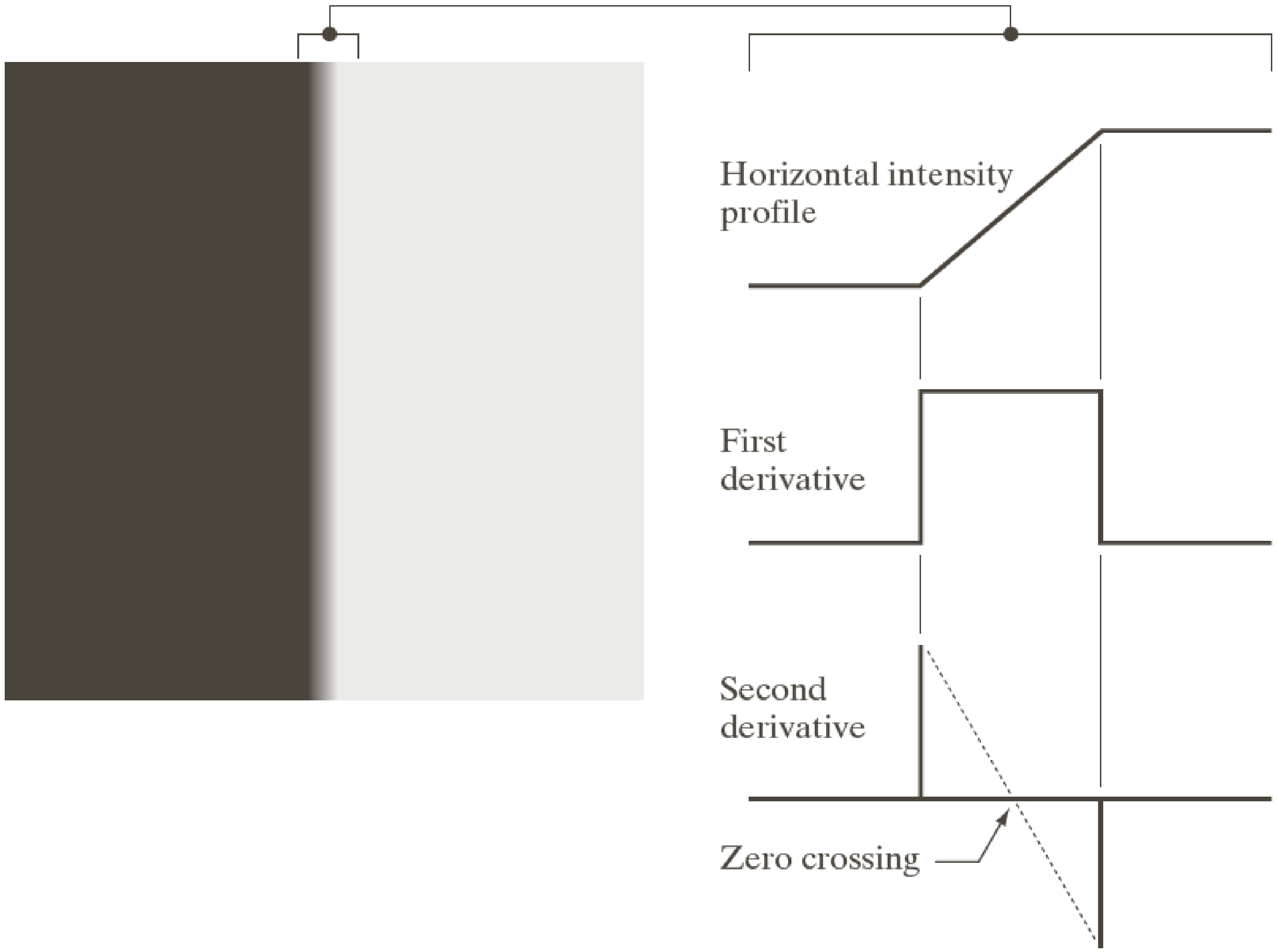


FIGURE 10.9 A 1508 × 1970 image showing (zoomed) actual ramp (bottom, left), step (top, right), and roof edge profiles. The profiles are from dark to light, in the areas indicated by the short line segments shown in the small circles. The ramp and "step" profiles span 9 pixels and 2 pixels, respectively. The base of the roof edge is 3 pixels. (Original image courtesy of Dr. David R. Pickens, Vanderbilt University.)

Edge Detection (contd.)



a b

FIGURE 10.10
(a) Two regions of constant intensity separated by an ideal vertical ramp edge.
(b) Detail near the edge, showing a horizontal intensity profile, together with its first and second derivatives.

Edge Detection (contd.)

a b
c d

FIGURE 10.15 Prewitt and Sobel masks for detecting diagonal edges.

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

a
b c
d e
f g

FIGURE 10.14 A 3 × 3 region of an image (the z's are intensity values) and various masks used to compute the gradient at the 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

Edges

a b
c d

FIGURE 10.16 (a) Original image of size 834×1114 pixels, with intensity values scaled to the range $[0, 1]$. (b) $|g_x|$, the component of the gradient in the x-direction, obtained using the Sobel mask in Fig. 10.14(f) to filter the image. (c) $|g_y|$, obtained using the mask in Fig. 10.14(g). (d) The gradient image, $|g_x| + |g_y|$.

LoG ≡ DoG

Marr-Hildreth Edge Detector (LoG)

1. Gaussian filtering
2. Laplacian
3. Find zero crossing

Gaussian kernel

$$g(x,y) = \nabla^2[G(x,y) * f(x,y)]$$

$$g(x,y) = [\nabla^2 G(x,y)] * f(x,y)$$

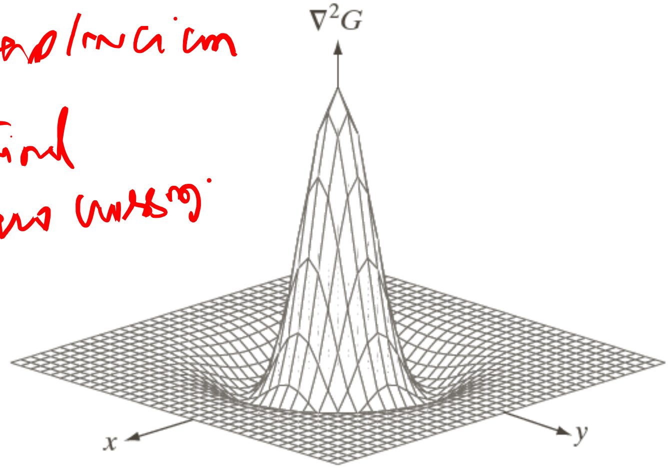
$$G(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2}}$$

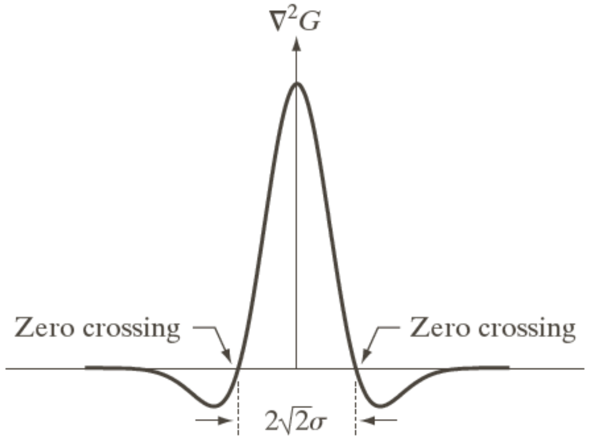
$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

$$\nabla^2 G(x,y) = \frac{\partial^2 G(x,y)}{\partial x^2} + \frac{\partial^2 G(x,y)}{\partial y^2}$$

$$= \frac{\partial}{\partial x}\left[-\frac{x}{\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}\right] + \frac{\partial}{\partial y}\left[-\frac{y}{\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}\right]$$

$$\nabla^2 G(x,y) = \left[\frac{x^2+y^2-2\sigma^2}{\sigma^4}\right] e^{-\frac{x^2+y^2}{2\sigma^2}}$$



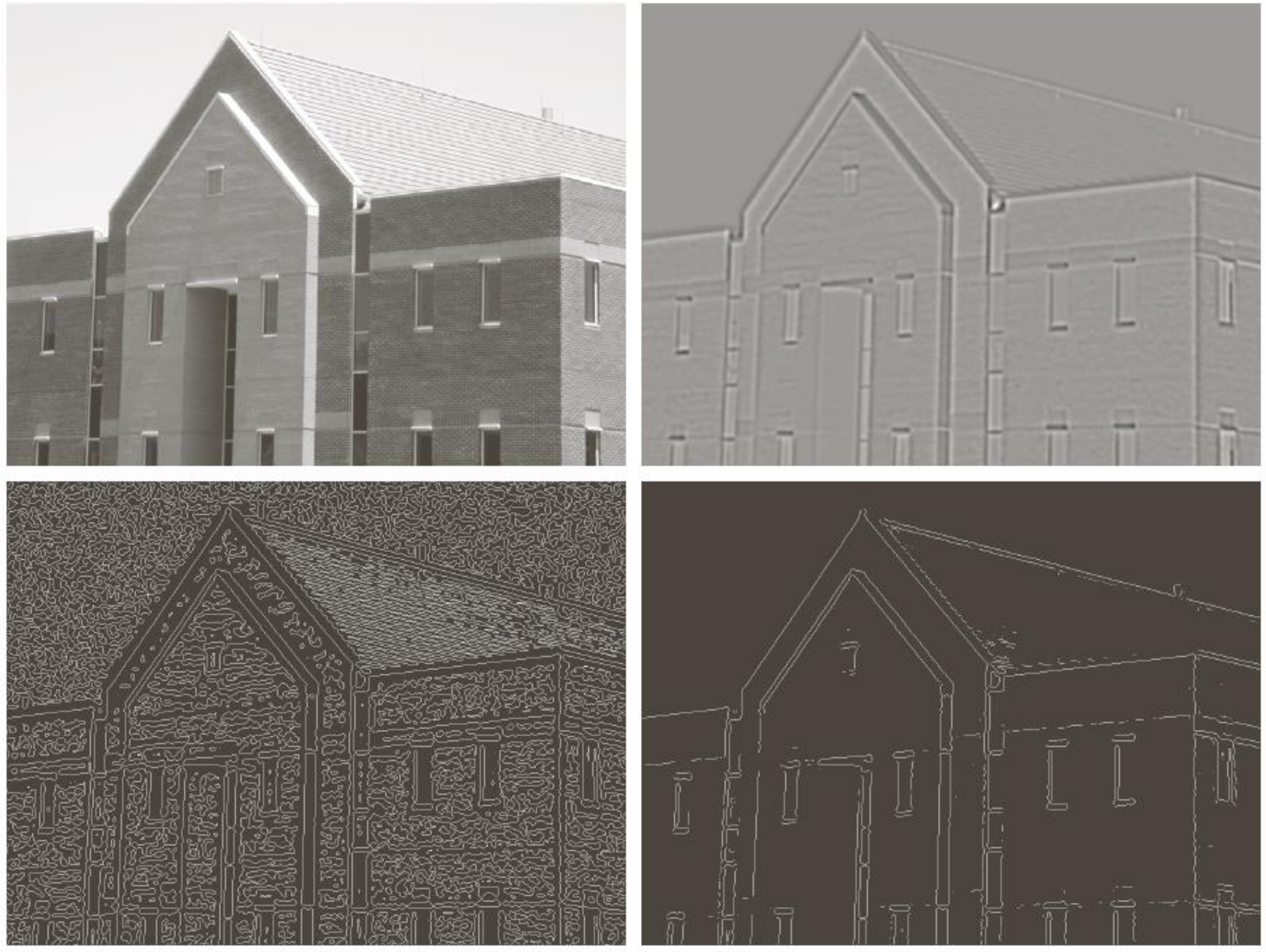


0	0	−1	0	0
0	−1	−2	−1	0
−1	−2	16	−2	−1
0	−1	−2	−1	0
0	0	−1	0	0

a	b
c	d

FIGURE 10.21 (a) Three-dimensional plot of the *negative* of the LoG. (b) Negative of the LoG displayed as an image. (c) Cross section of (a) showing zero crossings. (d) 5 × 5 mask approximation to the shape in (a). The negative of this mask would be used in practice.

Results

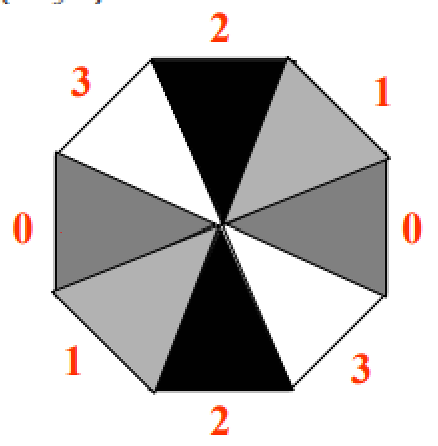


a b
c d

FIGURE 10.22
(a) Original image of size 834×1114 pixels, with intensity values scaled to the range $[0, 1]$. (b) Results of Steps 1 and 2 of the Marr-Hildreth algorithm using $\sigma = 4$ and $n = 25$. (c) Zero crossings of (b) using a threshold of 0 (note the closed-loop edges). (d) Zero crossings found using a threshold equal to 4% of the maximum value of the image in (b). Note the thin edges.

Canny Edge Detector

- Convolution with Gaussian kernel $f_s(i,j) = G(i,j,\sigma) * f(i,j)$
- Compute the gradient $\nabla f_s = \left[\frac{\partial f_s}{\partial x}, \frac{\partial f_s}{\partial y}\right]^t$
- Magnitude and orientation computation $m(i,j) = \sqrt{\left(\frac{\partial f_s}{\partial x}\right)^2 + \left(\frac{\partial f_s}{\partial y}\right)^2}$ $\theta(i,j) = \arctan\left(\frac{\partial f_s}{\partial y} \Big/ \frac{\partial f_s}{\partial x}\right)$
- Partition of angle orientations $\vartheta(i,j) = \mathrm{sector}(\theta(i,j))$

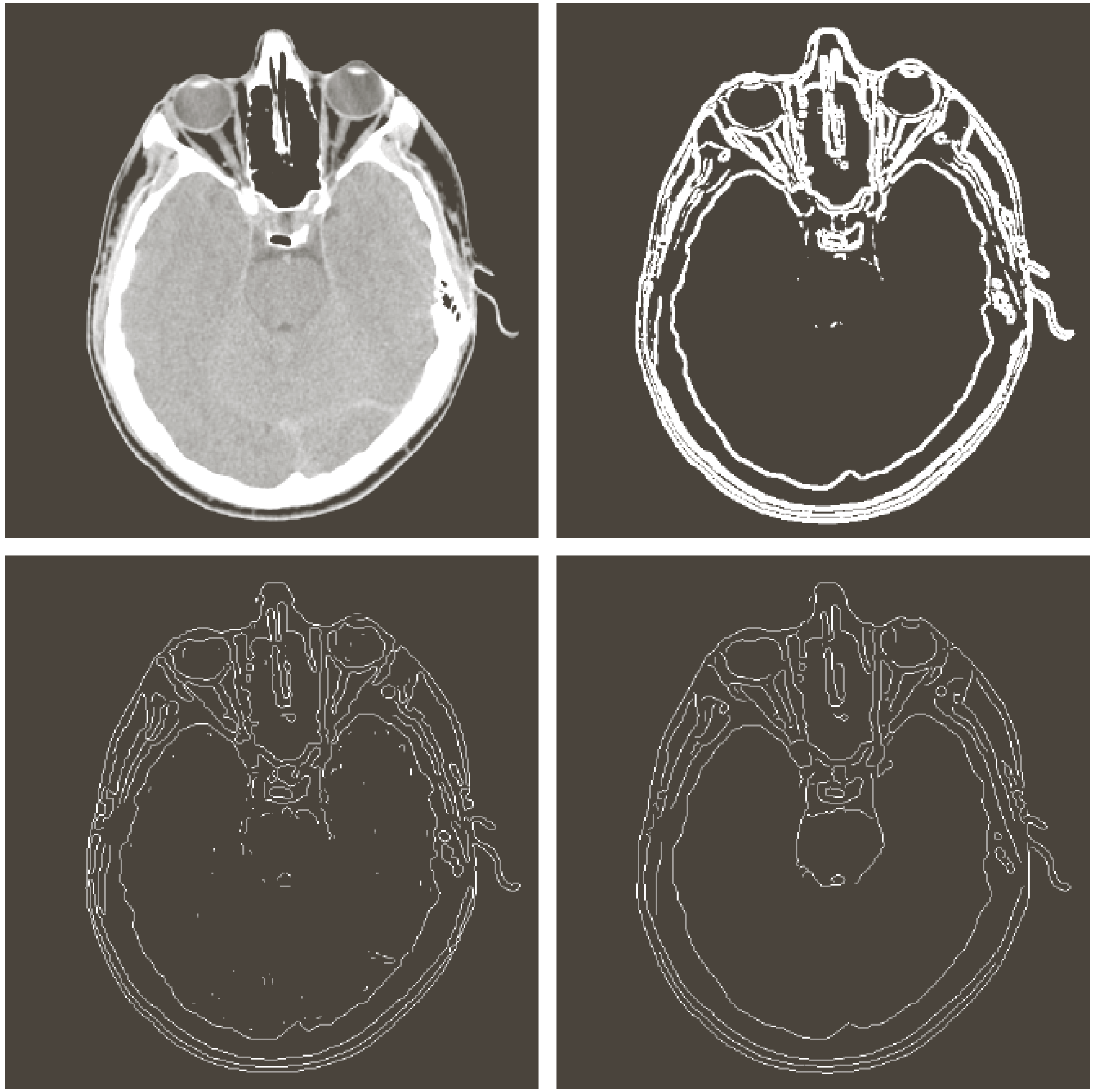


- At each pixel DO:
  - n(i,j) = m(i,j);
  - IF m(i,j) ≤ the neighbors along the gradient sector
  - THEN n(i,j)=0;
- Double Thresholding:
  - Create two thresholded images t1(i,j) and t2(i,j), using two thresholds T1 and T2, with T1 ≈ 0.4 T2.
  - This double threshold method allow to add weaker edges (those above T1) if they are neighbors of stronger edges (those above T2). So the threshold image is formed by t2(i,j) including some of the edges in t1(i,j)

Results

FIGURE 10.25 (a) Original image of size 834×1114 pixels, with intensity values scaled to the range $[0, 1]$. (b) Thresholded gradient of smoothed image. (c) Image obtained using the Marr-Hildreth algorithm. (d) Image obtained using the Canny algorithm. Note the significant improvement of the Canny image compared to the other two.

Results (contd.)



a b
c d

FIGURE 10.26 (a) Original head CT image of size 512 × 512 pixels, with intensity values scaled to the range [0, 1]. (b) Thresholded gradient of smoothed image. (c) Image obtained using the Marr-Hildreth algorithm. (d) Image obtained using the Canny algorithm. (Original image courtesy of Dr. David R. Pickens, Vanderbilt University.)

Edge Linking

- Local processing
- Global processing

(Hough Transform)

$\cdot\ (x,y)$

$(x',y') \in N_{xy}$

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

$|\alpha(x,y) - \alpha(x',y')| < A$

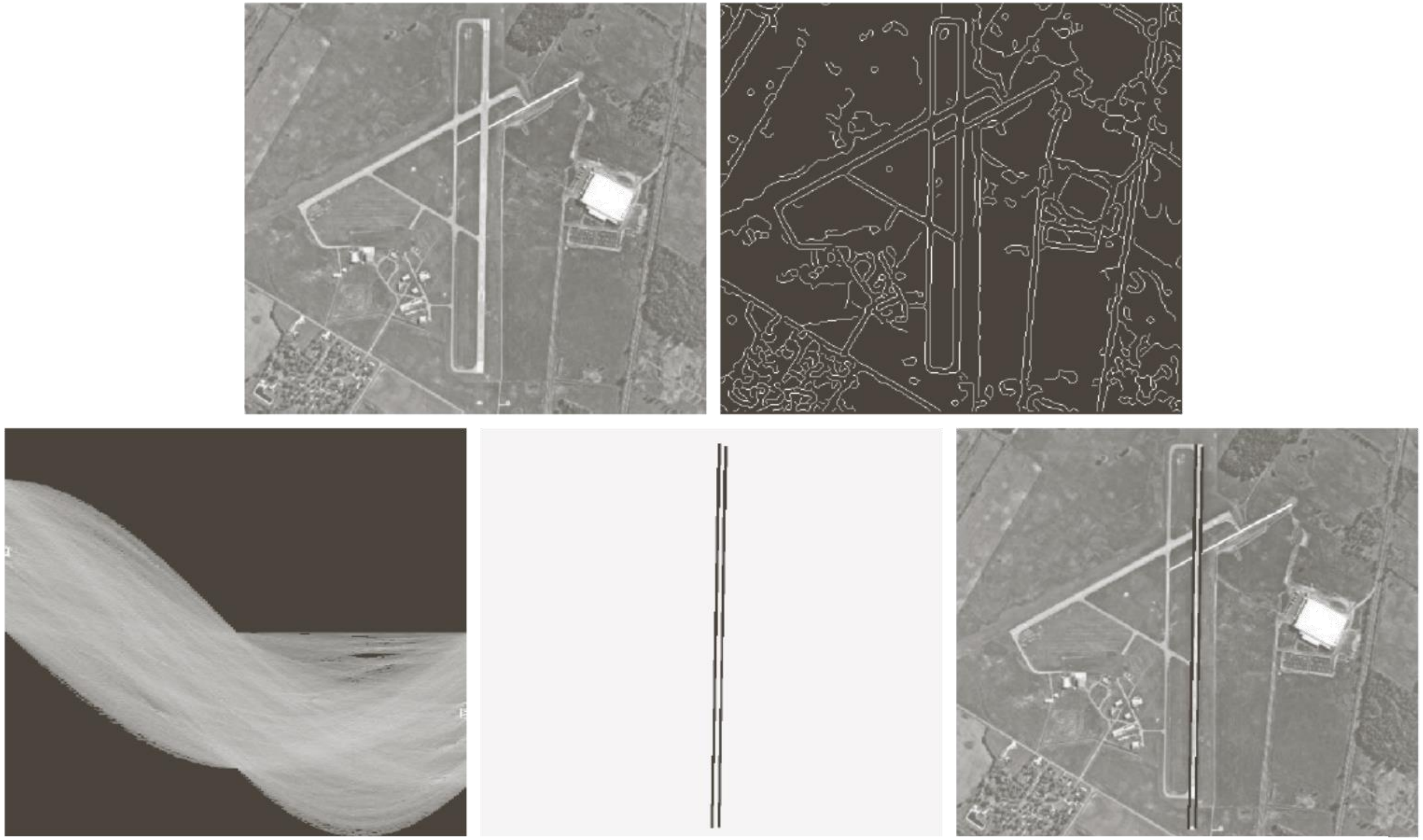
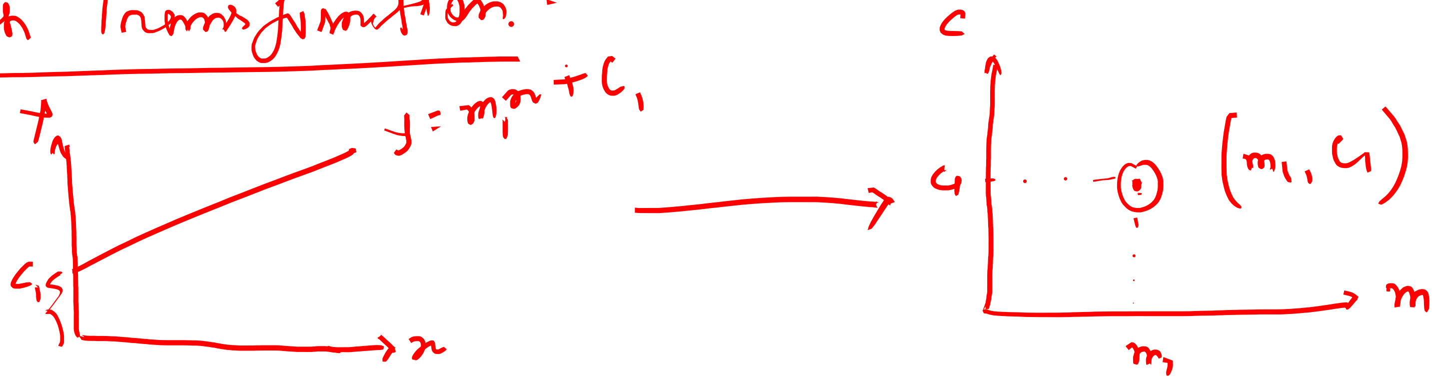
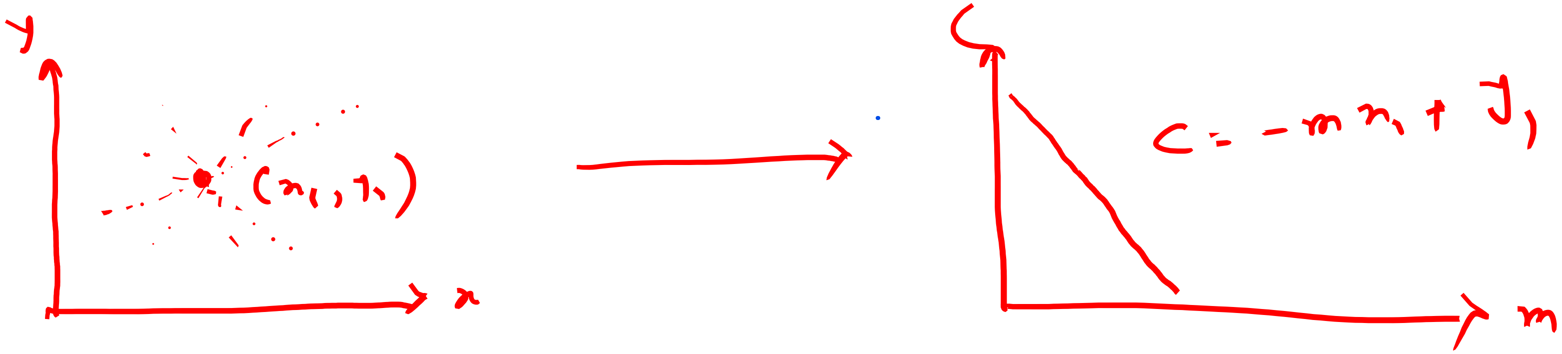


FIGURE 10.34 (a) A 502 × 564 aerial image of an airport. (b) Edge image obtained using Canny's algorithm. (c) Hough parameter space (the boxes highlight the points associated with long vertical lines). (d) Lines in the image plane corresponding to the points highlighted by the boxes). (e) Lines superimposed on the original image.

Hough Transformation:

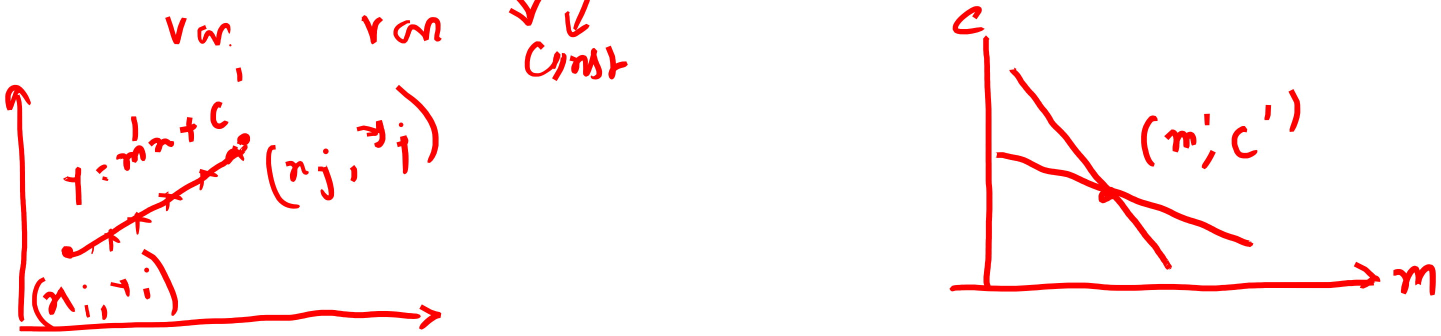


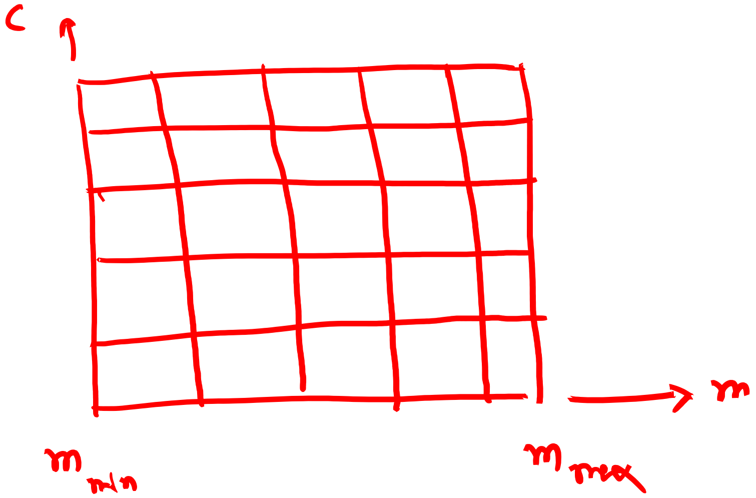


$$y_1 = m x_1 + c$$

$$c = -m x_1 + y_1$$

c → var, m → var, x_1, y_1 → const





$(x_k, y_k) \longrightarrow c = -m x_k + y_k$

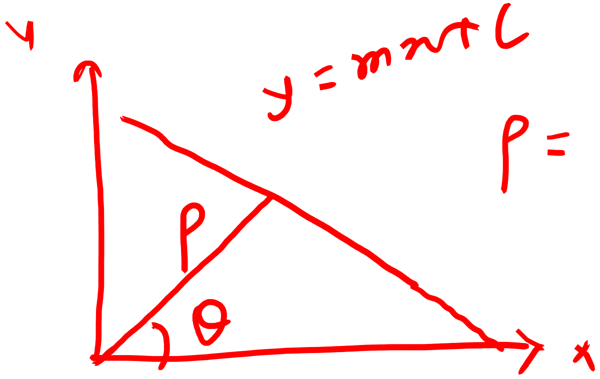
(m, c)

(m_p, c_q) $\quad A(p, q) = A(p, q) + 1$

if $A(i, j) = Q$.

Q no. of points lying on a st. line. $y = m_i x + c_j$

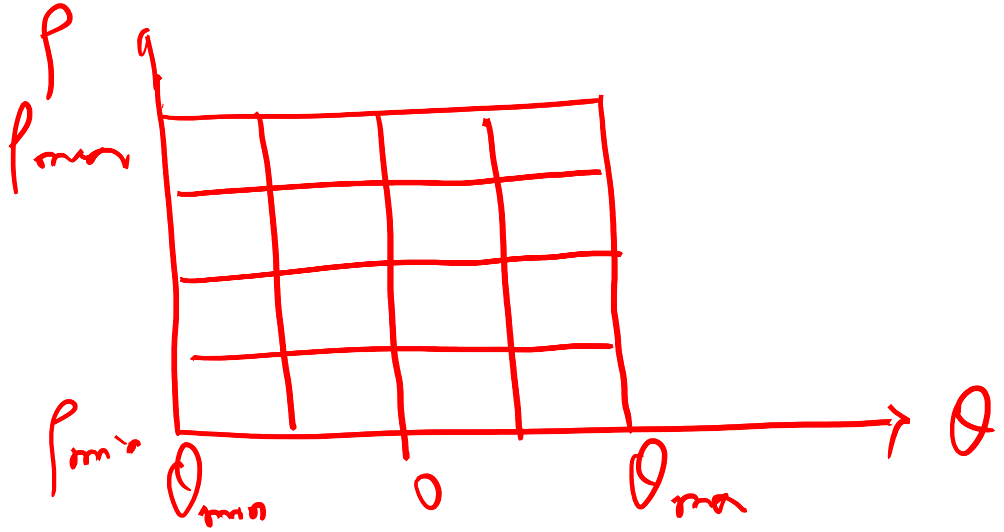
$m = \tan 90° = \text{Inf}$.



$\rho = x \cos\theta + y \sin\theta$ $\quad (\rho, \theta)$

$\rho_{max} = \sqrt{M^2 + N^2}$ $\quad$ [M x N dimensional image].

$\theta_{max} = \pm 90°$

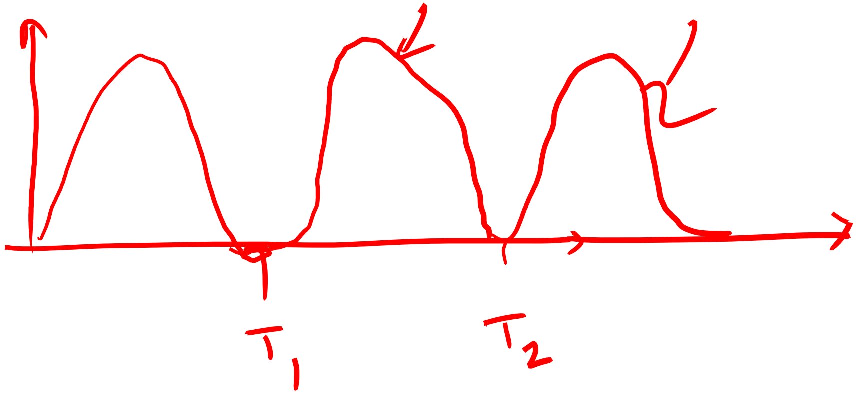


$$A(i,j) = 0$$

$$\rho_j = x\cos\theta_i + y \sin \theta_i$$

Similarity-based Image Segmentation

- Thresholding
  - Global: Single threshold for the entire image
  - Dynamic or adaptive: multiple thresholds for different parts of the image
  - Local: considering local region nearby the object



1. T = arbitrary $\rightarrow G_1, G_2$
2. μ_{G_1} & μ_{G_2}.
3. $T = \frac{\mu_{G_1} + \mu_{G_2}}{2}$.

$|T_k - T_{k+1}| \leq Th$