VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
-Estd. u/s 3 of UGC Act 1956

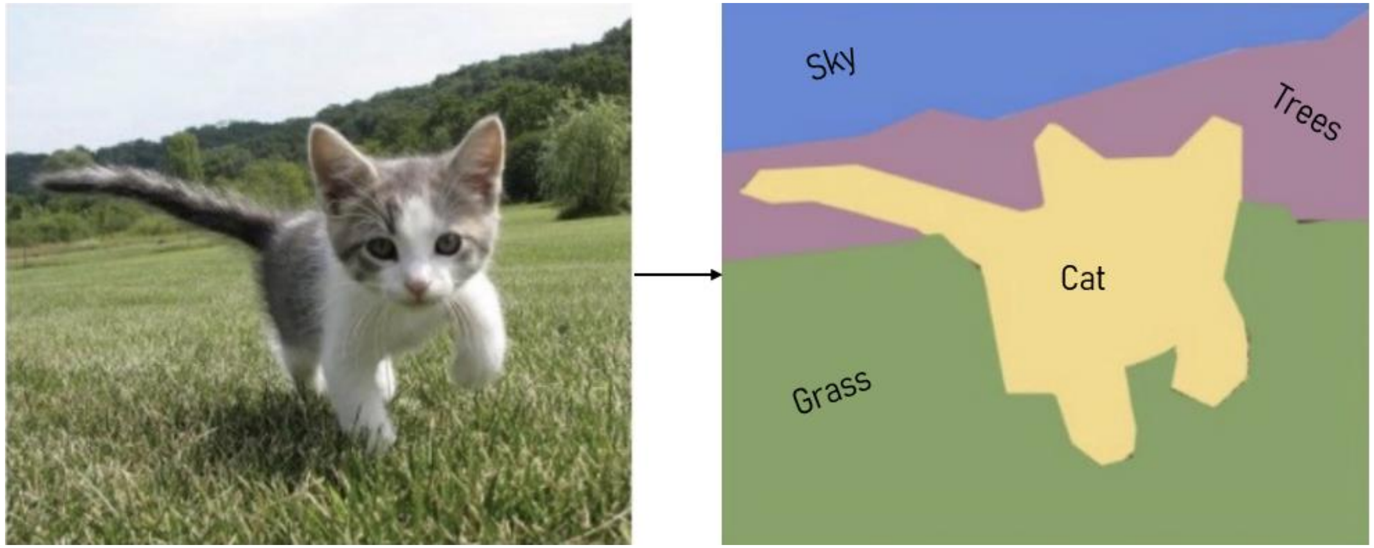
Image Segmentation

Dr. Divya Mishra

Advanced Computer Science and Engineering
School of Computing and Informatics

Email: dm_acse@vignan.ac.in

➢ Fundamentals



- Image segmentation **divides an image into connected regions that share some similarities within each region and some differences in adjacent regions.**
- The **goal is to find individual objects in an image**.
- Two things to consider in segmentation:

1. **Similarity**: Similarity due to pixel intensity, color, or texture.

2. **Differences** are sudden changes (discontinuities) in any of these, but especially sudden changes in intensity along a boundary line called an edge.

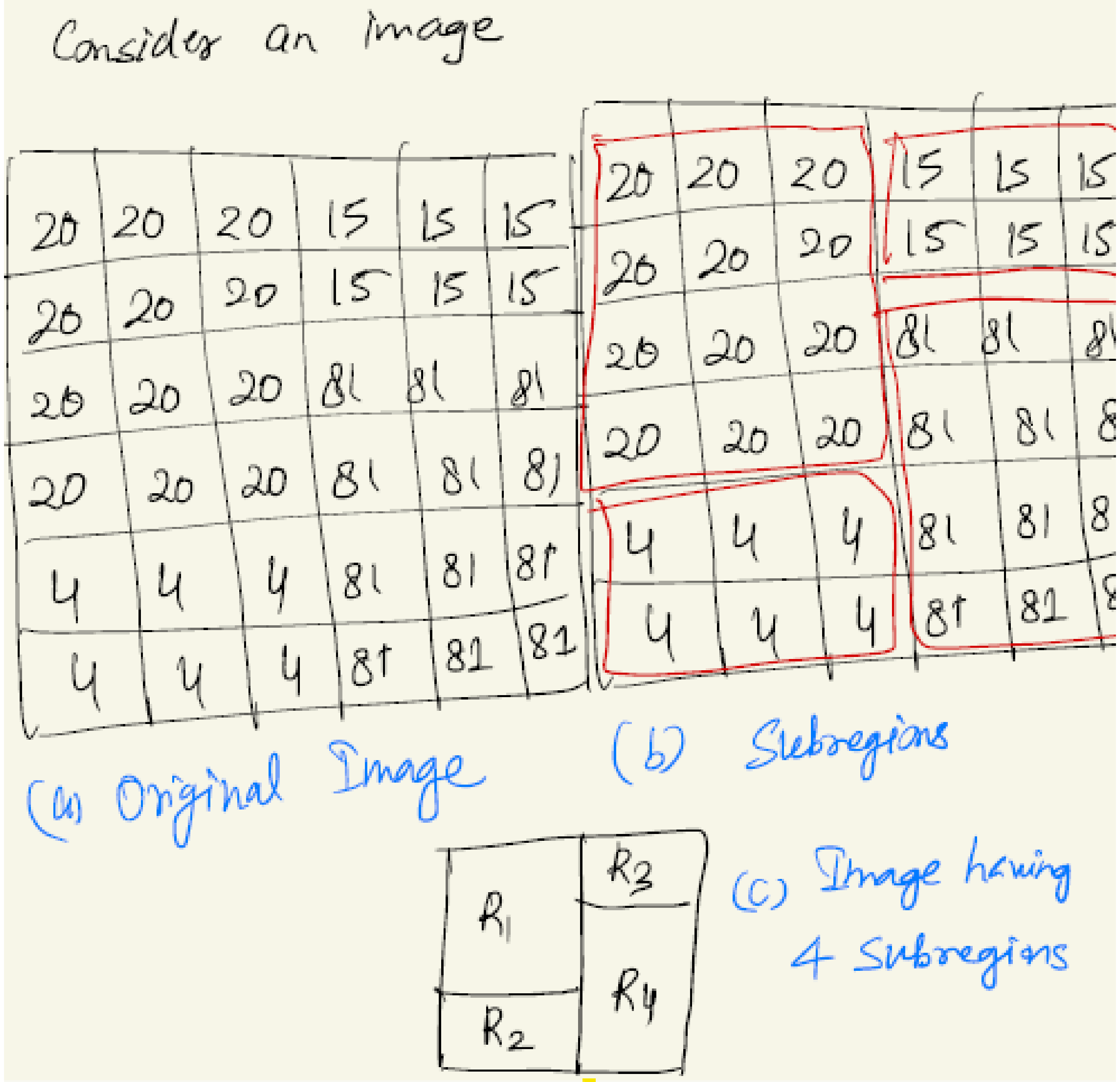
➢ Definition of Segmentation

Let Complete Area of Image $\longrightarrow R$

An image can be partitioned into multiple

Regions $\longrightarrow R_1, R_2, R_3 \text{ - - - - - } R_n$

➤ Definition of Segmentation



➢ Definition of Segmentation

Characterstics of Segmentation

(1) If Subregions are Combined, original region can be obtained.

$$R_1 \cup R_2 \cup R_3 \; \ldots \ldots \; R_n = R$$

or

$$\bigcup R_i = R \quad \text{for } i = 1, 2, 3, \ldots \; n$$

Definition of Segmentation

② Subregions R_i should be Connected. Means a region cannot be open-ended during the tracing process.

③ Regions $R_1, R_2, \ldots R_n$ do not share any common property.

$$R_i \cap R_j \neq \phi \quad \text{for all } i \,\&\, j,$$

where $i \neq j$

➢ Types of Segmentation

- **Semantic segmentation:** Segments out a **broad boundary of objects belonging to a particular class**. For example, tongue image segmentation is a lightweight semantic segmentation that uses binary image processing to separate the tongue from the rest of the image.
- **Instance segmentation:** It provides a **segment map for each object it views in the image** without any idea of the class the object belongs to.
- **Panoptic segmentation:** This technique **combines instance and semantic segmentation** tasks to provide segment maps of all the objects of any particular class in the image.

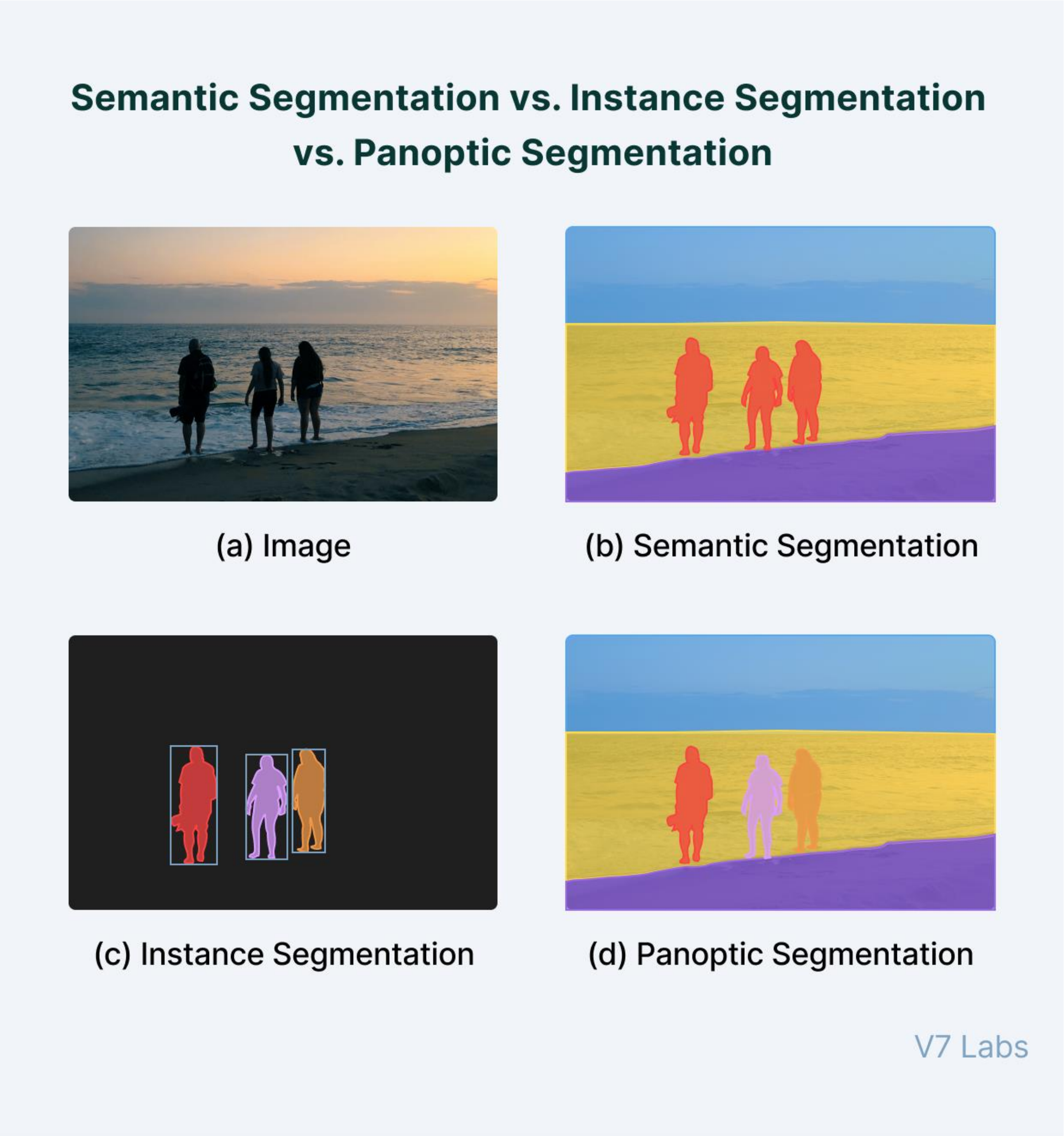


Image source: https://www.v7labs.com/blog/image-segmentation-guide

➢ Point, Line and Edge Detection

- There are three kinds of discontinuities in intensity:
- 1. Point
- 2. Line and
- 3. Edges

- The most common way to look for discontinuities is to **scan a small mask over the image**. The mask determines which kind of discontinuity to look for.

➢ Point detection

$$R = w_1 z_1 + w_2 z_2 + \ldots + w_9 z_9 = \sum_{i=1}^{9} w_i z_i$$

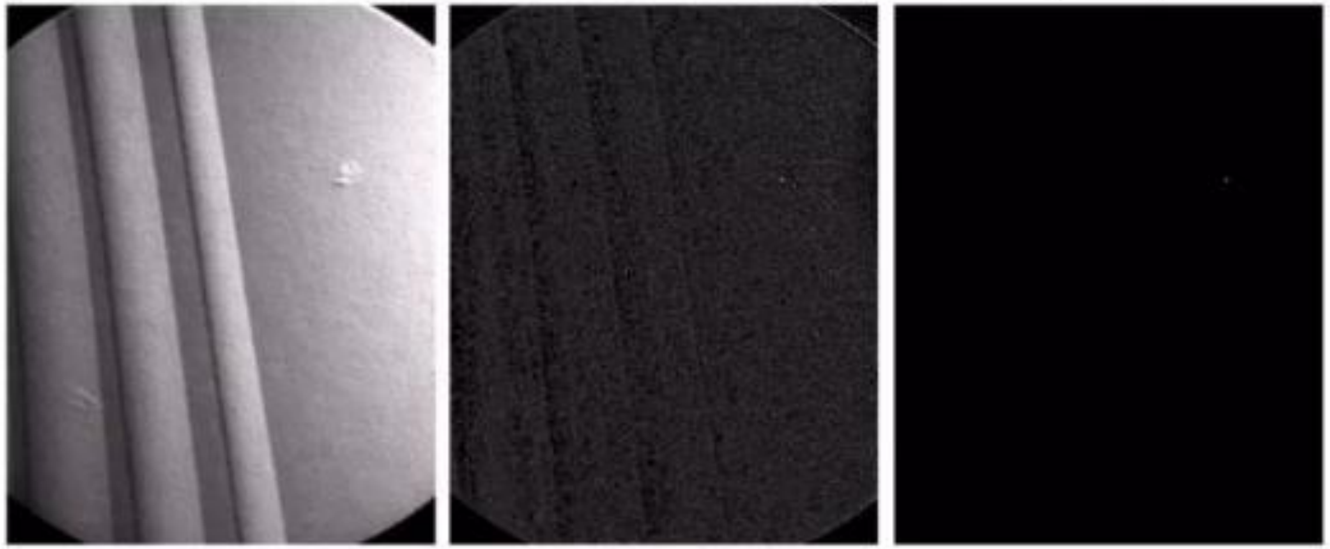
w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

$$|R| \geq T$$

where T : a nonnegative threshold

Point Mask

−1	−1	−1
−1	8	−1
−1	−1	−1



a
b c d

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.)

➢ Line detection

- For digital images, there are only three-point straight lines that are **horizontal, vertical, or diagonal (+ 0 or (+,– 45) degrees)**

−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°

Line Mask

Edge detection

- First-order derivatives:
  - The gradient of an image $f(x,y)$ at location (x,y) is defined as the vector:

$$\nabla \mathbf{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

  - The magnitude of this vector: $\nabla f = \text{mag}(\nabla \mathbf{f}) = \left[G_x^2 + G_y^2\right]^{1/2}$
  - The direction of this vector: $\alpha(x, y) = \tan^{-1}\left(\frac{G_y}{G_x}\right)$

➢ Gradient Operators (Edge detection)

Roberts cross-gradient operators ➡

−1	0
0	1

0	−1
1	0

Roberts

Prewitt operators ➡

−1	−1	−1
0	0	0
1	1	1

−1	0	1
−1	0	1
−1	0	1

Prewitt

Sobel operators ➡

−1	−2	−1
0	0	0
1	2	1

−1	0	1
−2	0	2
−1	0	1

Sobel

➢ Gradient Operators (Edge detection)

Prewitt masks for detecting diagonal edges

0	1	1
−1	0	1
−1	−1	0

−1	−1	0
−1	0	1
0	1	1

Prewitt

Sobel masks for detecting diagonal edges

0	1	2
−1	0	1
−2	−1	0

−2	−1	0
−1	0	1
0	1	2

Sobel

a	b
c	d

➢ Detection of Discontinuities: Gradient Operators: Example of Edge detection

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, $|G_x| + |G_y|$.

$$\nabla f \approx |G_x| + |G_y|$$

➢ Detection of Discontinuities:

- Second-order derivatives: (The Laplacian)
  - The Laplacian of an 2D function $f(x,y)$ is defined as

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

  - Two forms in practice:

FIGURE 10.13
Laplacian masks used to implement Eqs. (10.1-14) and (10.1-15), respectively.

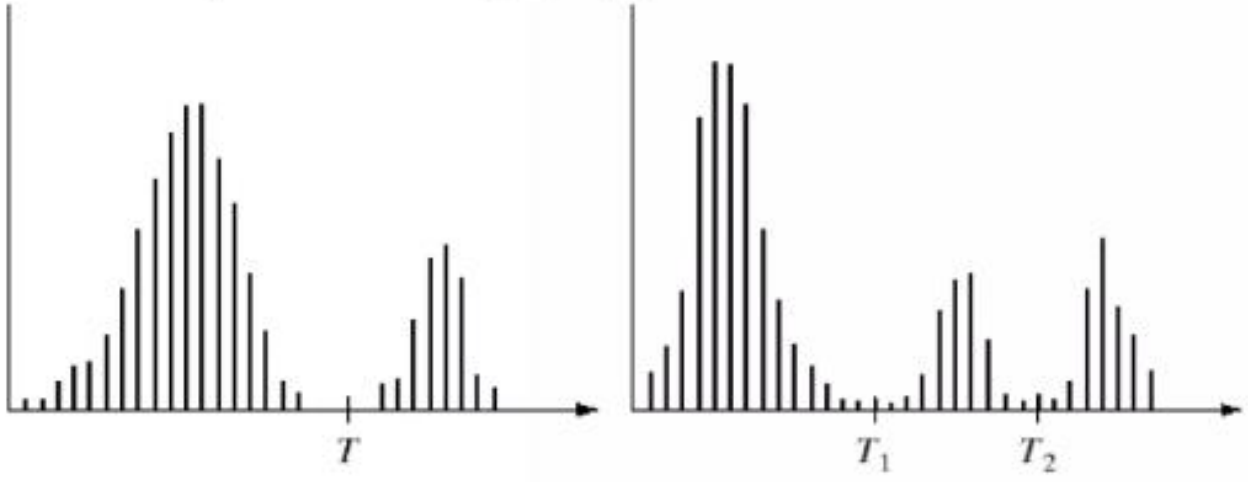
0	−1	0
−1	4	−1
0	−1	0

−1	−1	−1
−1	8	−1
−1	−1	−1

➢ Thresholding

- Assumption: the range of intensity levels covered by objects of interest is different from the background.

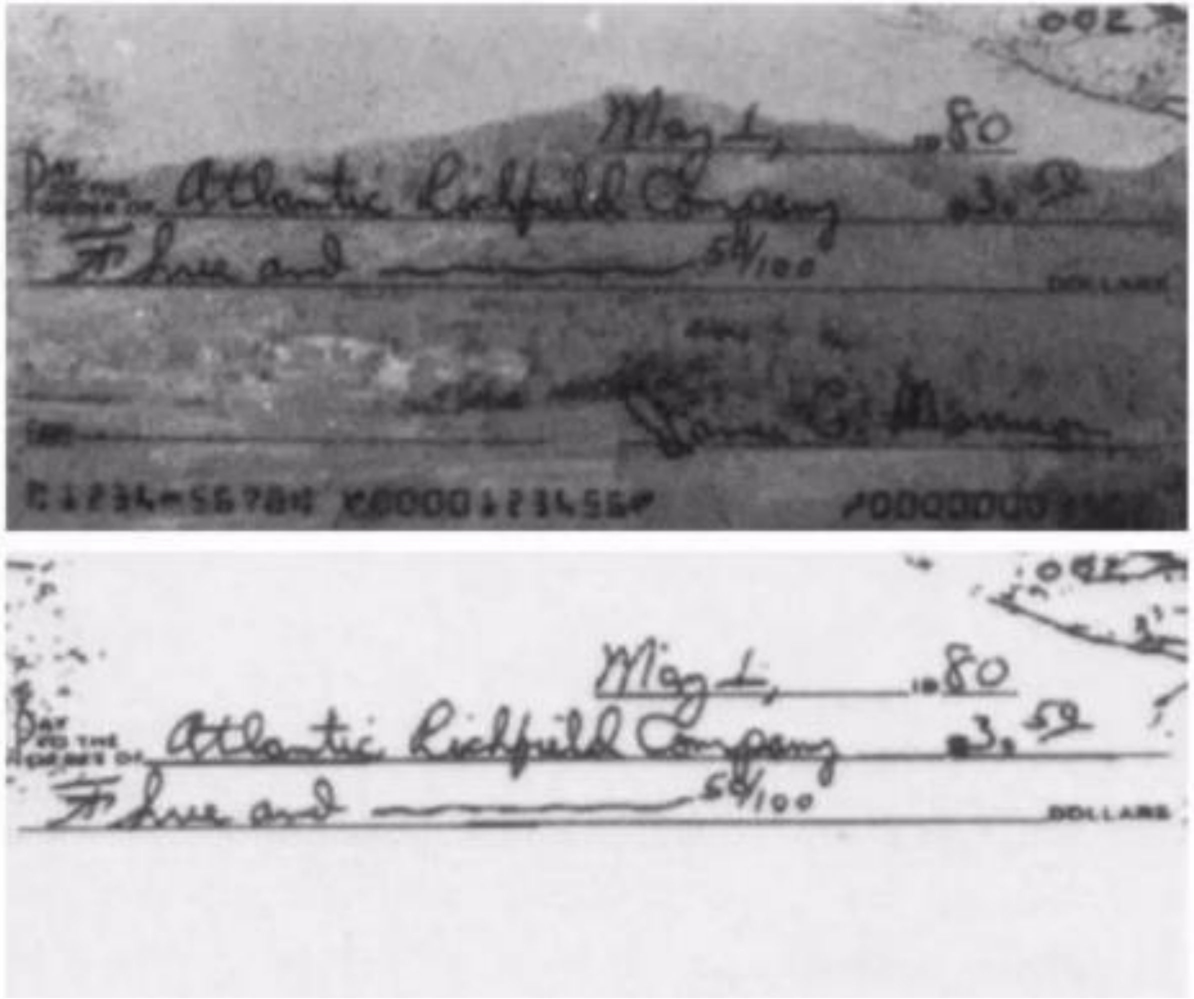
$$g(x,y)=\begin{cases}1 & \text{if } f(x,y)>T\\ 0 & \text{if } f(x,y)\le T\end{cases}$$



a b Single threshold Multiple threshold

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

➢ Application of Thresholding



a
b

FIGURE 10.37 (a) Original image. (b) Image segmented by local thresholding. (Courtesy of IBM Corporation.)

Region-based Segmentation: Basic formulation Summary

- Let R represent the entire image region.
- Segmentation is a process that partitions R into subregions, $R_1, R_2, \ldots, R_n$, such that

(a) $\bigcup_{i=1}^{n} R_i = R$

(b) R_i is a connected region, $i = 1, 2, \ldots, n$

(c) $R_i \cap R_j = \phi$ for all i and $j, i \neq j$

(d) $P(R_i) = \text{TRUE}$ for $i = 1, 2, \ldots, n$

(e) $P(R_i \cup R_j) = \text{FALSE}$ for any adjacent regions R_i and R_j

where $P(R_k)$: a logical predicate defined over the points in set R_k

For example: $P(R_k)$=TRUE if all pixels in R_k have the same gray level.

Thank You