Image Processing and Visual Communications

Image Segmentation

Zhou Wang

Dept. of Electrical and Computer Engineering
University of Waterloo

Concepts and Approaches

- **What is Image Segmentation?**

  Partition an image into regions, each associated with an object

  but what defines an object?



From Prof. Xin Li

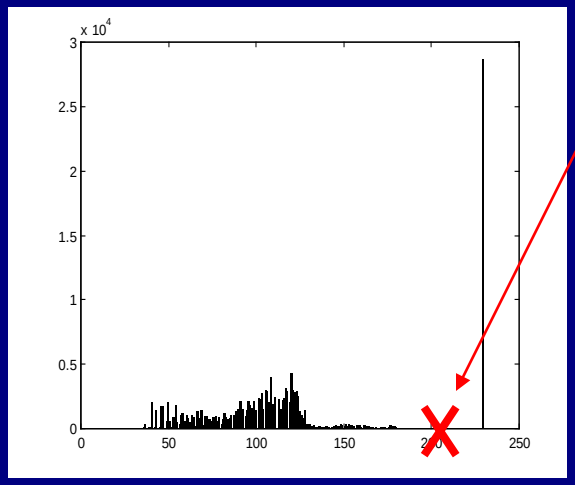
- **Image Segmentation Methods**
  - Thresholding
  - Boundary-based
  - Region-based: region growing, splitting and merging

Thresholding Method

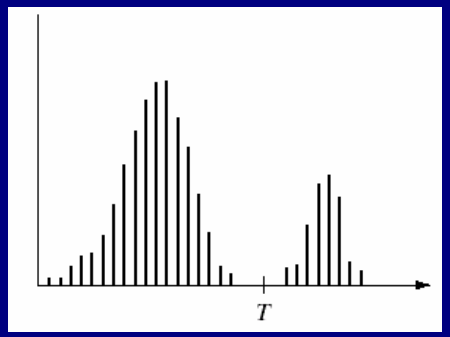
thresholding

From Prof. Xin Li

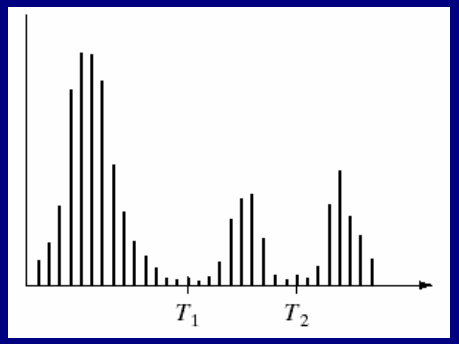
histogram



single threshold



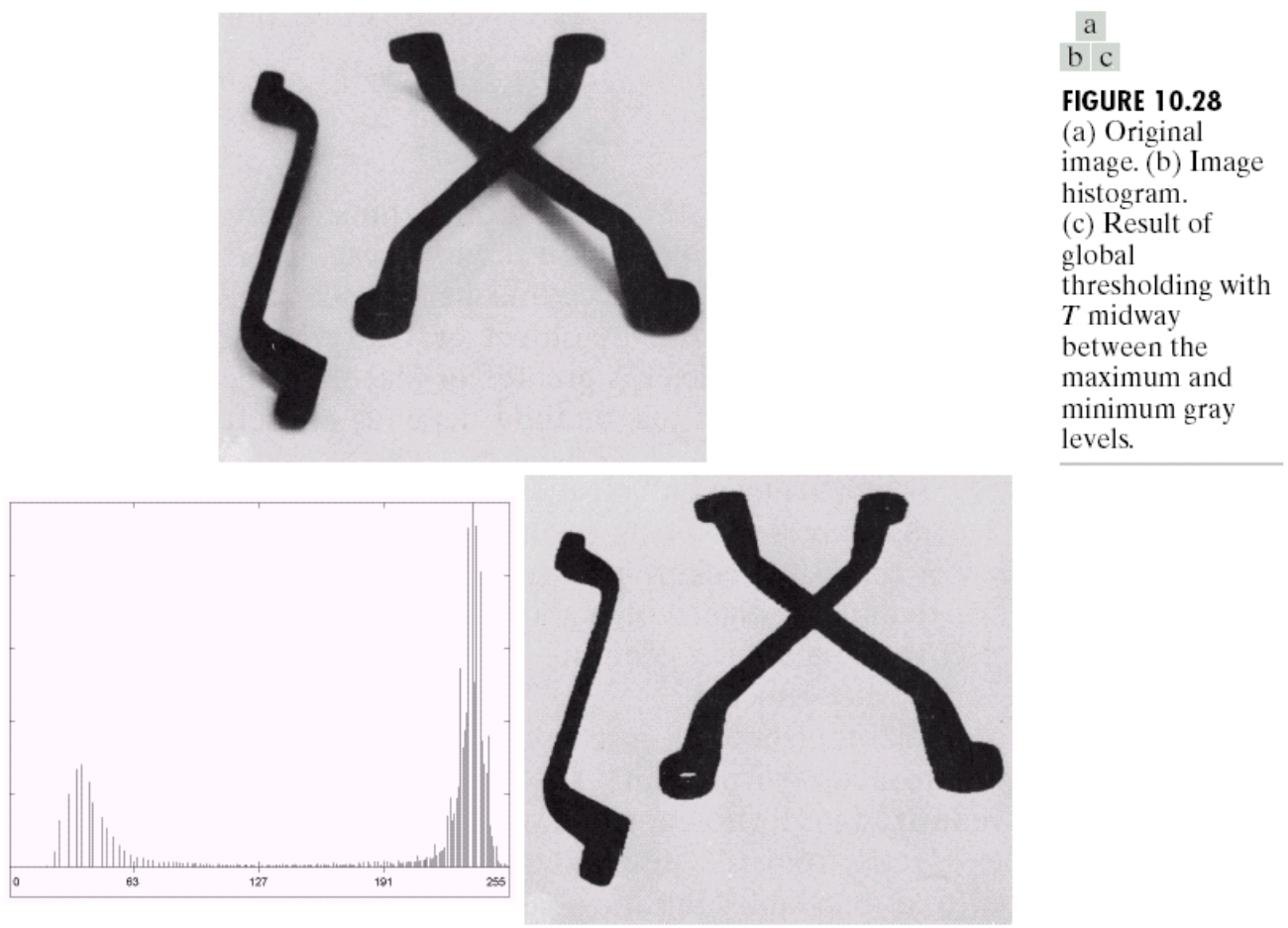
multiple thresholds



From [Gonzalez & Woods]

Thresholding Method

- Global Thresholding: When does It Work?



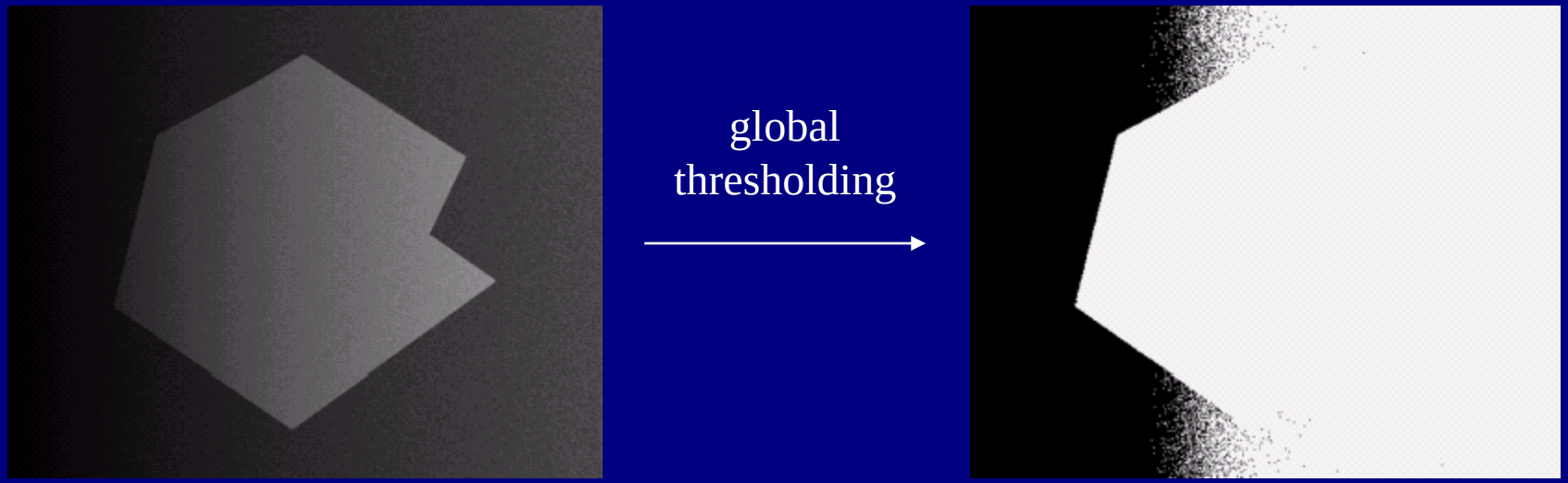
a
b c

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

From [Gonzalez & Woods]

Thresholding Method

- **Global Thresholding: When does It NOT Work?**
  - A meaningful global threshold may not exist
  - Image-dependent



From [Gonzalez & Woods]

Thresholding Method

true object boundary

1	1	2	2	3	3	4	4	5	5
1	1	2	2	8	3	4	4	5	5
1	1	2	7	8	9	4	4	5	5
1	1	6	7	8	9	10	4	5	5
1	5	6	7	8	9	10	11	5	5
1	5	6	7	8	9	10	11	5	5
1	5	6	7	3	9	10	11	5	5
1	5	6	2	3	3	10	11	5	5
1	5	2	2	3	3	4	11	5	5
1	1	2	2	3	3	4	4	5	5

Thresholding
$T = 4.5$

0	0	0	0	0	0	0	0	1	1
0	0	0	0	1	0	0	0	1	1
0	0	0	1	1	1	0	0	1	1
0	0	1	1	1	1	1	0	1	1
0	1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	1	1
0	1	1	1	0	1	1	1	1	1
0	1	1	0	0	0	1	1	1	1
0	1	0	0	0	0	0	1	1	1
0	0	0	0	0	0	0	0	1	1

Thresholding
$T = 5.5$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	1	1	1	1	1	0	0	0
0	0	1	1	1	1	1	1	0	0
0	0	1	1	1	1	1	1	0	0
0	0	1	1	0	1	1	1	0	0
0	0	1	0	0	0	1	1	0	0
0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0

Thresholding Method

- **Solution**
  - Spatially adaptive thresholding
  - Localized processing

1	1	2	2	3	3	4	4	5	5
1	1	2	2	8	3	4	4	5	5
1	1	2	7	8	9	4	4	5	5
1	1	6	7	8	9	10	4	5	5
1	5	6	7	8	9	10	11	5	5
1	5	6	7	8	9	10	11	5	5
1	5	6	7	3	9	10	11	5	5
1	5	6	2	3	3	10	11	5	5
1	5	2	2	3	3	4	11	5	5
1	1	2	2	3	3	4	4	5	5

Split

1	1	2	2	3
1	1	2	2	8
1	1	2	7	8
1	1	6	7	8
1	5	6	7	8

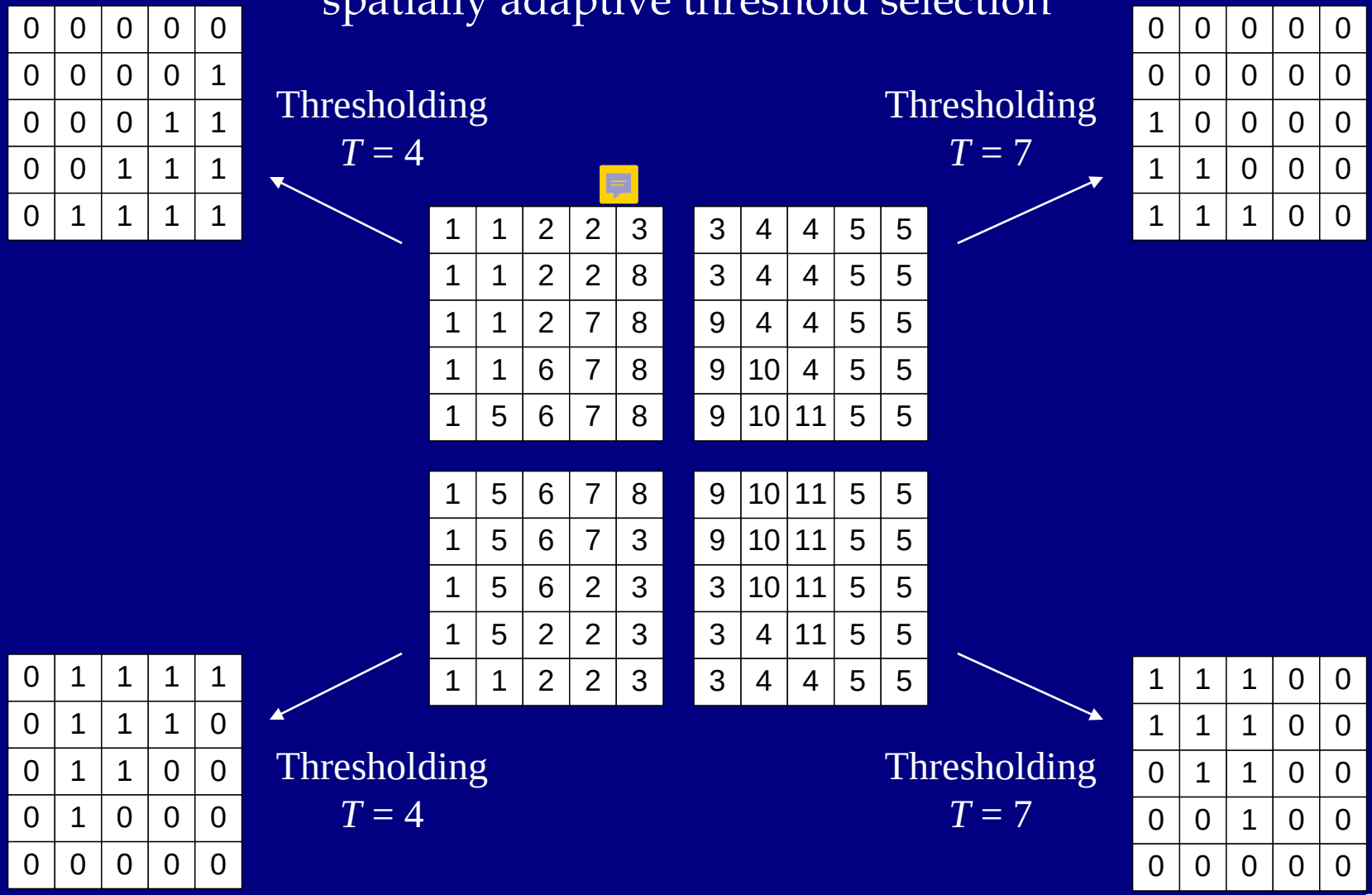
3	4	4	5	5
3	4	4	5	5
9	4	4	5	5
9	10	4	5	5
9	10	11	5	5

1	5	6	7	8
1	5	6	7	3
1	5	6	2	3
1	5	2	2	3
1	1	2	2	3

9	10	11	5	5
9	10	11	5	5
3	10	11	5	5
3	4	11	5	5
3	4	4	5	5

Thresholding Method

spatially adaptive threshold selection



0	0	0	0	0
0	0	0	0	1
0	0	0	1	1
0	0	1	1	1
0	1	1	1	1

1	1	2	2	3
1	1	2	2	8
1	1	2	7	8
1	1	6	7	8
1	5	6	7	8

3	4	4	5	5
3	4	4	5	5
9	4	4	5	5
9	10	4	5	5
9	10	11	5	5

1	5	6	7	8
1	5	6	7	3
1	5	6	2	3
1	5	2	2	3
1	1	2	2	3

9	10	11	5	5
9	10	11	5	5
3	10	11	5	5
3	4	11	5	5
3	4	4	5	5

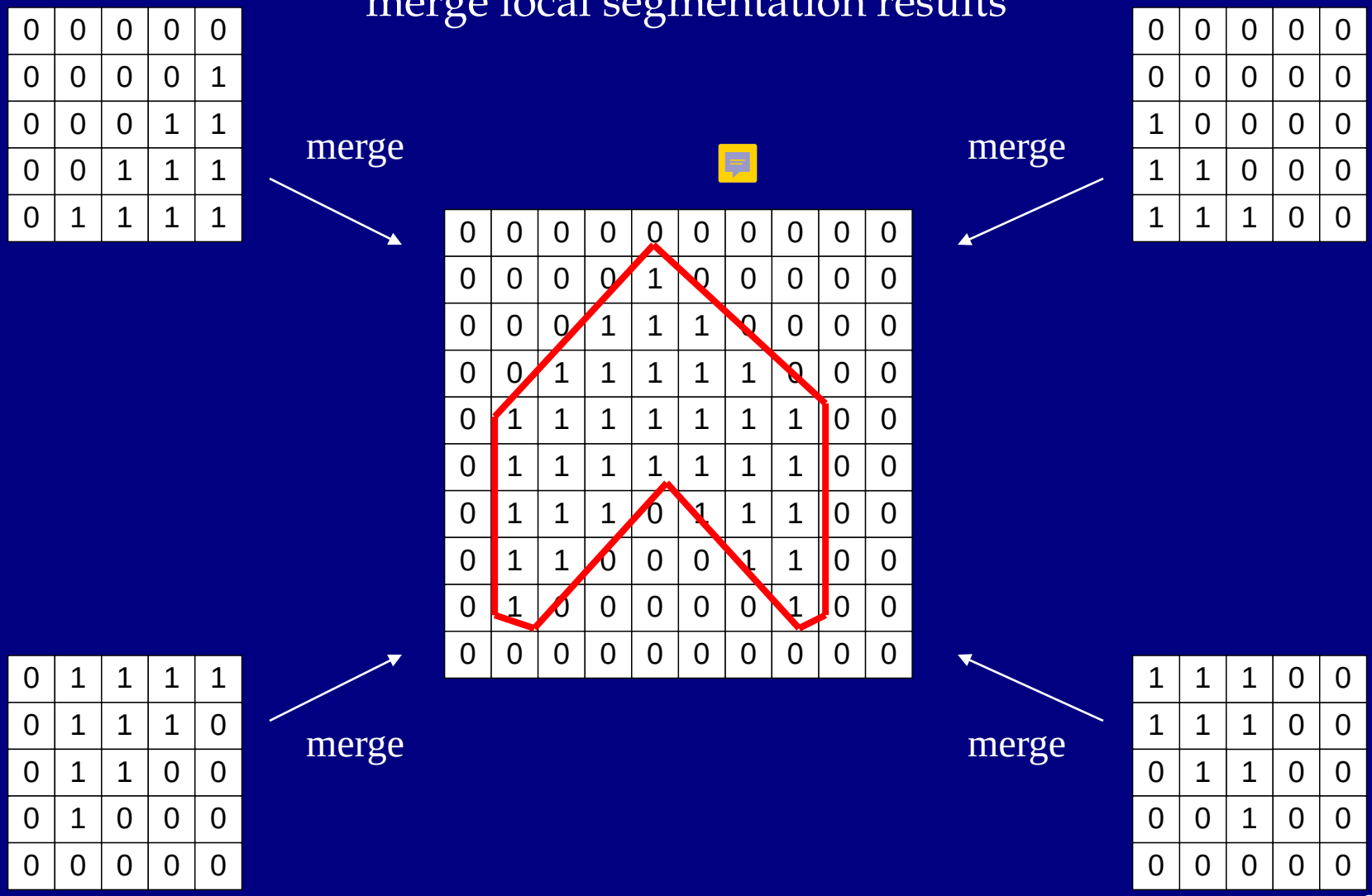
0	0	0	0	0
0	0	0	0	0
1	0	0	0	0
1	1	0	0	0
1	1	1	0	0

0	1	1	1	1
0	1	1	1	0
0	1	1	0	0
0	1	0	0	0
0	0	0	0	0

1	1	1	0	0
1	1	1	0	0
0	1	1	0	0
0	0	1	0	0
0	0	0	0	0

Thresholding Method

merge local segmentation results



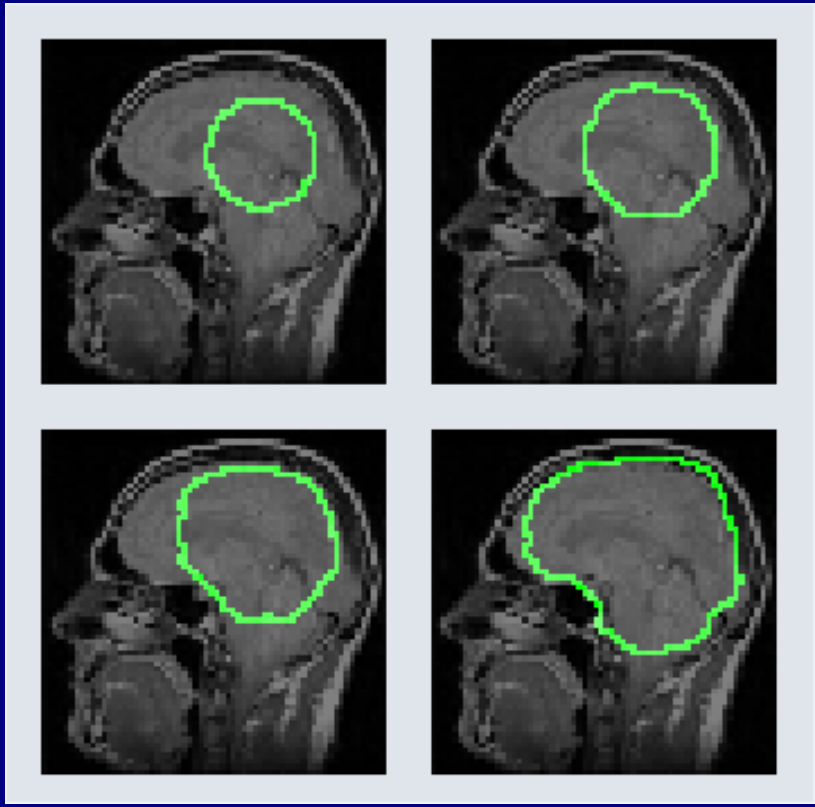
Boundary-Based Method

image → edge detection → boundary detection → classification and labeling → segmentation

From Prof. Xin Li

Boundary-Based Method

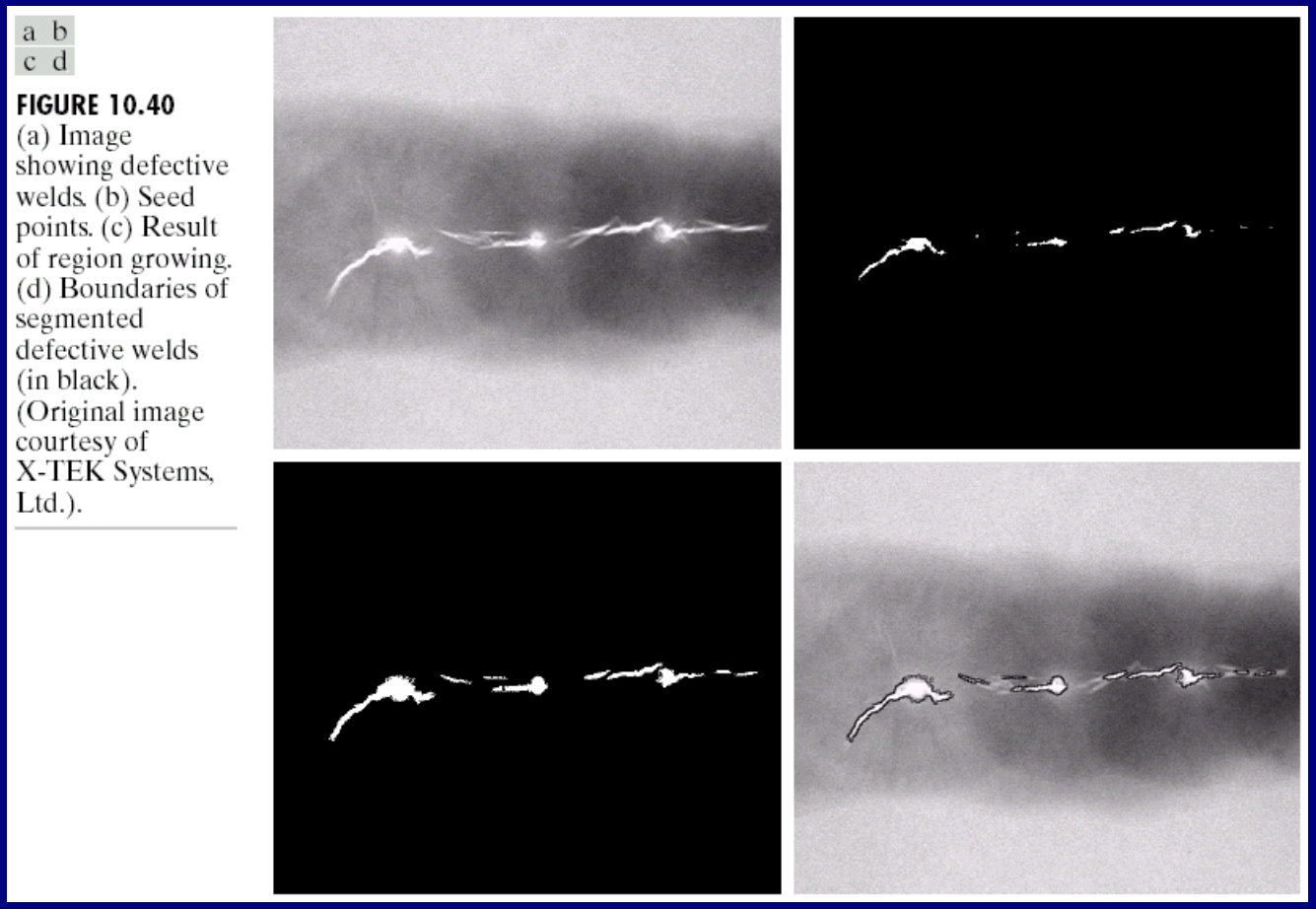
- **Advanced Method: Active Contour (Snake) Model**
  - Iteratively update contour (region boundary)
  - Partial differential equation (PDE) based optimization



From Prof. Xin Li

Region-Based Method: Region Growing

- **Region Growing**
  - Start from a seed, and let it grow (include similar neighborhood)



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.).

Key: similarity measure

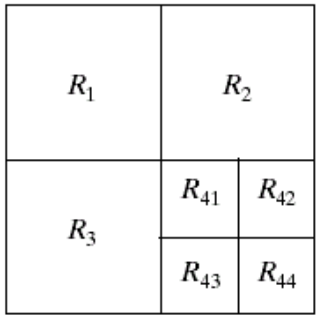
From [Gonzalez & Woods]

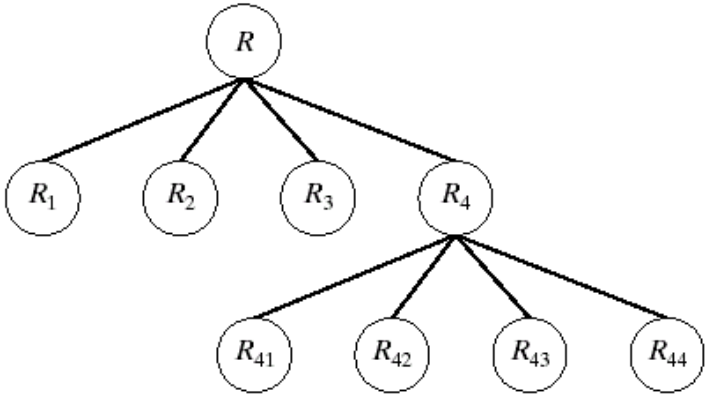
Region-Based Method: Split and Merge

- **Split and Merge**
  - Iteratively split (non-similar region) and merge (similar regions)
  - Example: quadtree approach

a b

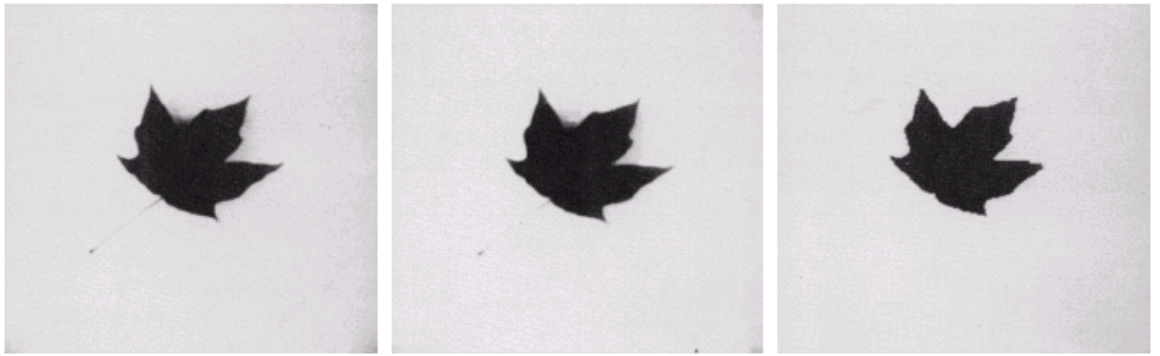
FIGURE 10.42
(a) Partitioned image.
(b) Corresponding quadtree.





a b c

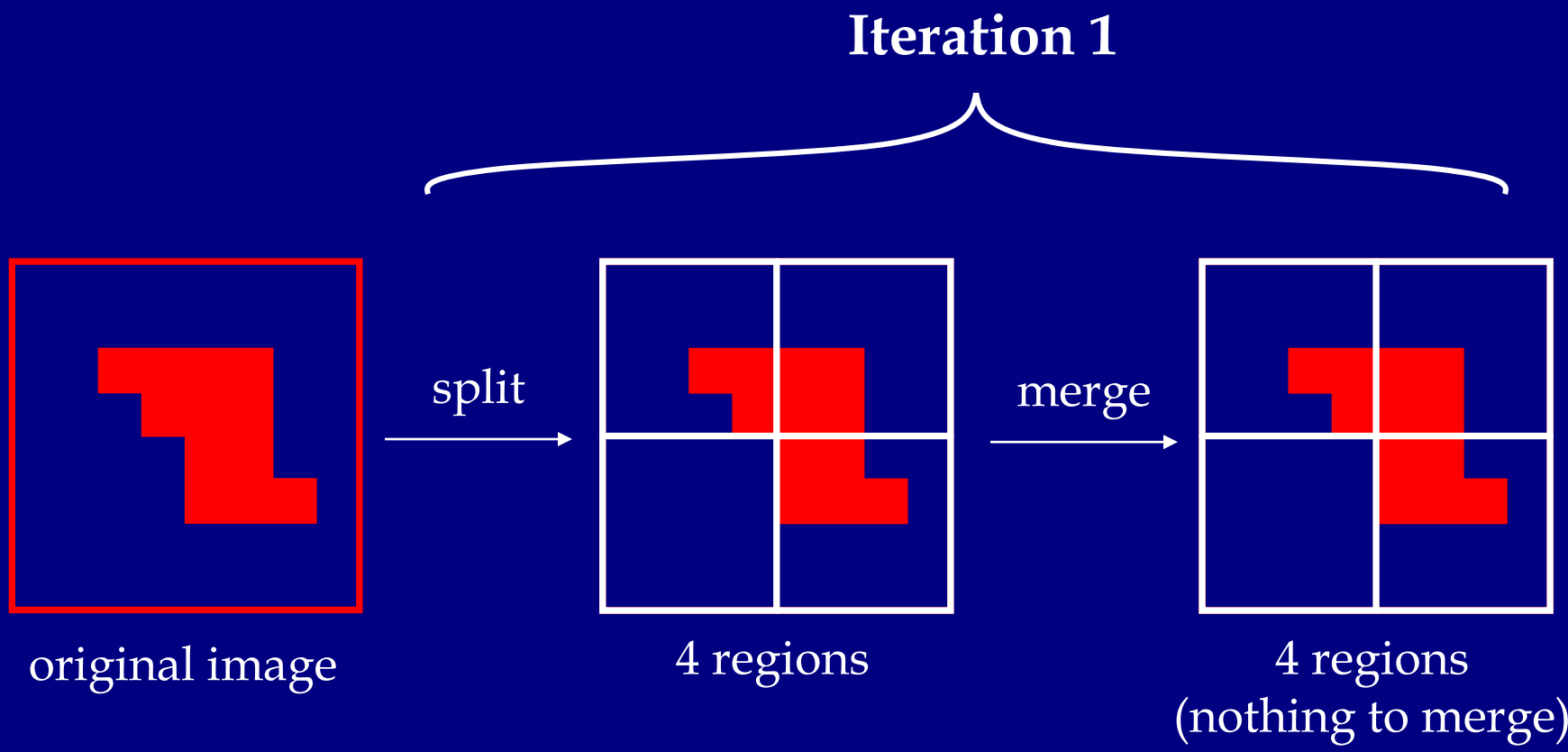
FIGURE 10.43
(a) Original image. (b) Result of split and merge procedure.
(c) Result of thresholding (a).



From [Gonzalez & Woods]

Region-Based Method: Split and Merge

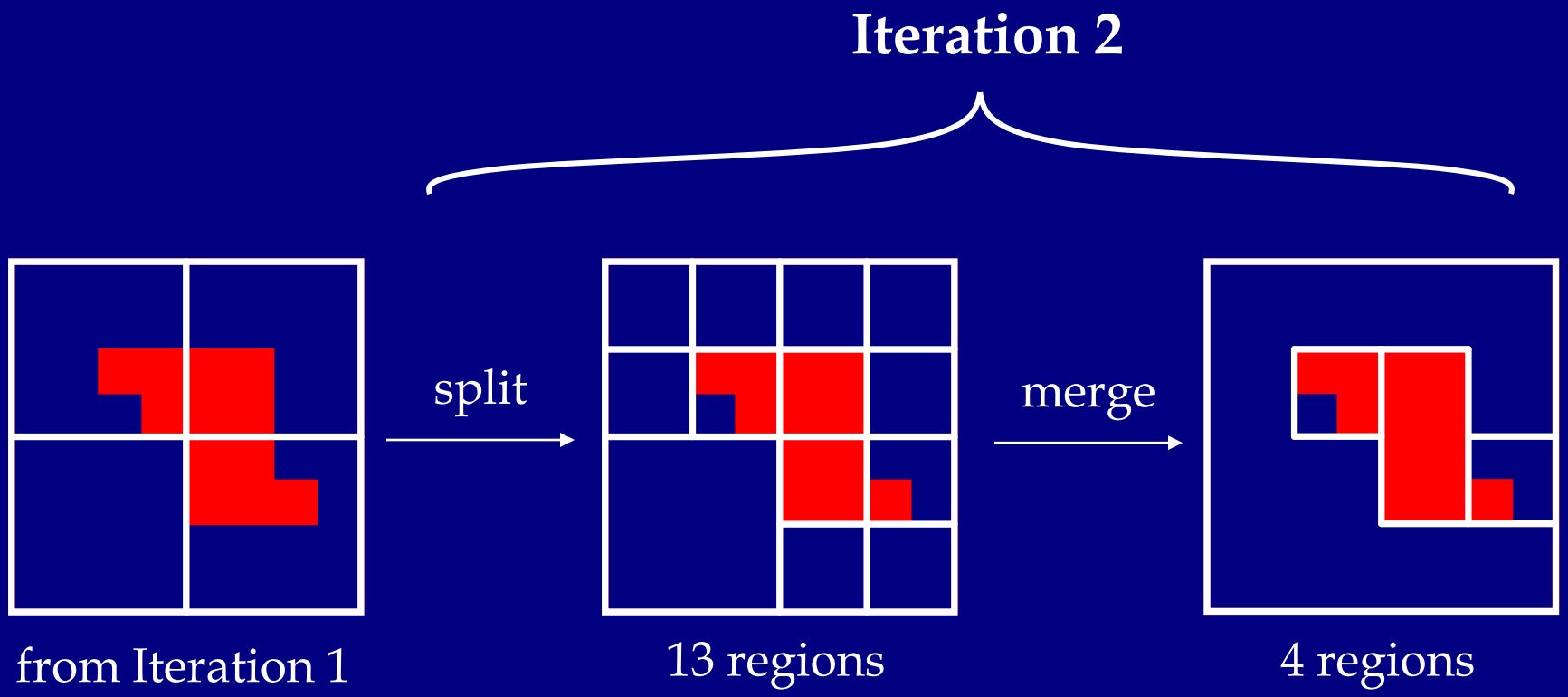
- **Example: Quadtree Split and Merge Procedure**



Split Step → split every non-uniform region to 4
Merge Step → merge all uniform adjacent regions

Region-Based Method: Split and Merge

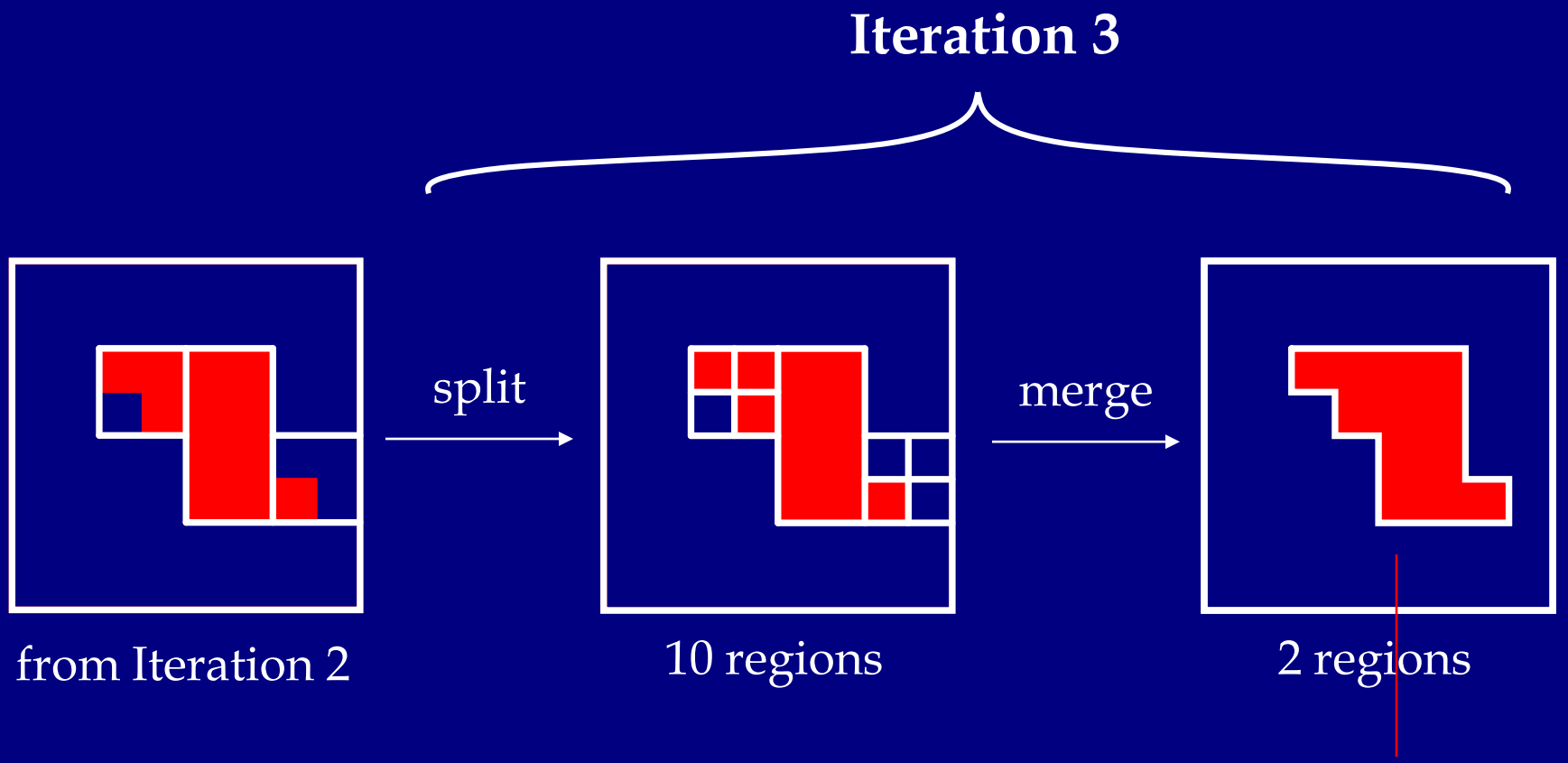
- **Example: Quadtree Split and Merge Procedure**



Split Step → split every non-uniform region to 4
Merge Step → merge all uniform adjacent regions

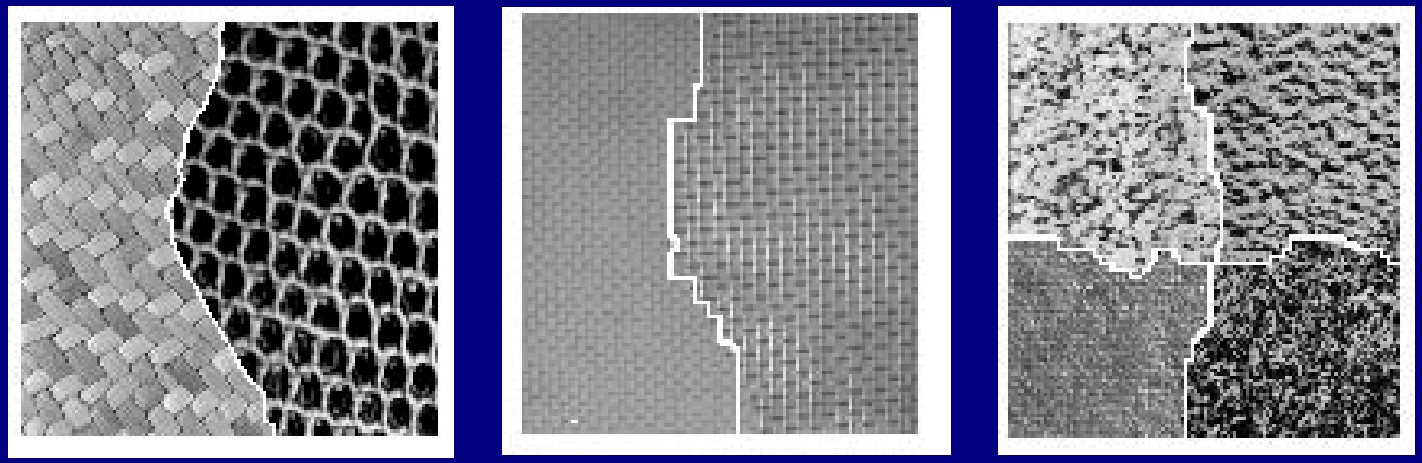
Region-Based Method: Split and Merge

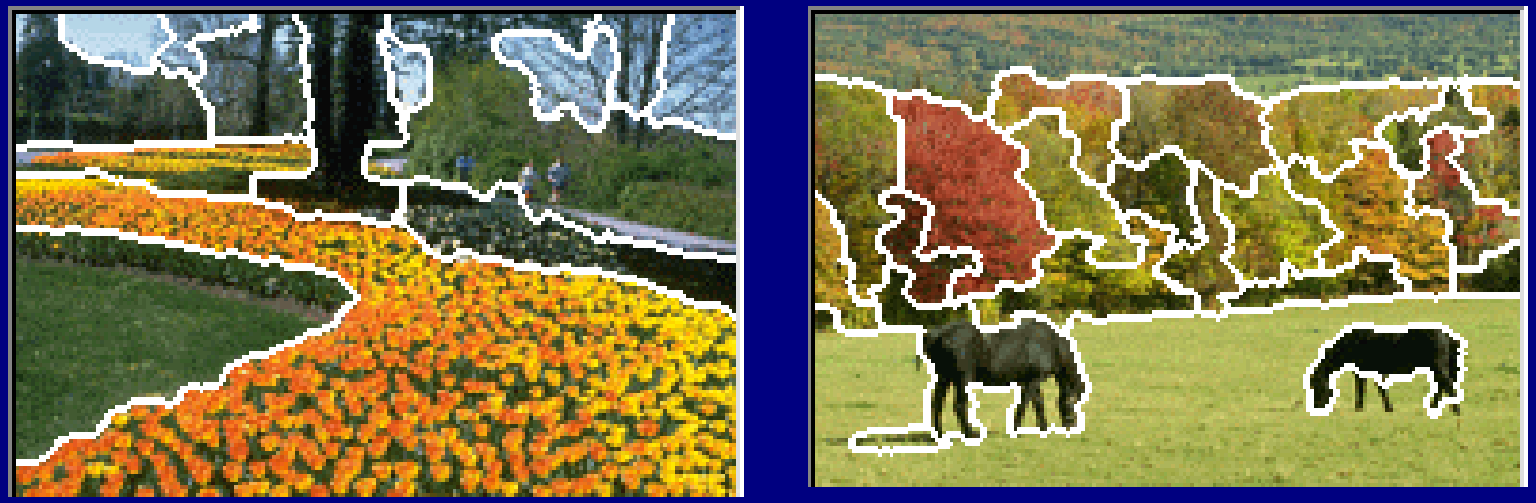
- **Example: Quadtree Split and Merge Procedure**



Split Step → split every non-uniform region to 4
Merge Step → merge all uniform adjacent regions

Hard Problem: Textures

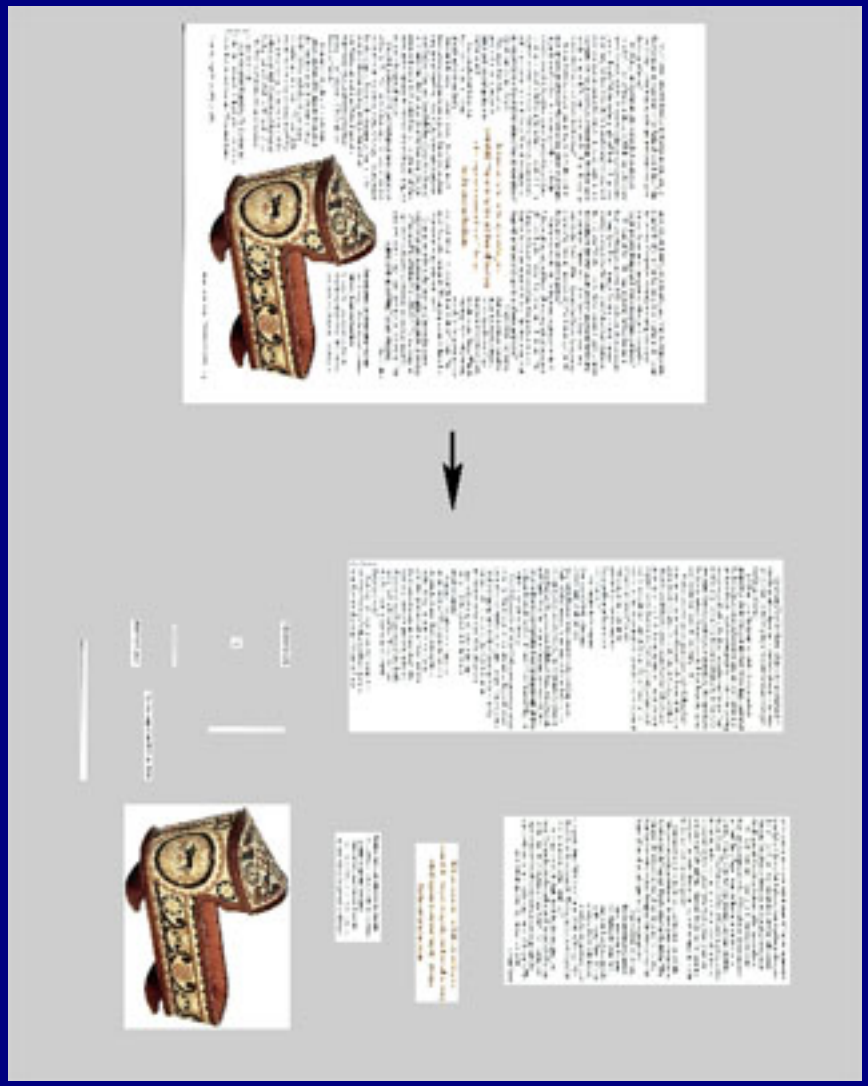


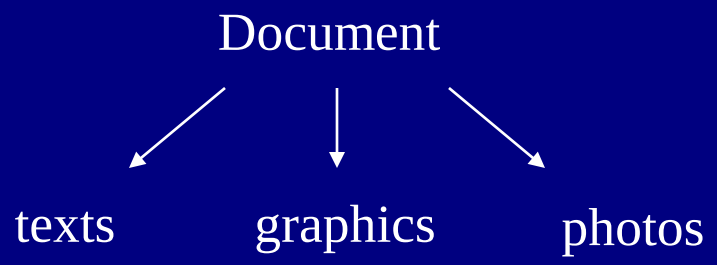


Similarity measure makes the difference

From Prof. Xin Li

Image Segmentation: Documents





- **Applications:**
  - compression
  - recognition
  - classification
  - retrieval