

# VC 15/16 – TP9

## Region-Based Segmentation

Mestrado em Ciência de Computadores  
Mestrado Integrado em Engenharia de Redes e  
Sistemas Informáticos

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# Outline

- Region-based Segmentation
- Morphological Filters

# Topic: Region-based Segmentation

- Region-based Segmentation
- Morphological Filters

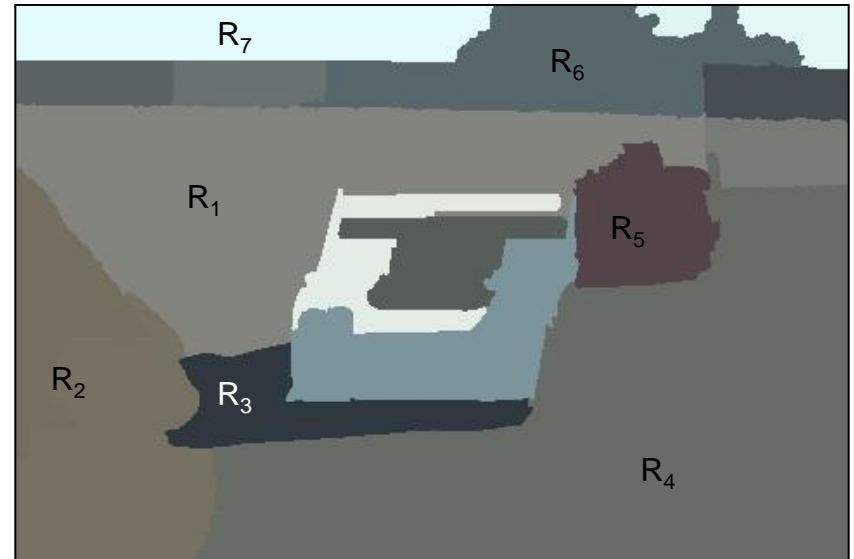
# Why Region-Based Segmentation?

- **Segmentation**
  - Edge detection and Thresholding not always effective.
- **Homogenous regions**
  - *Region-based segmentation.*
  - Effective in noisy images.

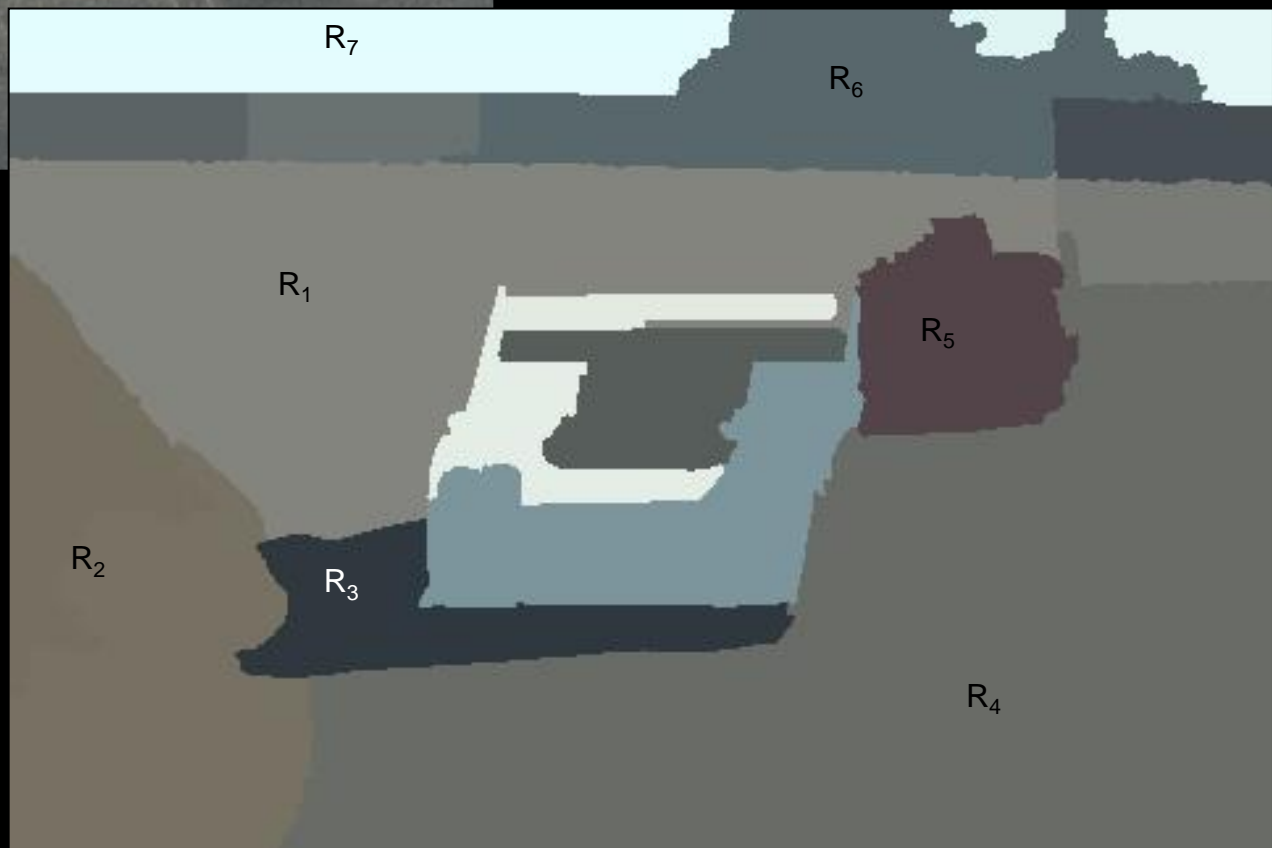


# Definitions

- Based on *sets*.
- Each image  $R$  is a set of regions  $R_i$ .
  - Every pixel belongs to one region.
  - One pixel can only belong to a single region.



$$R = \bigcup_{i=1}^S R_i \quad R_i \cap R_j = \emptyset$$



# Basic Formulation

Let  $R$  represent the entire image region. Segmentation partitions  $R$  into  $n$  subregions,  $R_1, R_2, \dots, R_n$ , such that:

- a)  $\bigcup_{i=1}^n R_i = R$
  - b)  $R_i$  is a connected region,  $i = 1, 2, \dots, n$ .
  - c)  $R_i \cap R_j = \emptyset$  for all  $i$  and  $j, i \neq j$
  - d)  $P(R_i) = TRUE$  for  $i = 1, 2, \dots, n$ .
  - e)  $P(R_i \cup R_j) = FALSE$  for  $i \neq j$ .
- a) Every pixel must be in a region
  - b) Points in a region must be connected.
  - c) Regions must be disjoint.
  - d) All pixels in a region satisfy specific properties.
  - e) Different regions have different properties.

# How do we form regions?

- Region Growing
- Region Merging
- Region Splitting
- Split and Merge
- Watershed
- ...

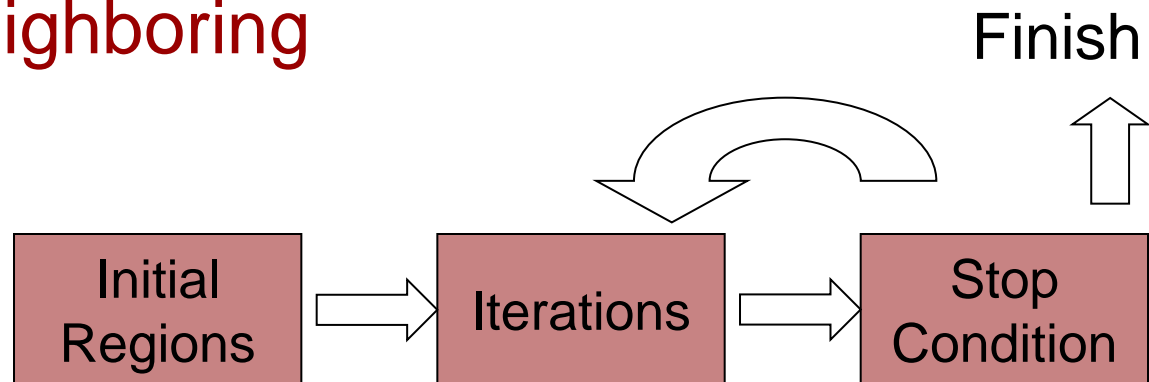
0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

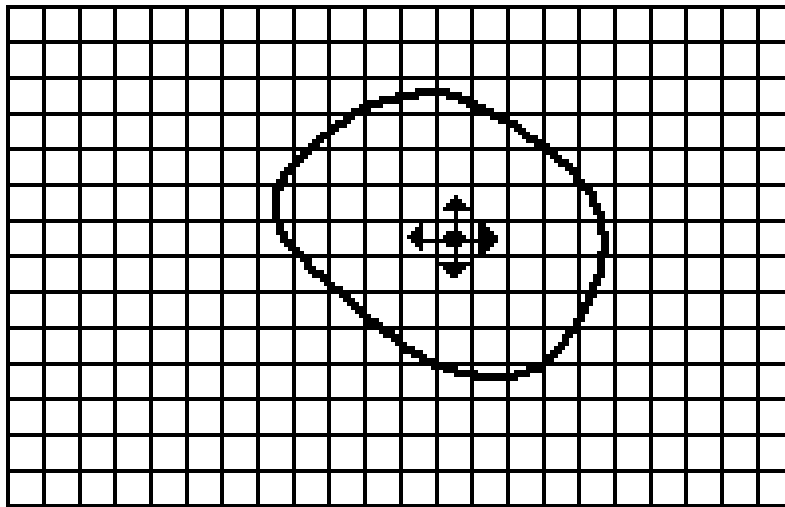
What a computer sees



# Region growing

- Groups pixels into larger regions.
- Starts with a **seed** region.
- **Grows** region by **merging** neighboring pixels.
- **Iterative process**
  - How to start?
  - How to iterate?
  - When to stop?

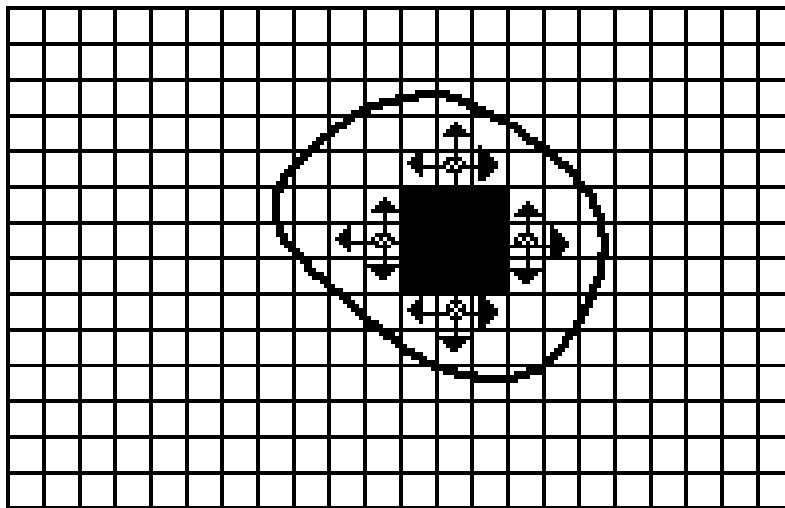




• Seed Pixel

↑ Direction of Growth

(a) Start of Growing a Region



■ Grown Pixels

⊙ Pixels Being Considered

(b) Growing Process After a Few Iterations

# *Region merging*

- **Algorithm**
  - Divide image into an initial set of regions.
    - One region per pixel.
  - Define a **similarity criteria** for merging regions.
  - **Merge** similar regions.
  - Repeat previous step until no more merge operations are possible.

# Similarity Criteria

- Homogeneity of regions is used as the main segmentation criterion in region growing.
  - gray level
  - color, texture
  - shape
  - model
  - etc.

Choice of criteria affects segmentation results dramatically!

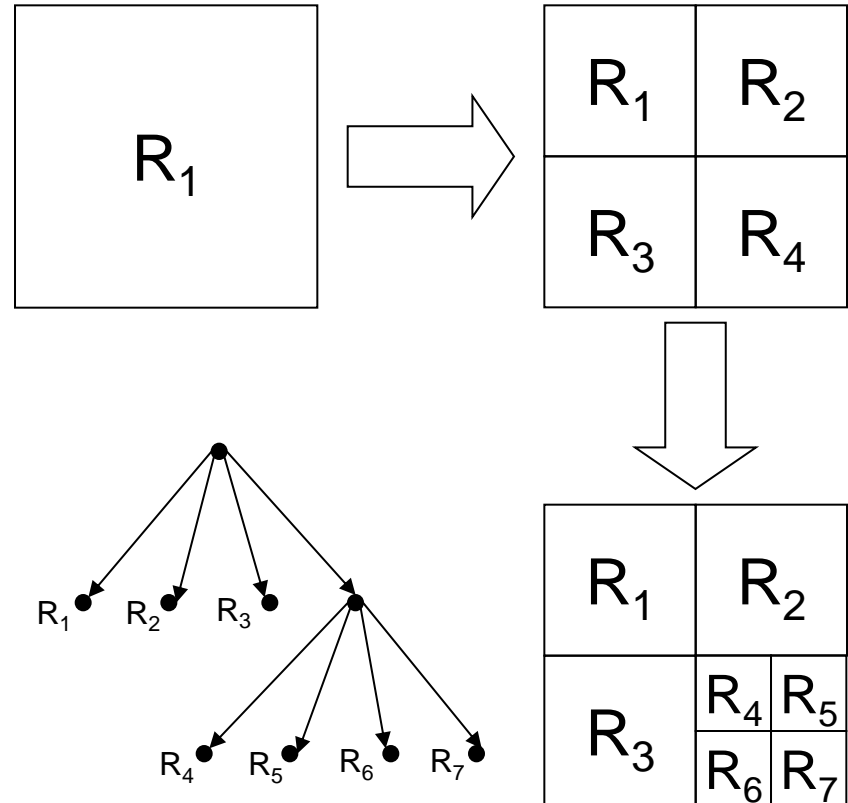
# Gray-Level Criteria

- **Comparing to Original Seed Pixel**
  - Very sensitive to choice of **seed point**.
- **Comparing to Neighbor in Region**
  - Allows gradual changes in the region.
  - Can cause significant drift.
- **Comparing to Region Statistics**
  - Acts as a **drift dampener**.
- **Other possibilities!**

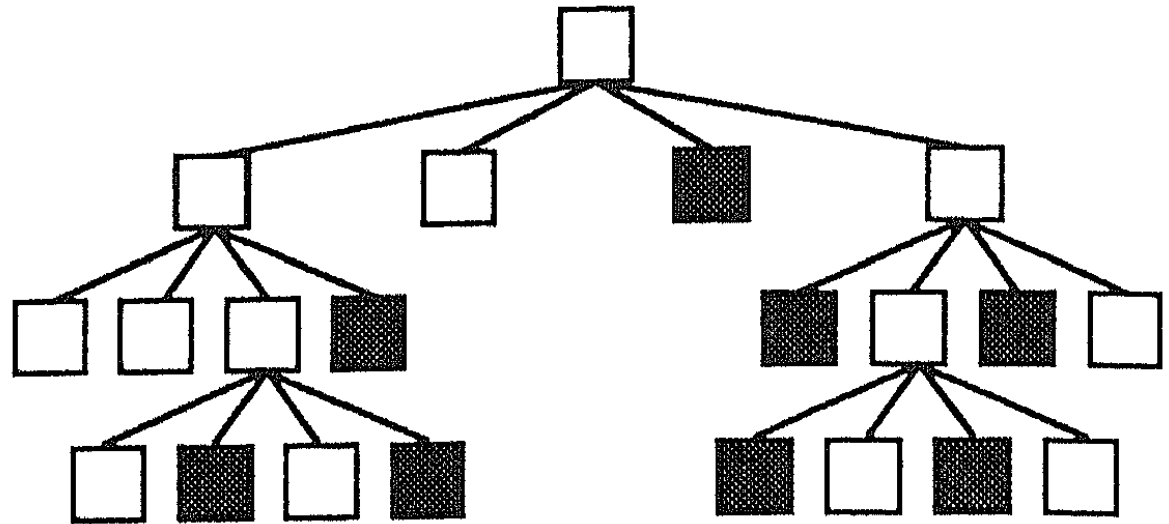
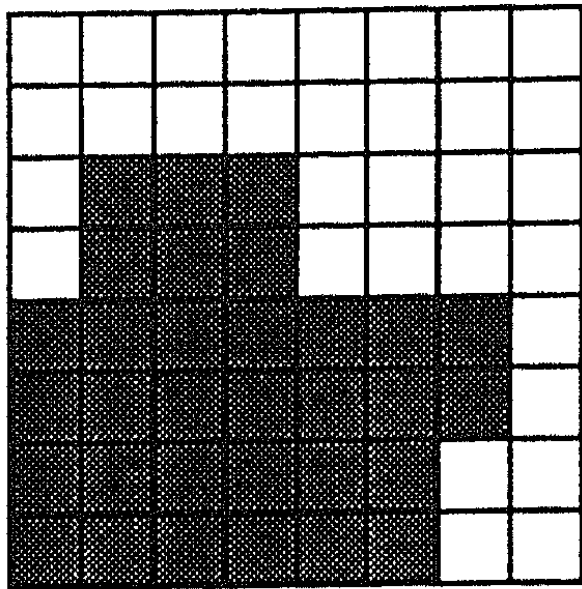
# Region splitting

- **Algorithm**

- One initial set that includes the **whole image**.
- **Similarity criteria.**
- Iteratively **split** regions into sub-regions.
- Stop when no more splittings are possible.



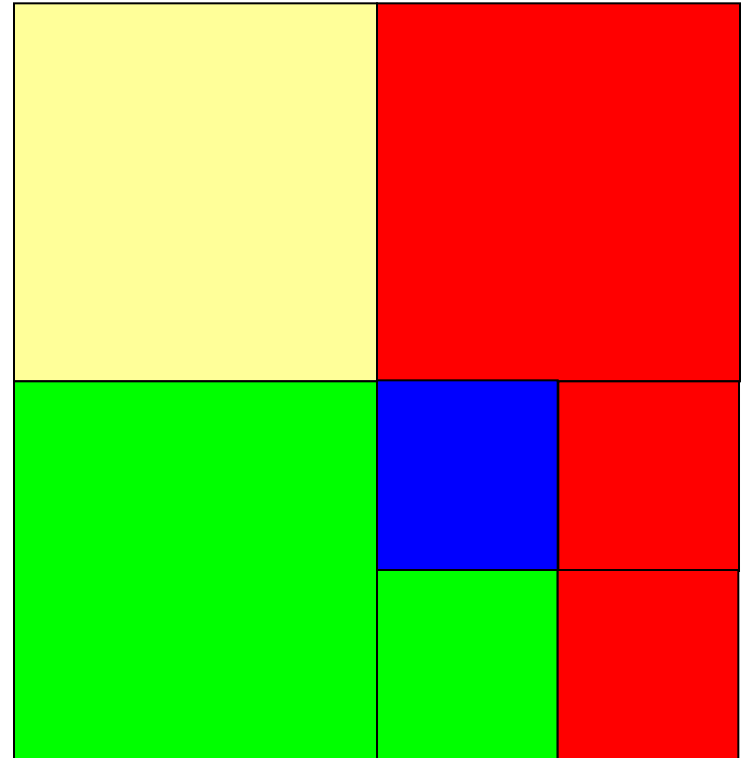
*The segmentation problem*



**Figure 5.23** A quad-tree representation of an  $8 \times 8$  binary image.

# *Split and Merge*

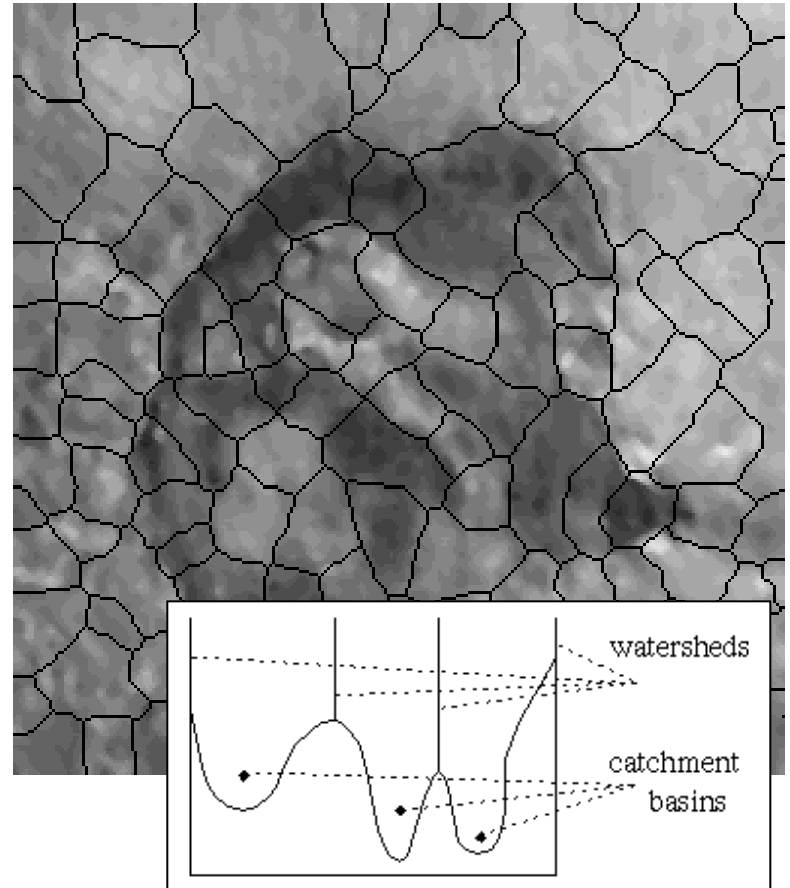
- Combination of both algorithms.
- Can handle a larger variety of shapes.
  - Simply apply previous algorithms consecutively.





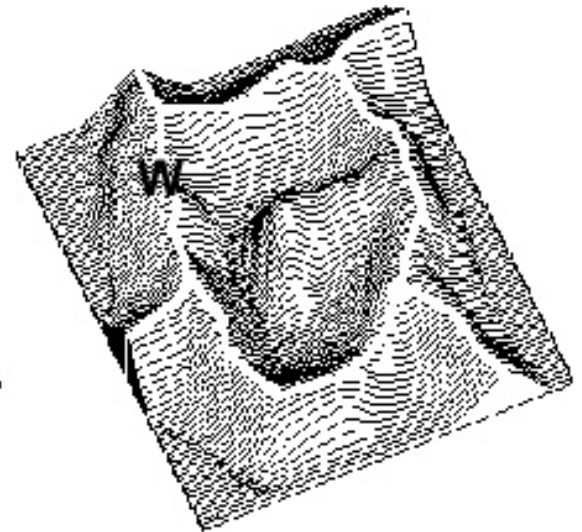
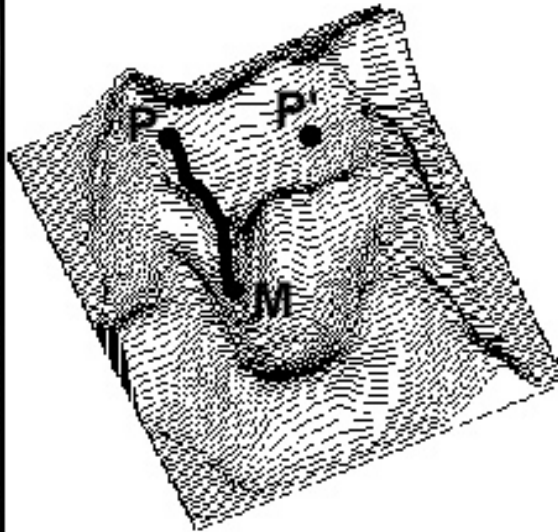
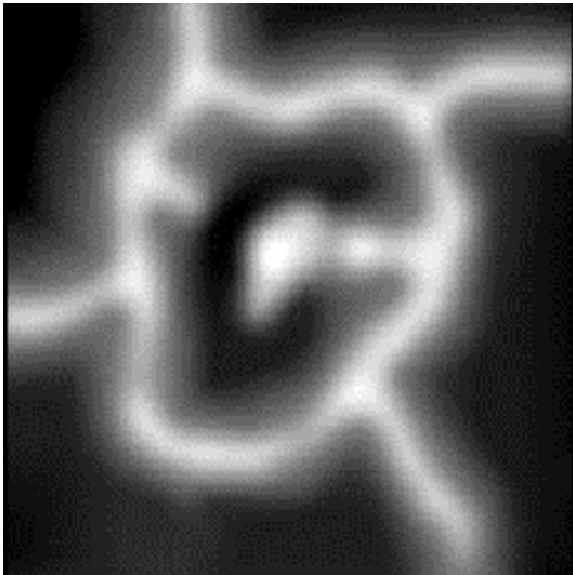
# The *Watershed* Transform

- **Geographical inspiration.**
  - Shed water over rugged terrain.
  - Each lake corresponds to a region.
- **Characteristics**
  - Computationally complex.
  - Great flexibility in segmentation.
  - Risk of over-segmentation.



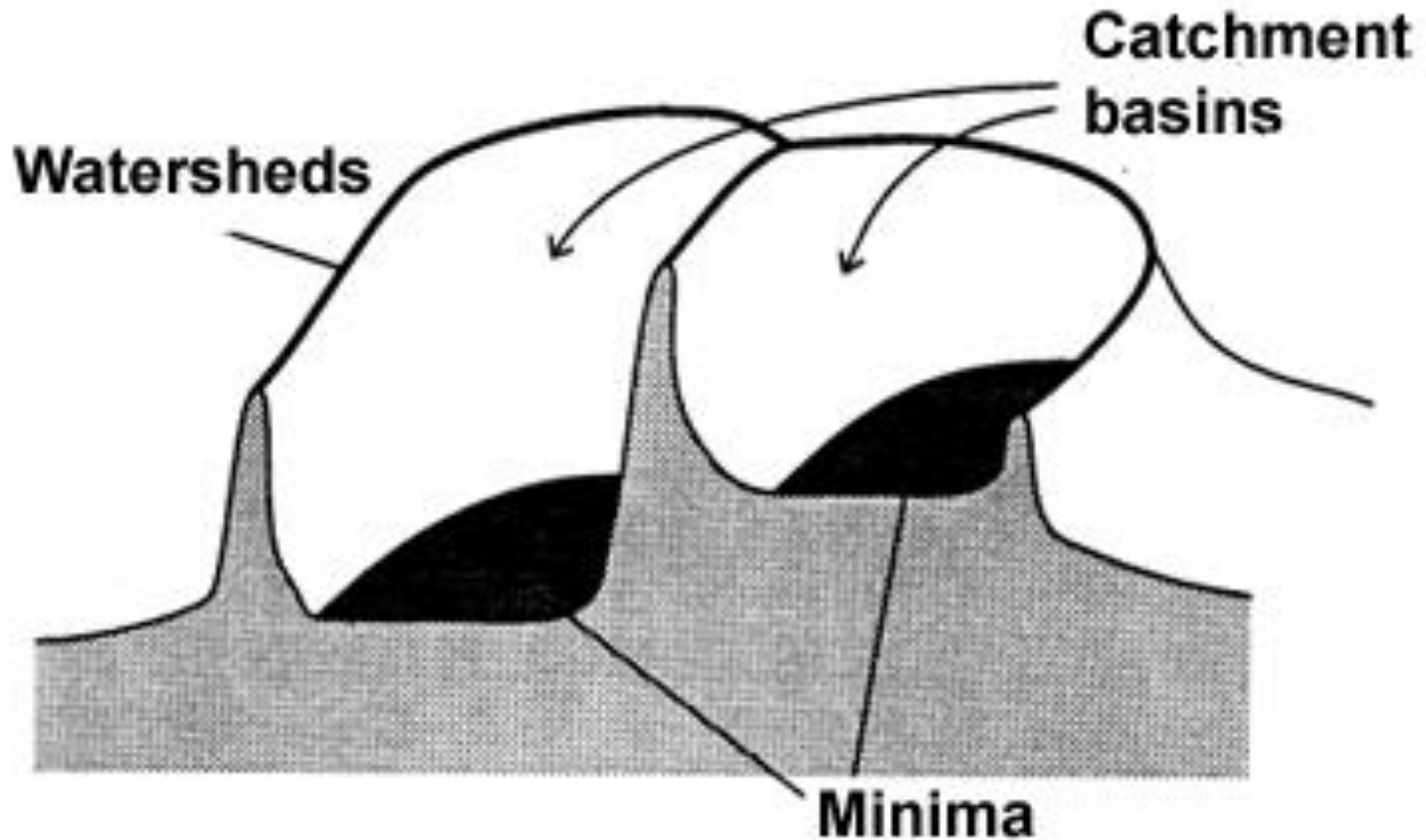
# The Drainage Analogy

- Two points are in the same region if they drain to the same point.



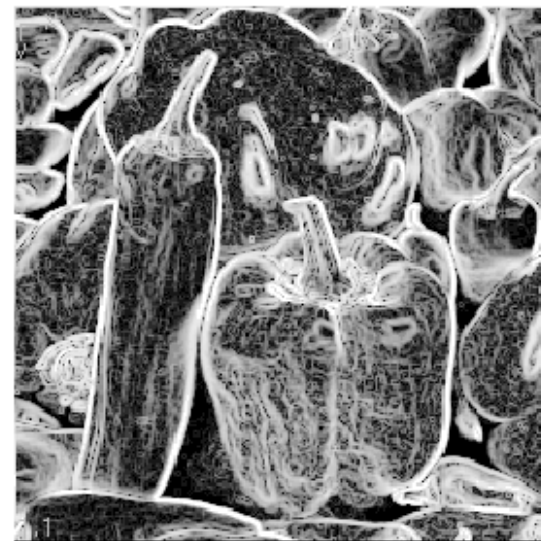
Courtesy of Dr. Peter Yim at National Institutes of Health, Bethesda, MD

# The Immersion Analogy





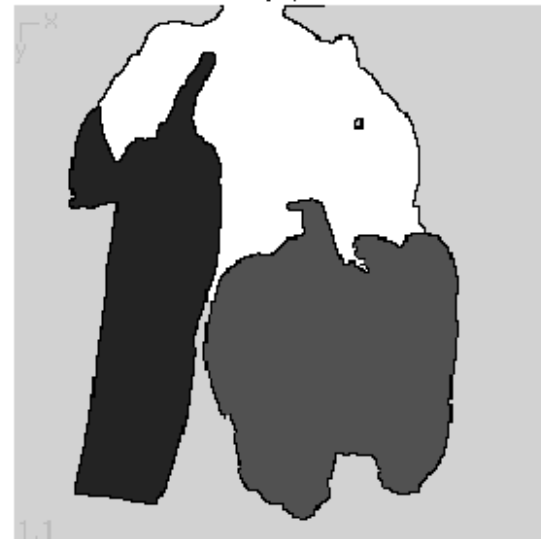
(a)



(b)



(c)



(d)

[Milan Sonka,  
Vaclav Hlavac,  
and Roger Boyle]

Figure 5.51: *Watershed segmentation: (a) original; (b) gradient image,  $3 \times 3$  Sobel edge detection, histogram equalized; (c) raw watershed segmentation; (d) watershed segmentation using region markers to control oversegmentation. Courtesy W. Higgins, Penn State University.*

# Over-Segmentation

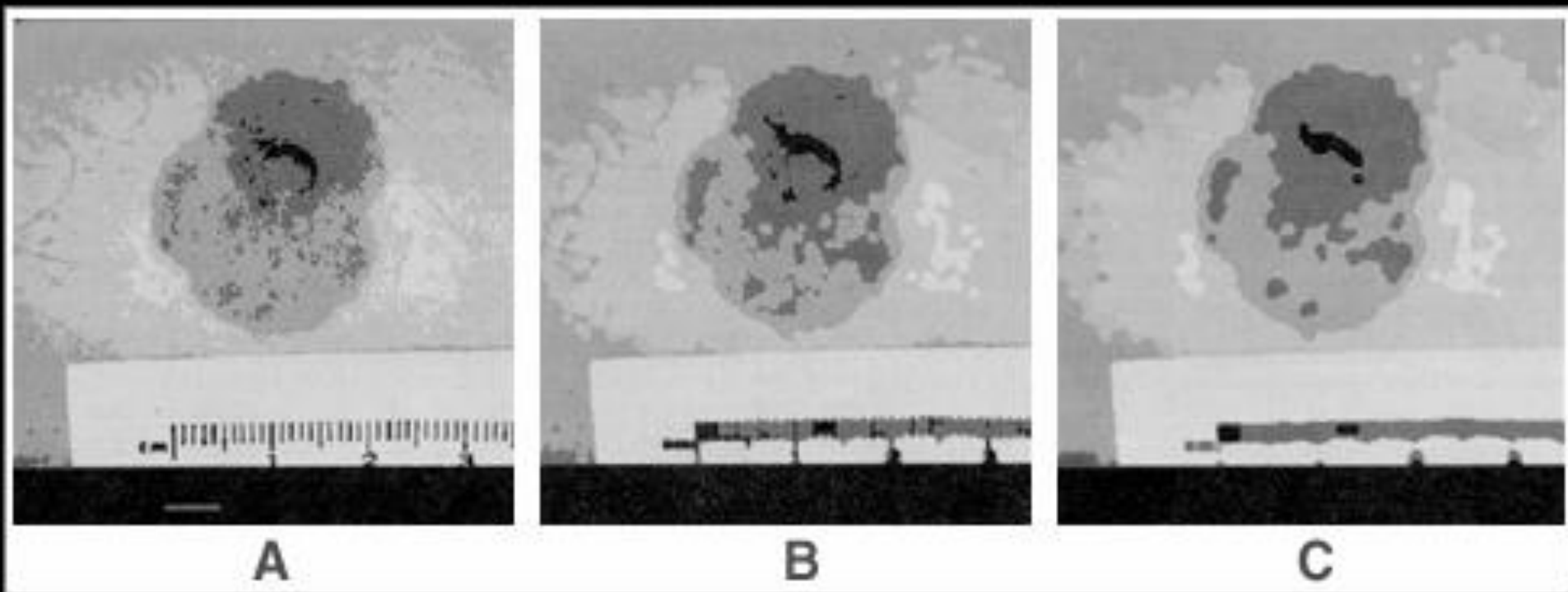
- **Over-segmentation.**
  - Raw watershed segmentation produces a severely oversegmented image with hundreds or thousands of catchment basins.
- **Post-Processing.**
  - Region merging.
  - Edge information.
  - Etc.

# Topic: Morphological Filters

- Region-based Segmentation
- **Morphological Filters**

# Mathematical Morphology

- Provides a mathematical description of geometric structures.
- Based on *sets*.
  - Groups of pixels which define an image region.
- What is this used for?
  - Binary images.
  - Can be used for **post-processing** segmentation results!
- Core techniques
  - Erosion, Dilation.
  - Open, Close.

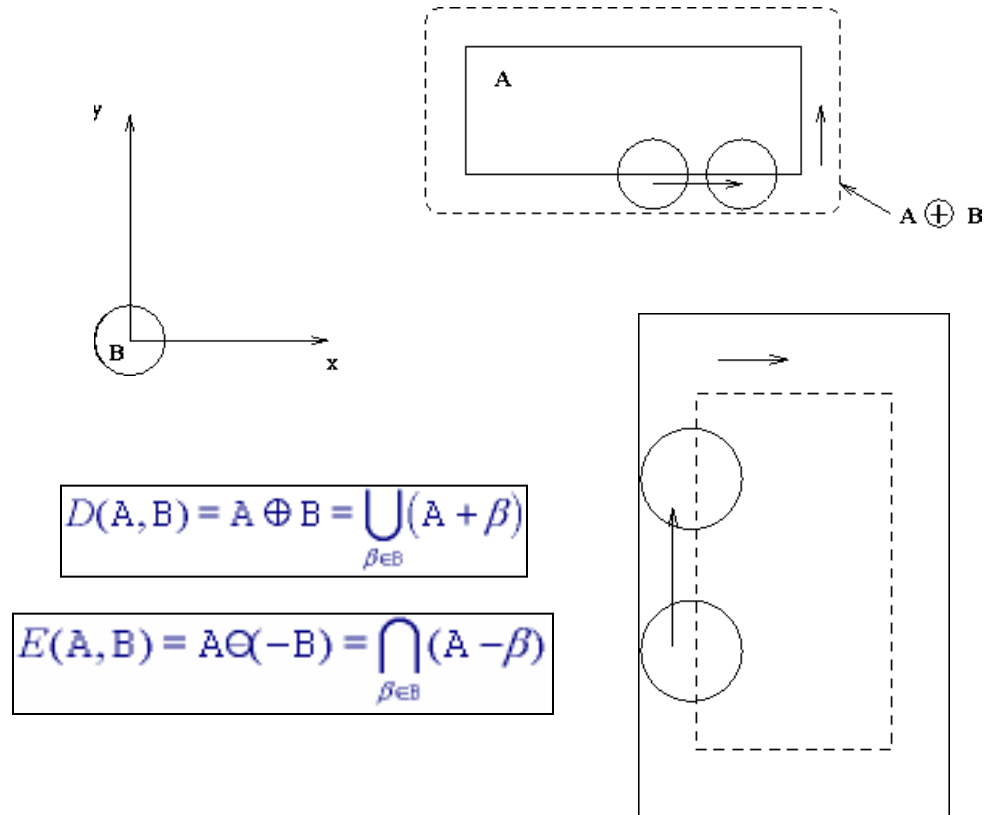


Tumor Segmentation using Morphologic Filtering



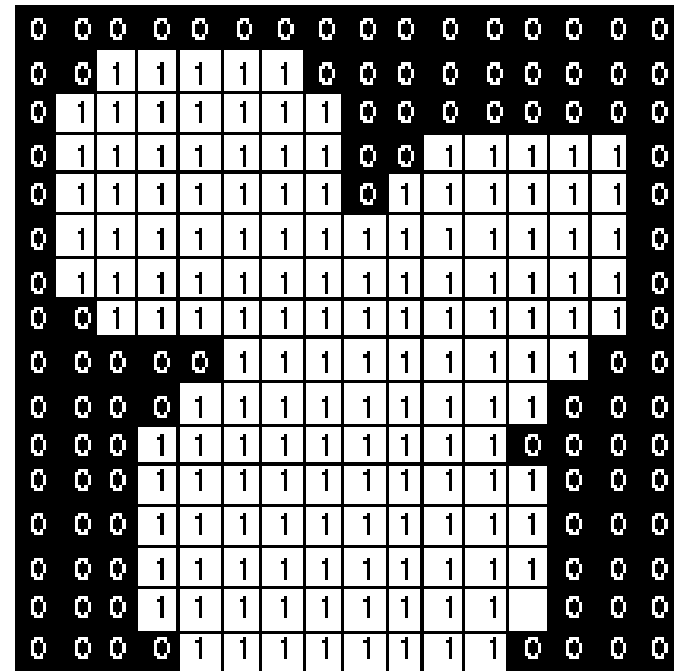
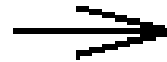
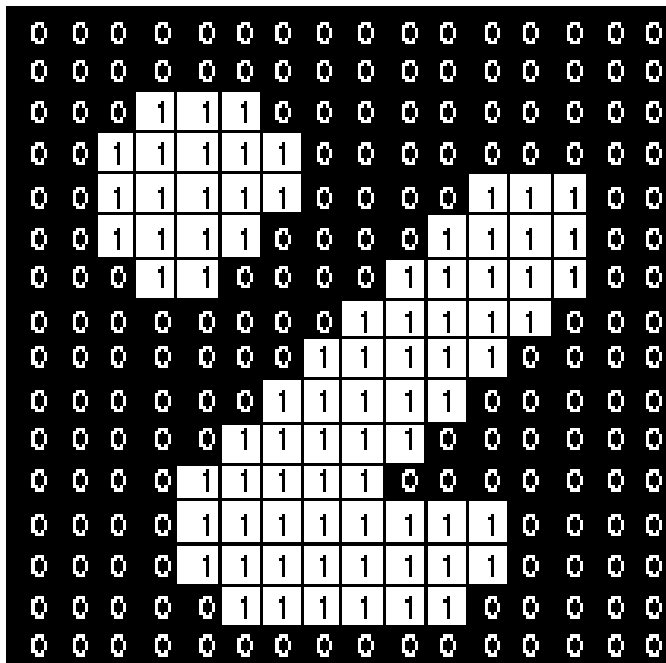
# Dilation, Erosion

- **Two sets:**
  - Image
  - Morphological *kernel*.
- **Dilation (D)**
  - Union of the **kernel** with the **image** set.
  - Increases resulting area.
- **Erosion (E)**
  - Intersection.
  - Decreases resulting area.



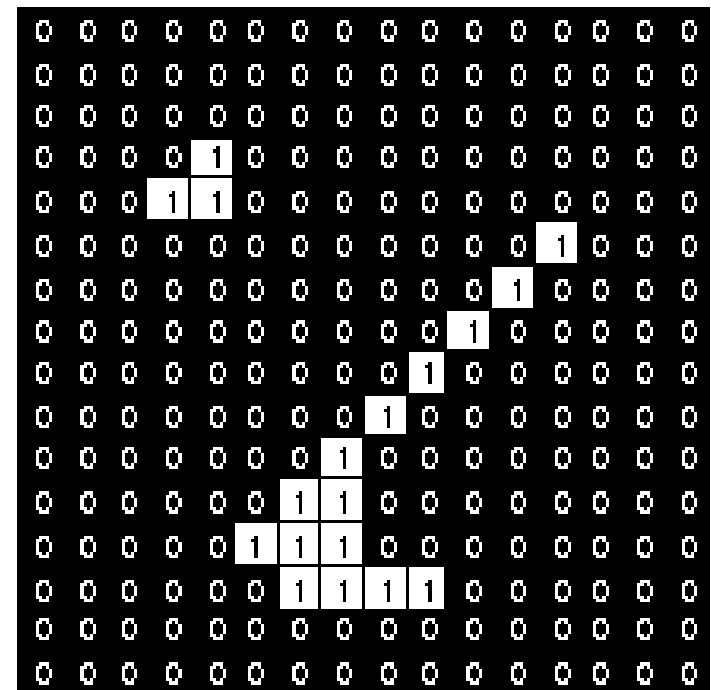
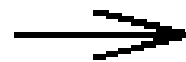
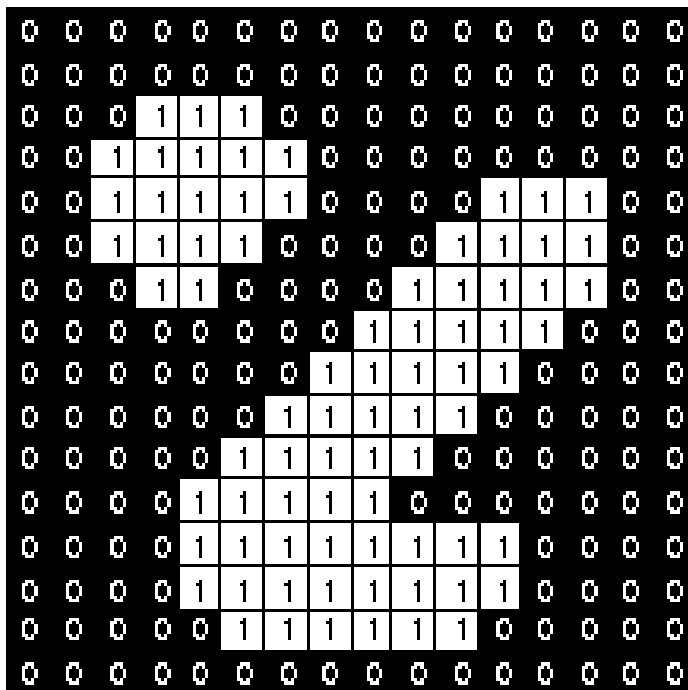
# Dilation

- Example using a 3x3 morphological kernel



# Erosion

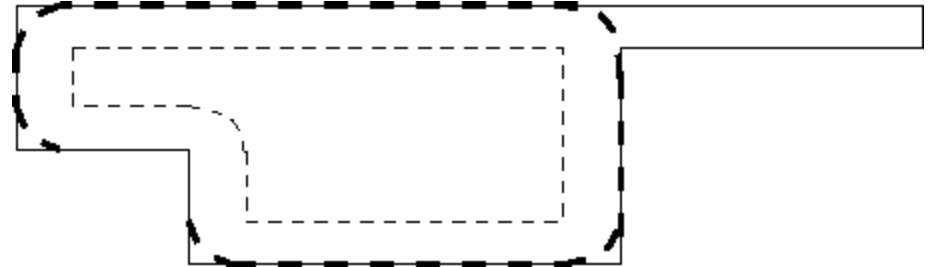
- Example using a 3x3 morphological kernel



# Opening, Closing

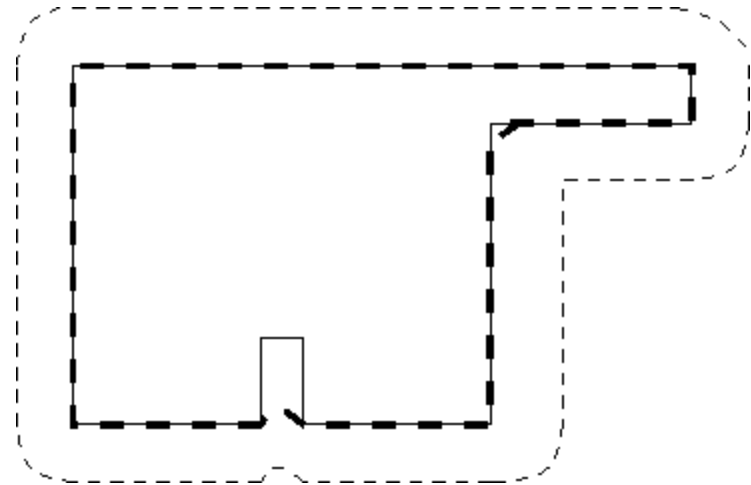
- **Opening**

- **Erosion**, followed by **dilation**.
- Less destructive than an erosion.
- **Adapts** image shape to kernel shape.



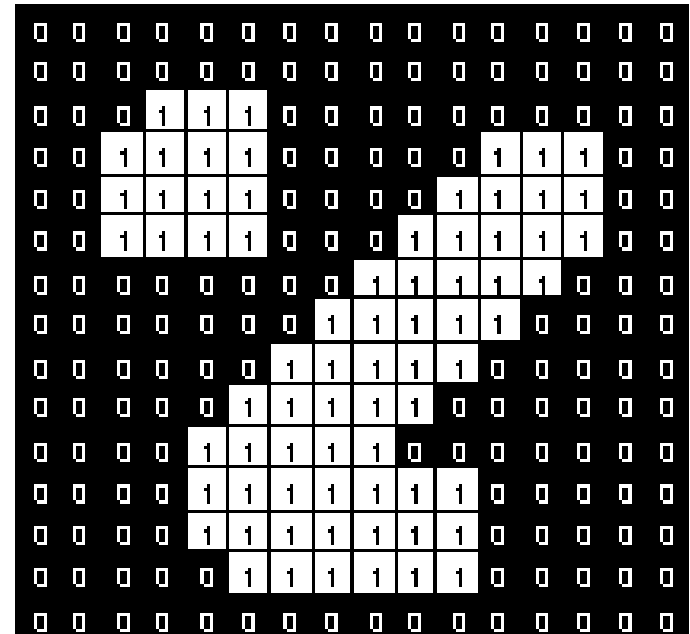
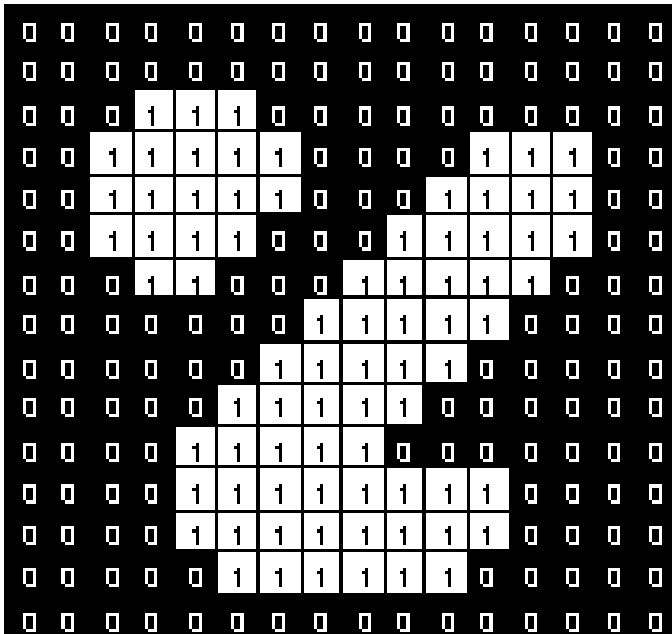
- **Closing**

- **Dilation**, followed by **erosion**.
- Less destructive than a dilation.
- Tends to **close** shape irregularities.



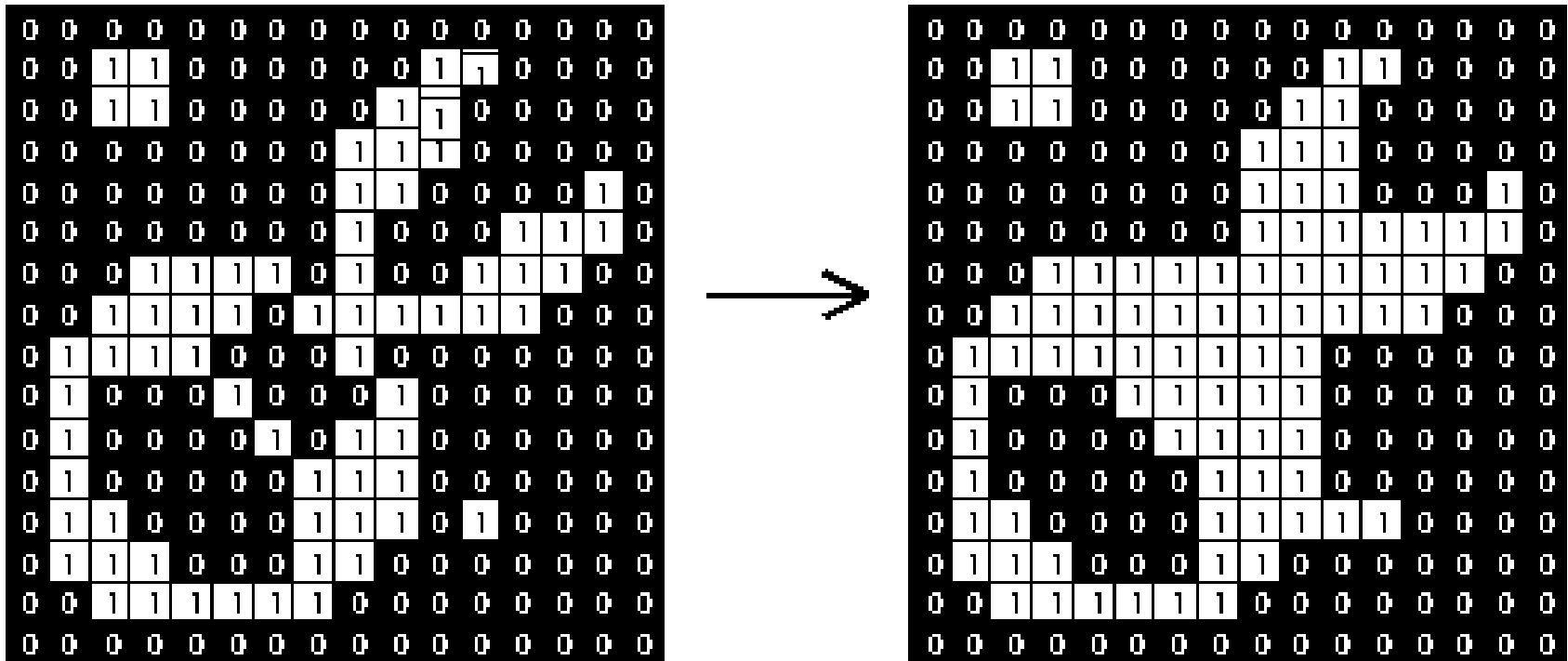
# Opening

- Example using a 3x3 morphological kernel



# Closing

- Example using a 3x3 morphological kernel



# Core morphological operators



Dilation



Erosion

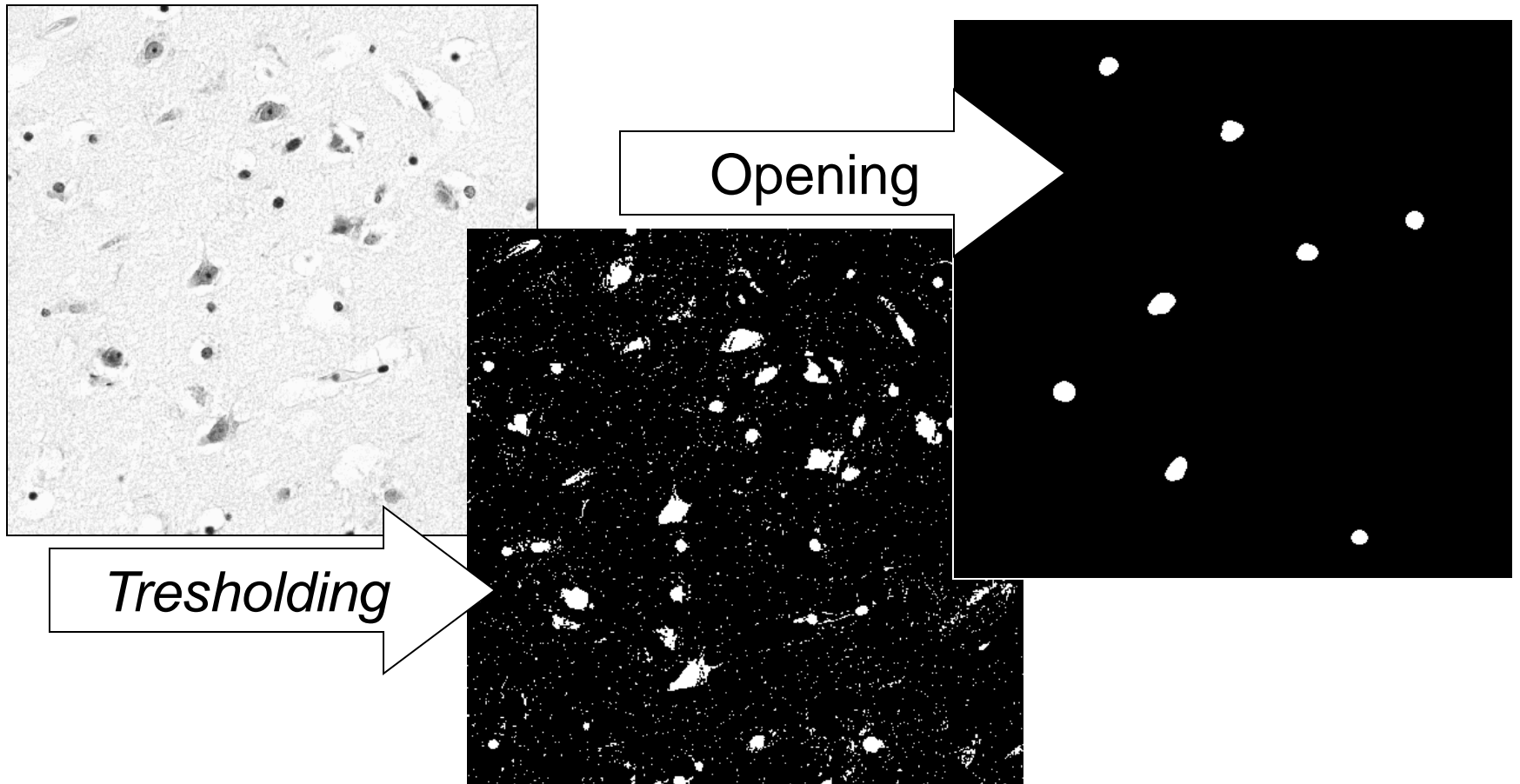


Closing



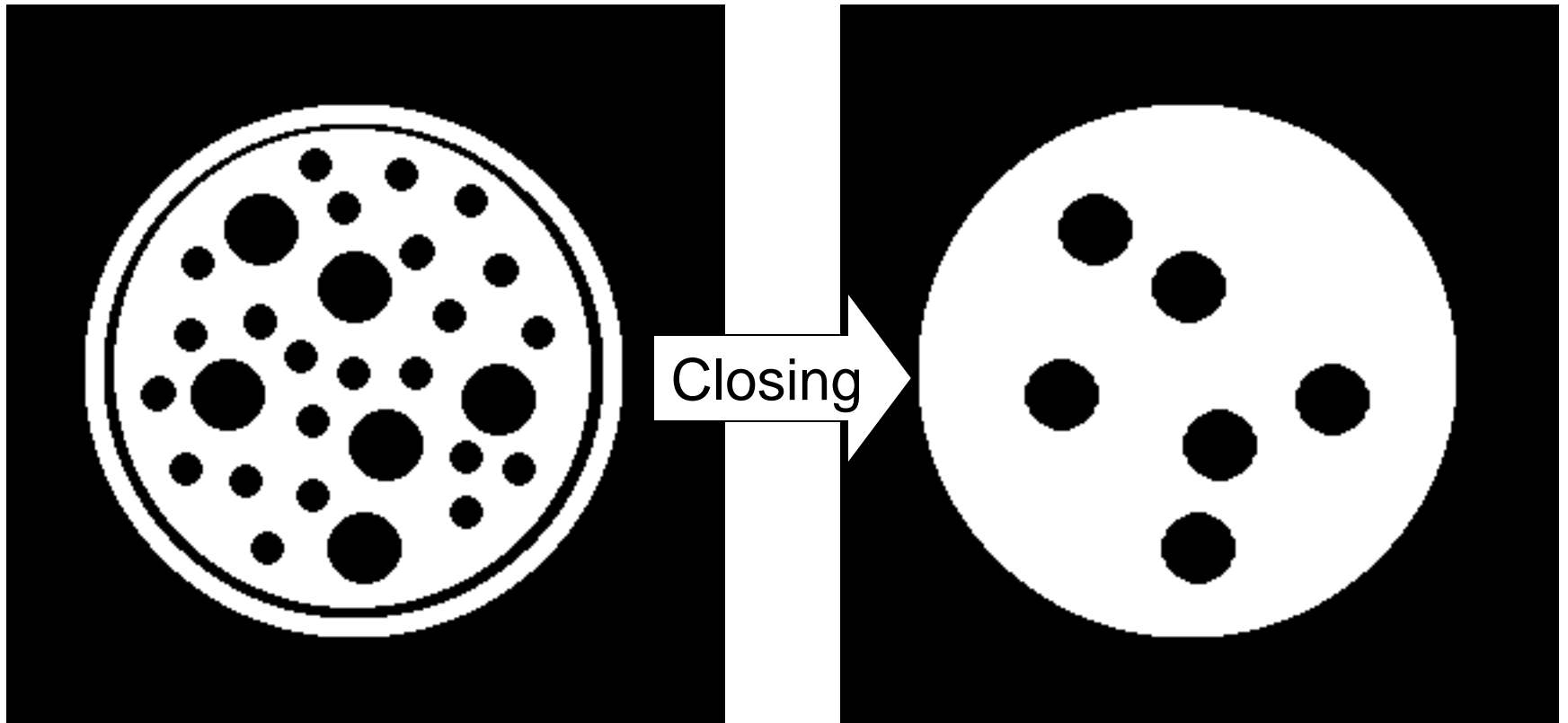
Opening

# Example: Opening



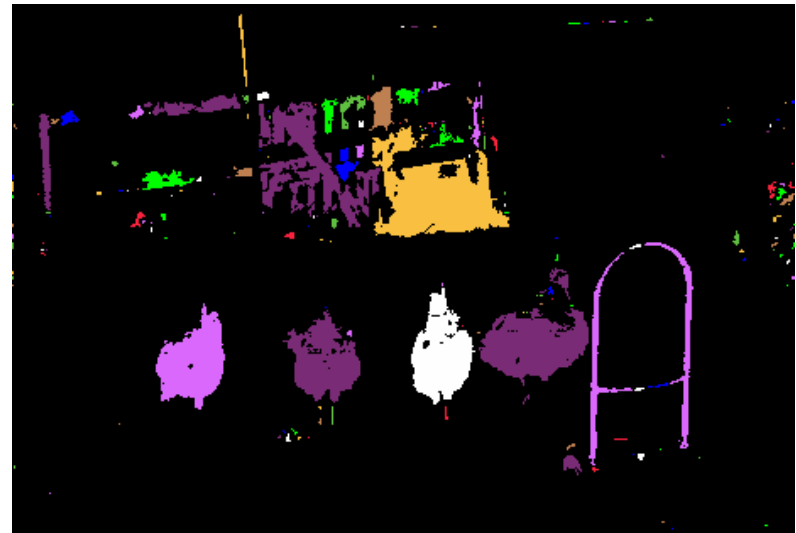
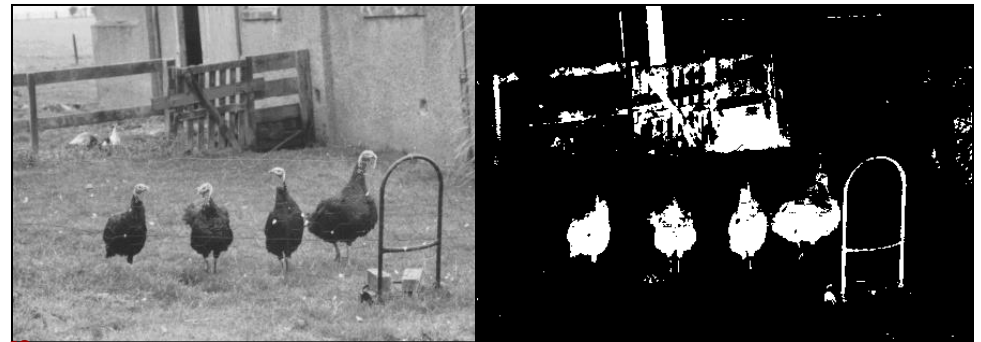


# Example: Closing



# Connected Component Analysis

- Define '**connected**'.
  - 4 neighbors.
  - 8 neighbors.
- Search the image for **seed points**.
- Recursively obtain all **connected points** of the seeded region.



# Resources

- Gonzalez & Woods - Chapter 7 and 8