VC 19/20 – TP9
Region-Based Segmentation

Mestrado em Ciência de Computadores

Mestrado Integrado em Engenharia de Redes e Sistemas Informáticos

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Outline

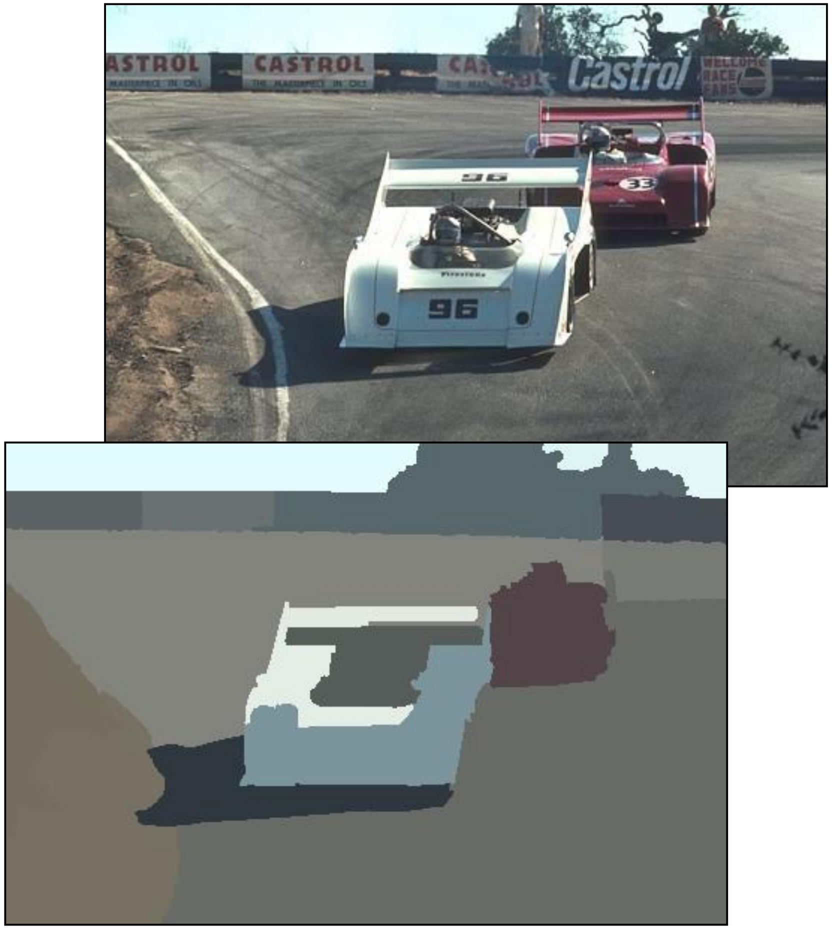
- Region-based Segmentation
- Morphological Filters

Topic: Region-based Segmentation

- Region-based Segmentation
- Morphological Filters

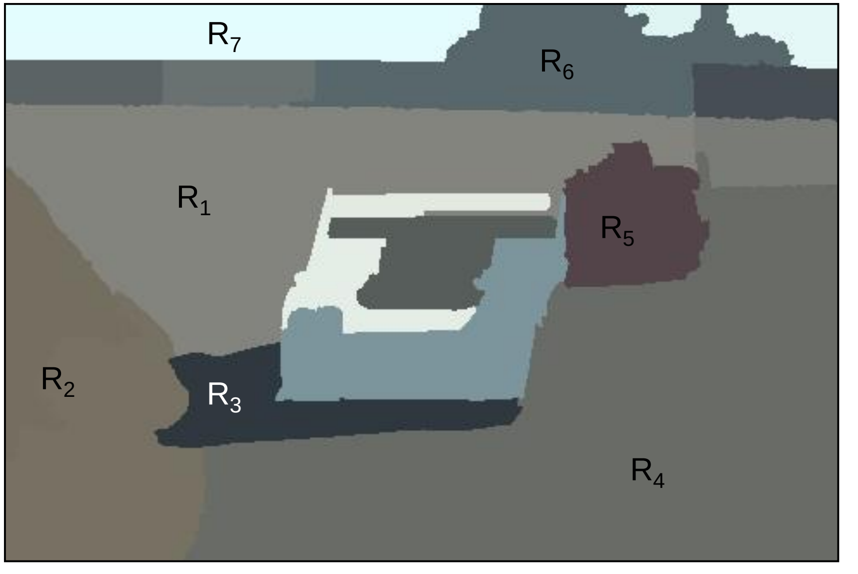
Why Region-Based Segmentation?

- 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.



$$R = \bigcup_{i=1}^{S} R_i \qquad R_i \bigcap R_j = \varnothing$$


CASTROL
Castrol
WELCOME RACE FANS
96
33
96


R_7
R_6
R_1
R_5
R_2
R_3
R_4

Basic Formulation

Let R represent the entire image region. Segmentation partitions R into n subregions, R_1, R_2, ..., 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) $P(R_i) = TRUE$ for $i = 1,2,\ldots,n$.

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
- ...

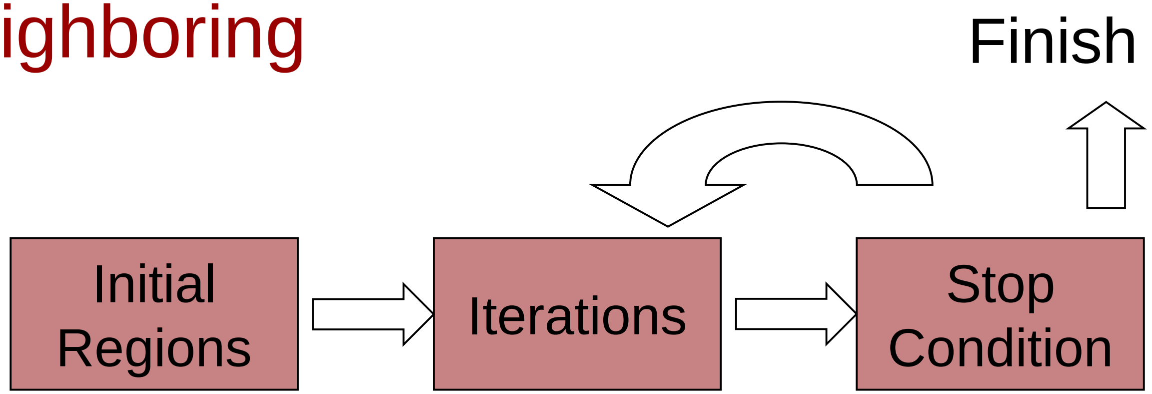
0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

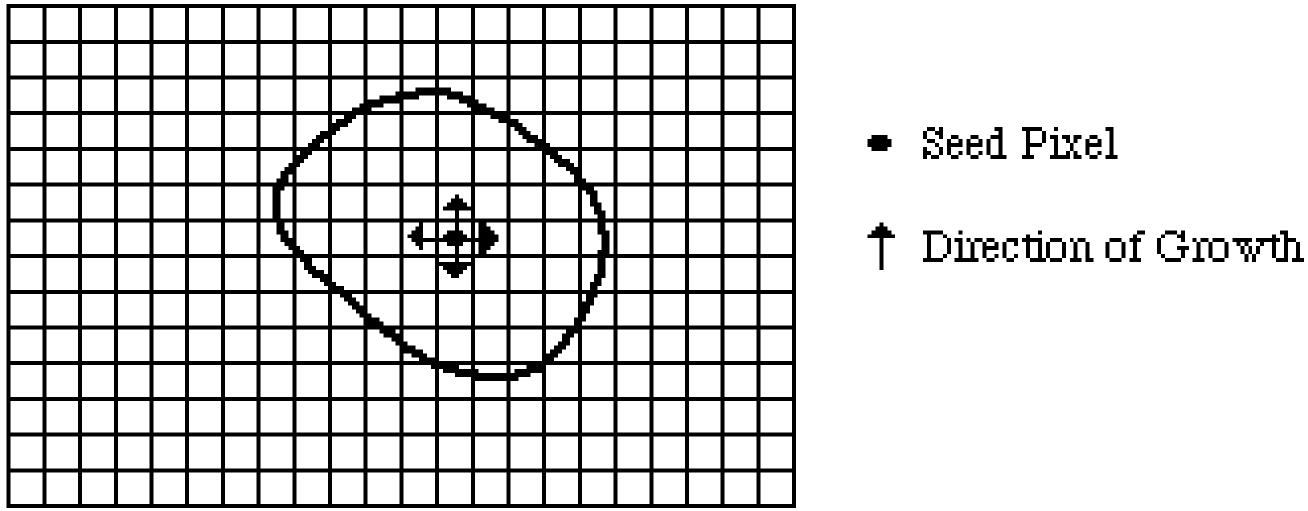
What a computer sees

Region growing

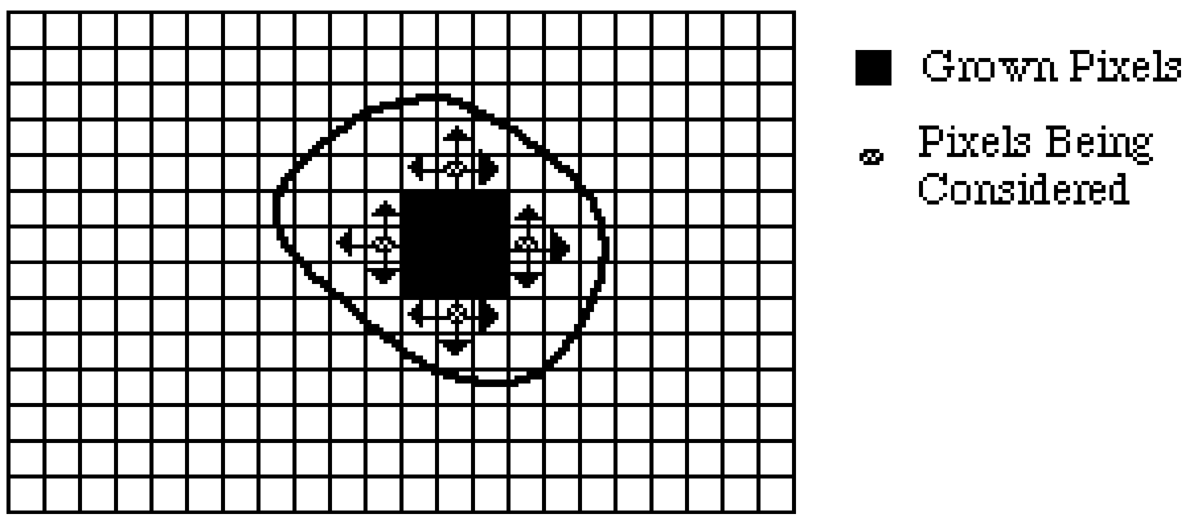
- Groups pixels into larger regions.
- Starts with a **seed** region.
- **Grows** region by **merging** neighboring pixels.

- Iterative process
  - How to start?
  - How to iterate?
  - When to stop?





(a) Start of Growing a Region



(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.

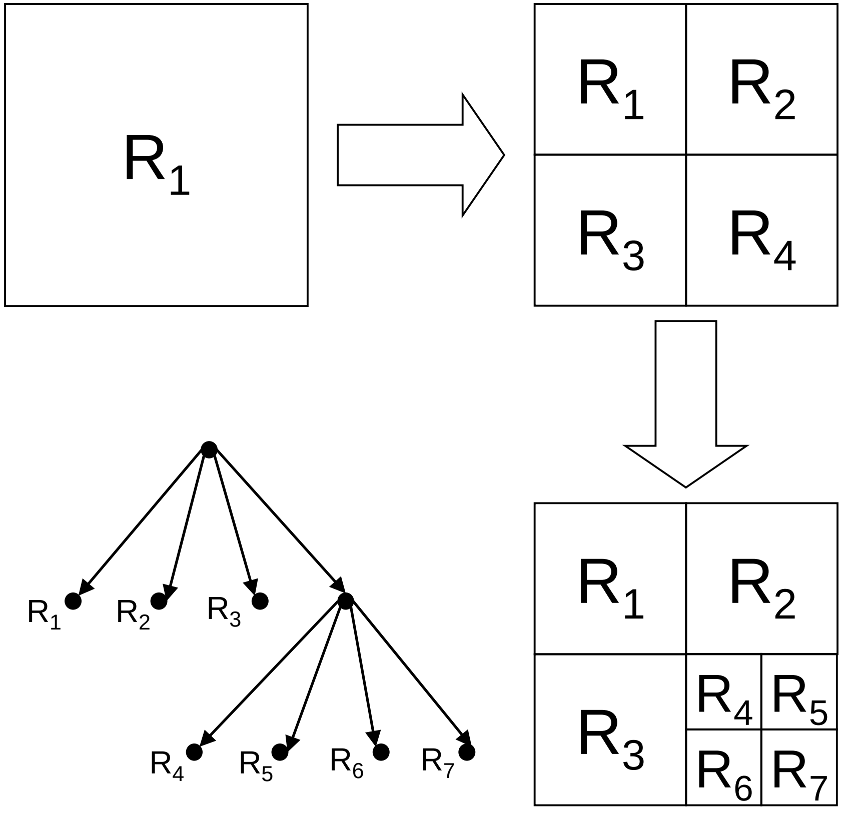
> Choice of criteria affects segmentation results dramatically!

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

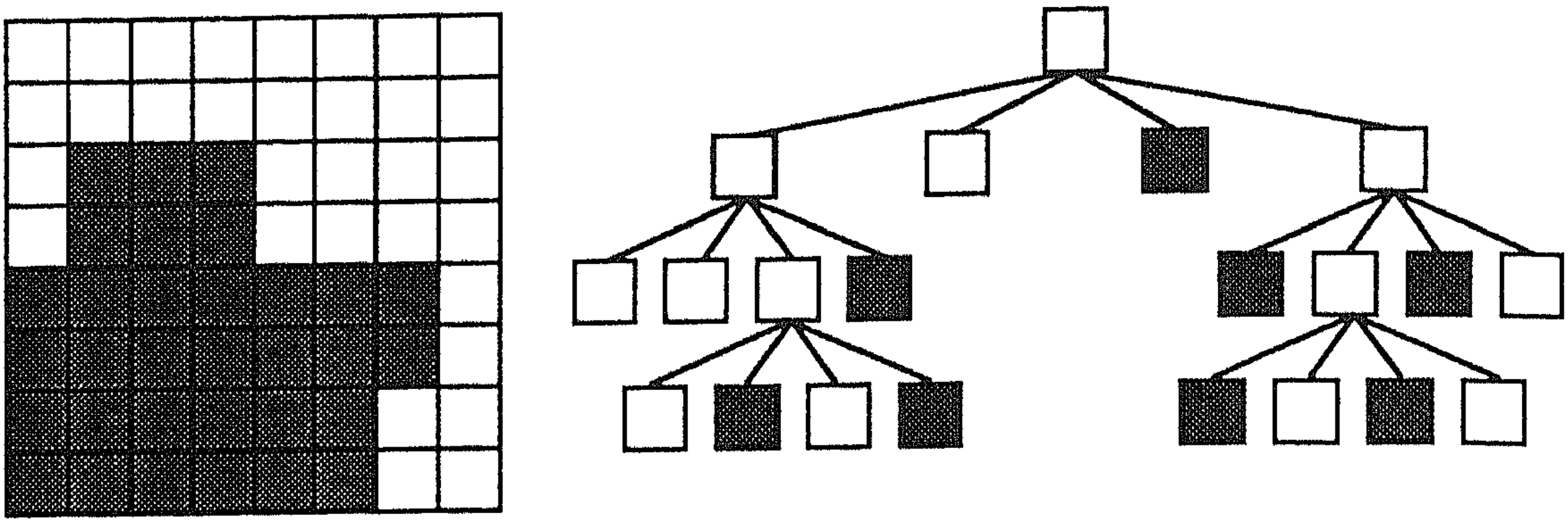
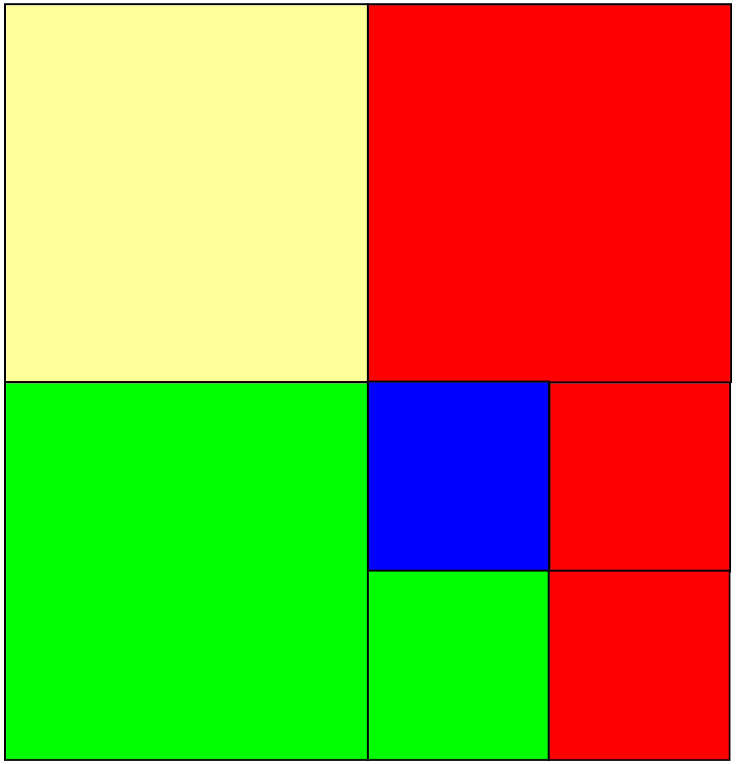


Figure 5.23 A quad-tree representation of an 8×8 binary image.

[Machine Vision; David Vernon]

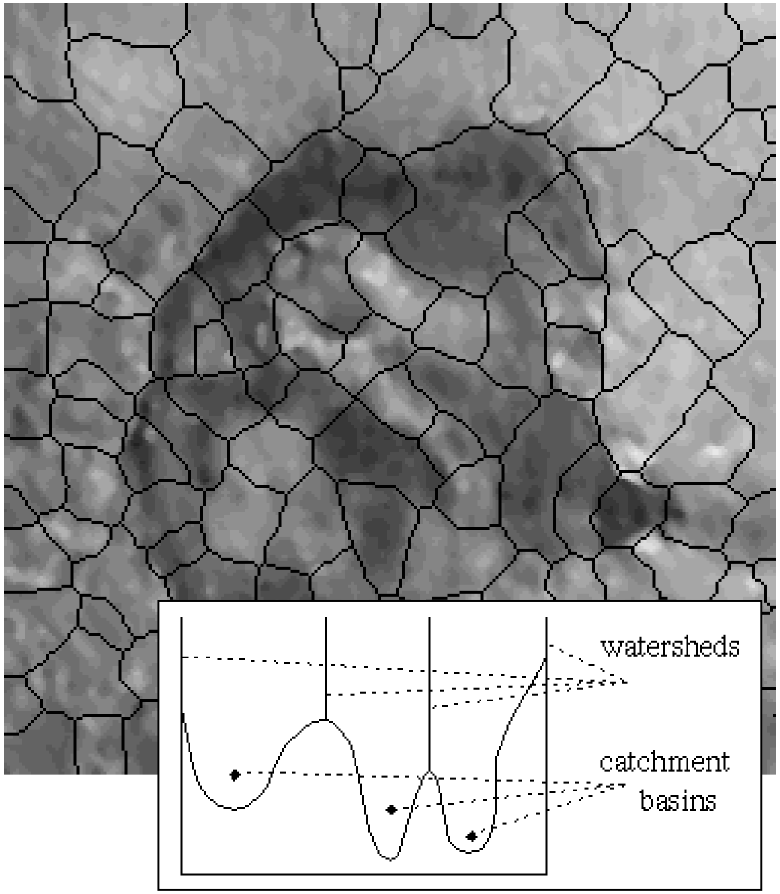
Split and Merge

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



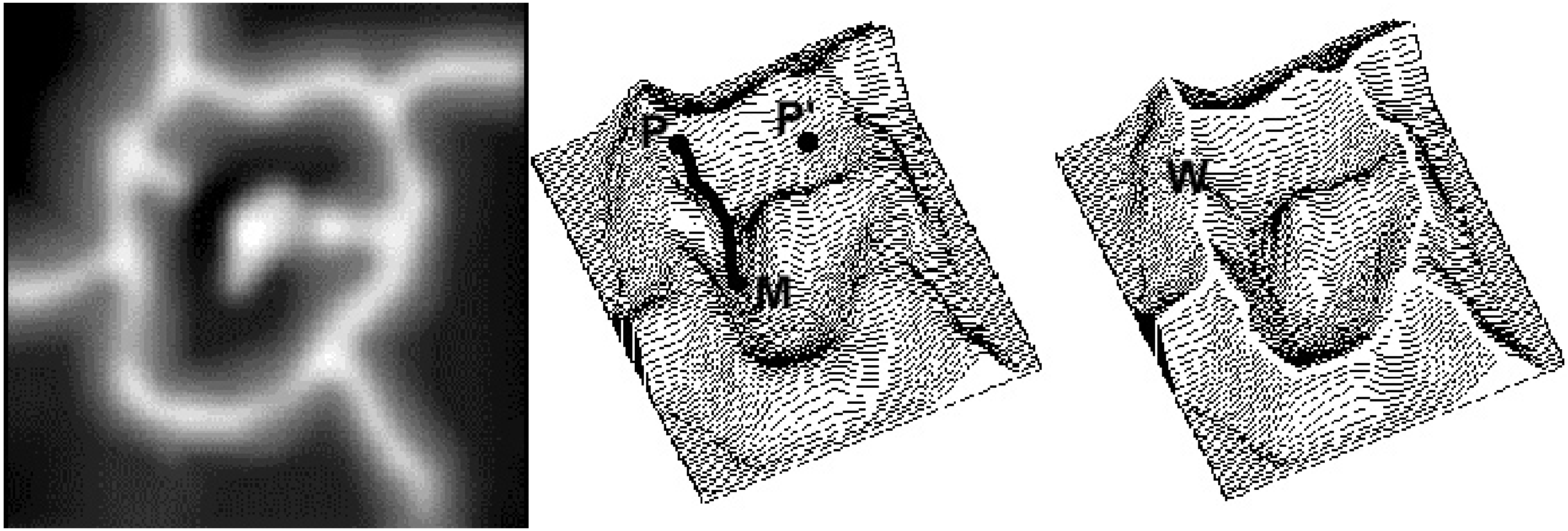
The *Watershed* Transform

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



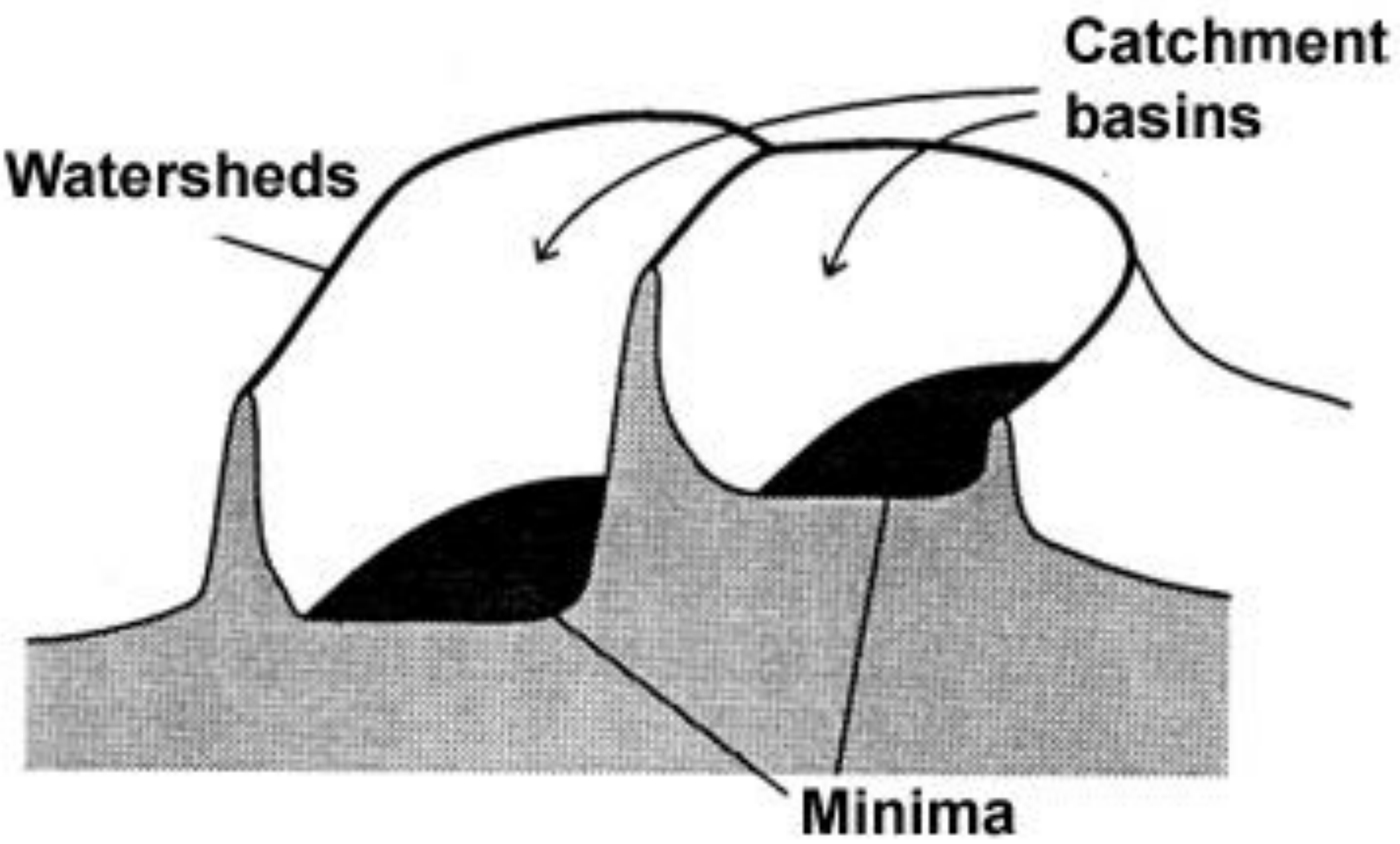
The Drainage Analogy

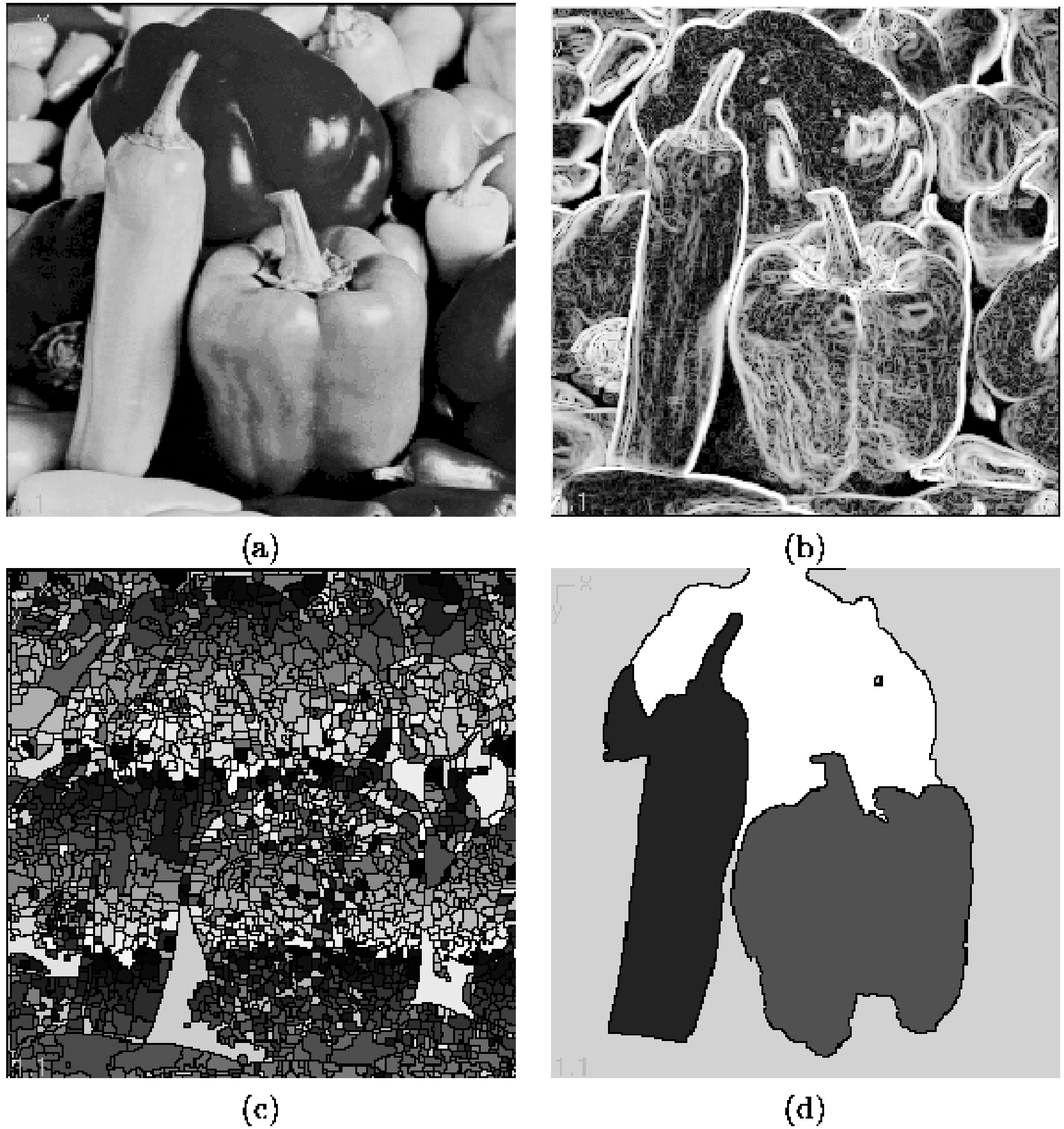
- Two points are in the same region if they drain to the same point.



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

The Immersion Analogy





[Milan Sonka, Vaclav Hlavac, and Roger Boyle]

Figure 5.51: *Watershed segmentation: (a) original; (b) gradient image, 3×3 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

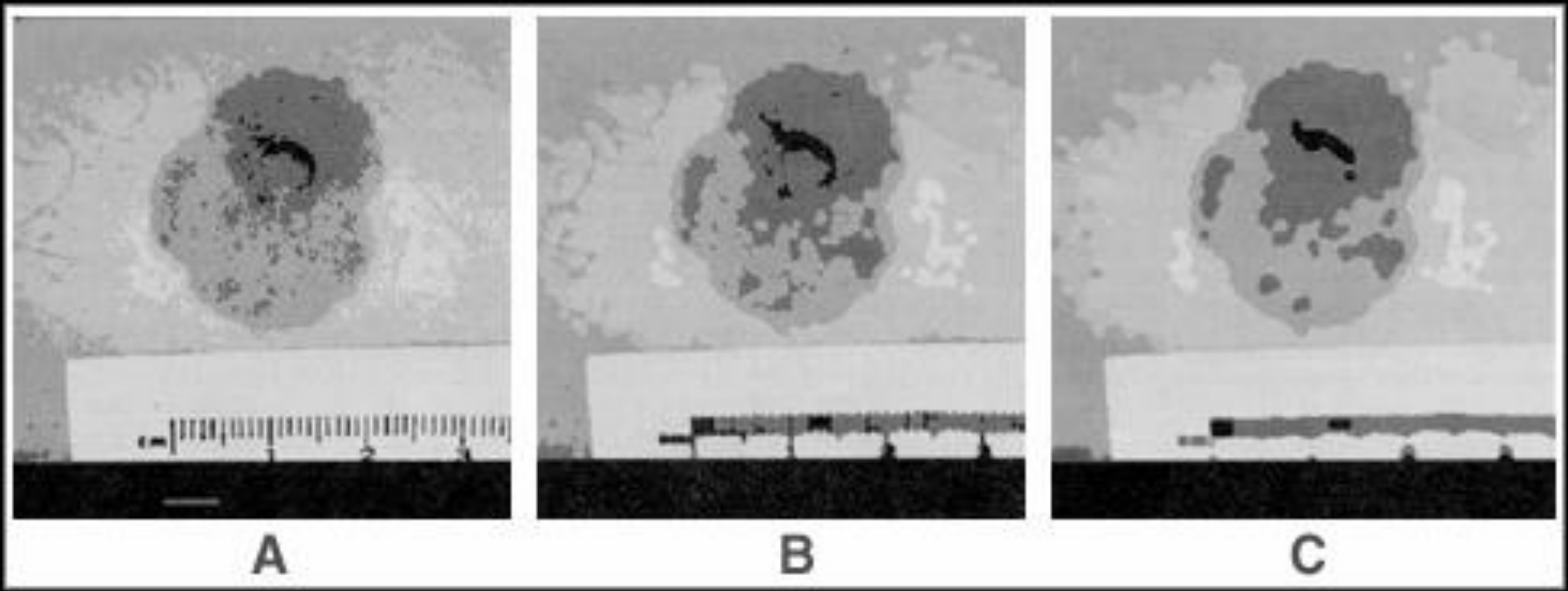
- Over-segmentation.
  – Raw watershed segmentation produces a severely oversegmented image with hundreds or thousands of catchment basins.
- Post-Processing.
  – Region merging.
  – Edge information.
  – Etc.

Topic: Morphological Filters

- Region-based Segmentation
- Morphological Filters

Mathematical Morphology

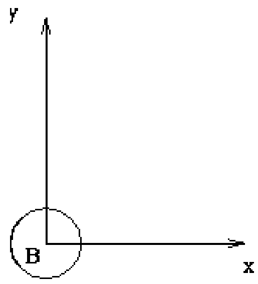
- Provides a mathematical description of geometric structures.
- Based on *sets*.
  - Groups of pixels which define an image region.
- What is this used for?
  - Binary images.
  - Can be used for **post-processing** segmentation results!
- Core techniques
  - Erosion, Dilation.
  - Open, Close.

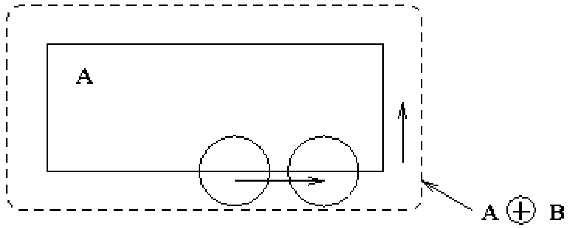


Tumor Segmentation using Morphologic Filtering

Dilation, Erosion

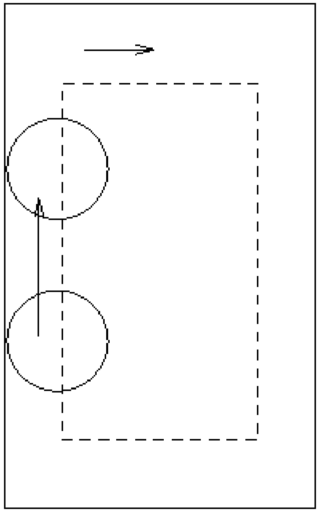
- Two sets:
  - Image
  - Morphological ***kernel.***
- Dilation (D)
  - Union of the **kernel** with the **image** set.
  - Increases resulting area.
- Erosion (E)
  - Intersection.
  - Decreases resulting area.





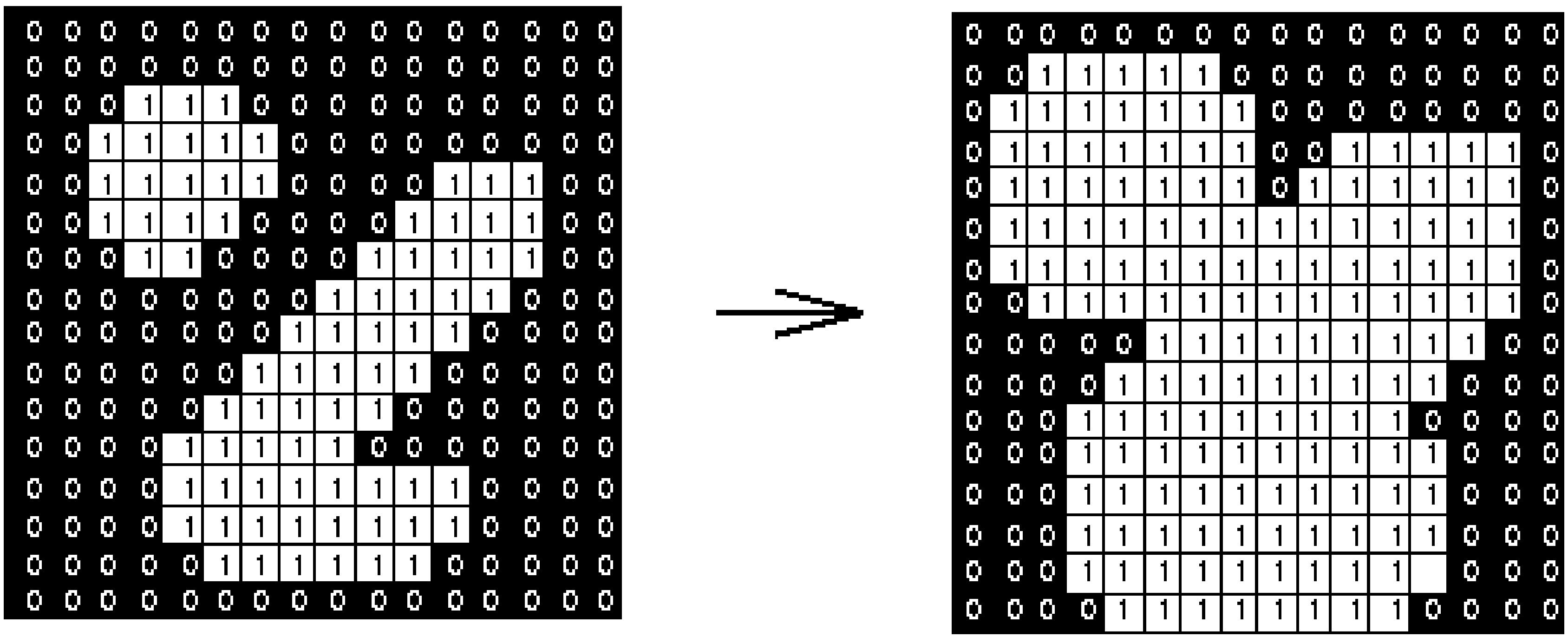
$$D(A,B) = A \oplus B = \bigcup_{\beta \in B} (A + \beta)$$

$$E(A,B) = A \ominus (-B) = \bigcap_{\beta \in B} (A - \beta)$$



Dilation

- Example using a 3x3 morphological kernel



Erosion

- Example using a 3x3 morphological kernel

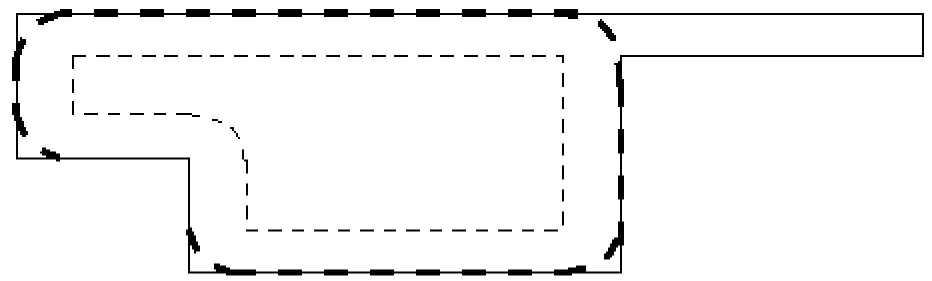
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	1	0	0	0	0	1	1	1	0	0
0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0
0	0	0	1	1	0	0	0	0	1	1	1	1	1	0	0
0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0
0	0	0	0	0	0	1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

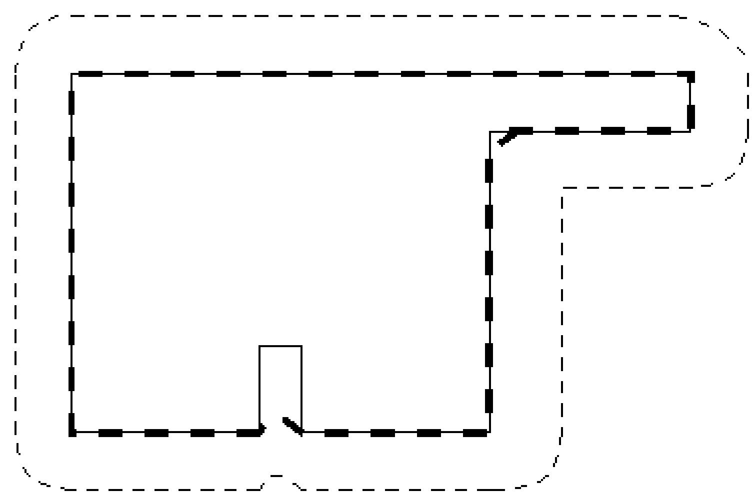
→

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

Opening, Closing

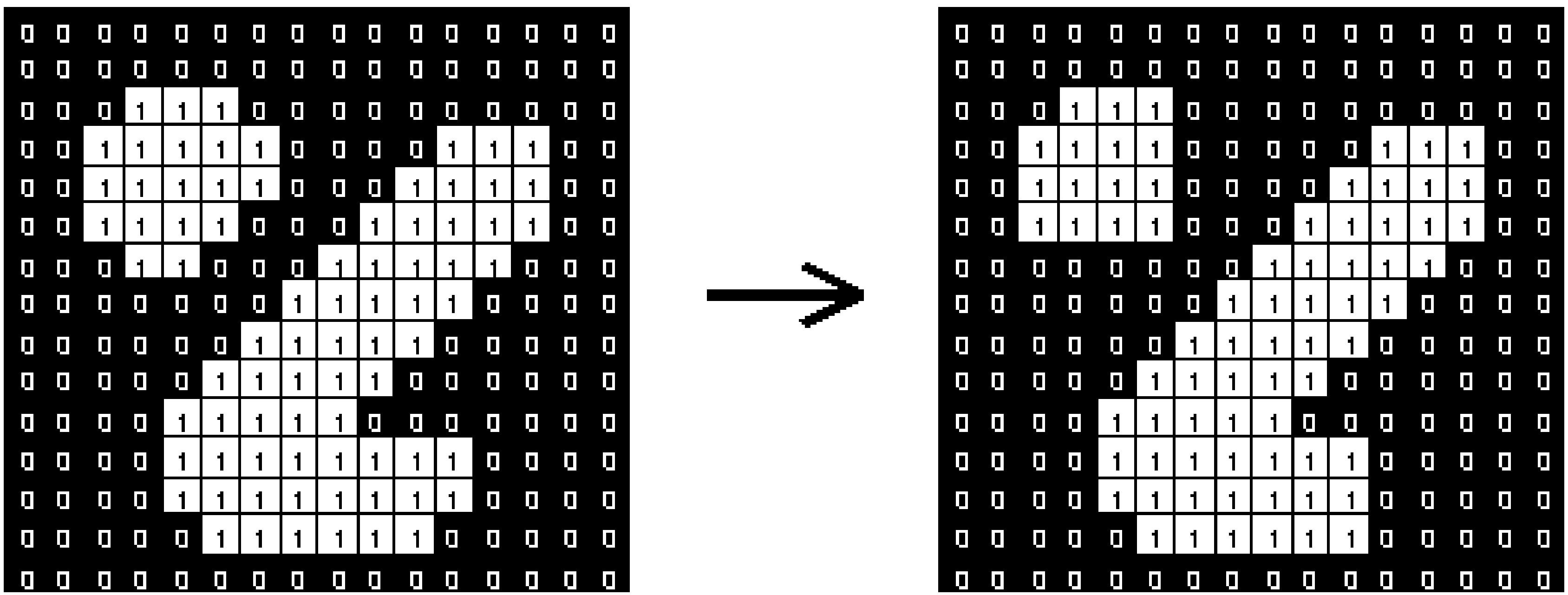
- Opening
  - **Erosion**, followed by **dilation**.
  - Less destructive than an erosion.
  - **Adapts** image shape to kernel shape.
- Closing
  - **Dilation**, followed by **erosion**.
  - Less destructive than a dilation.
  - Tends to **close** shape irregularities.





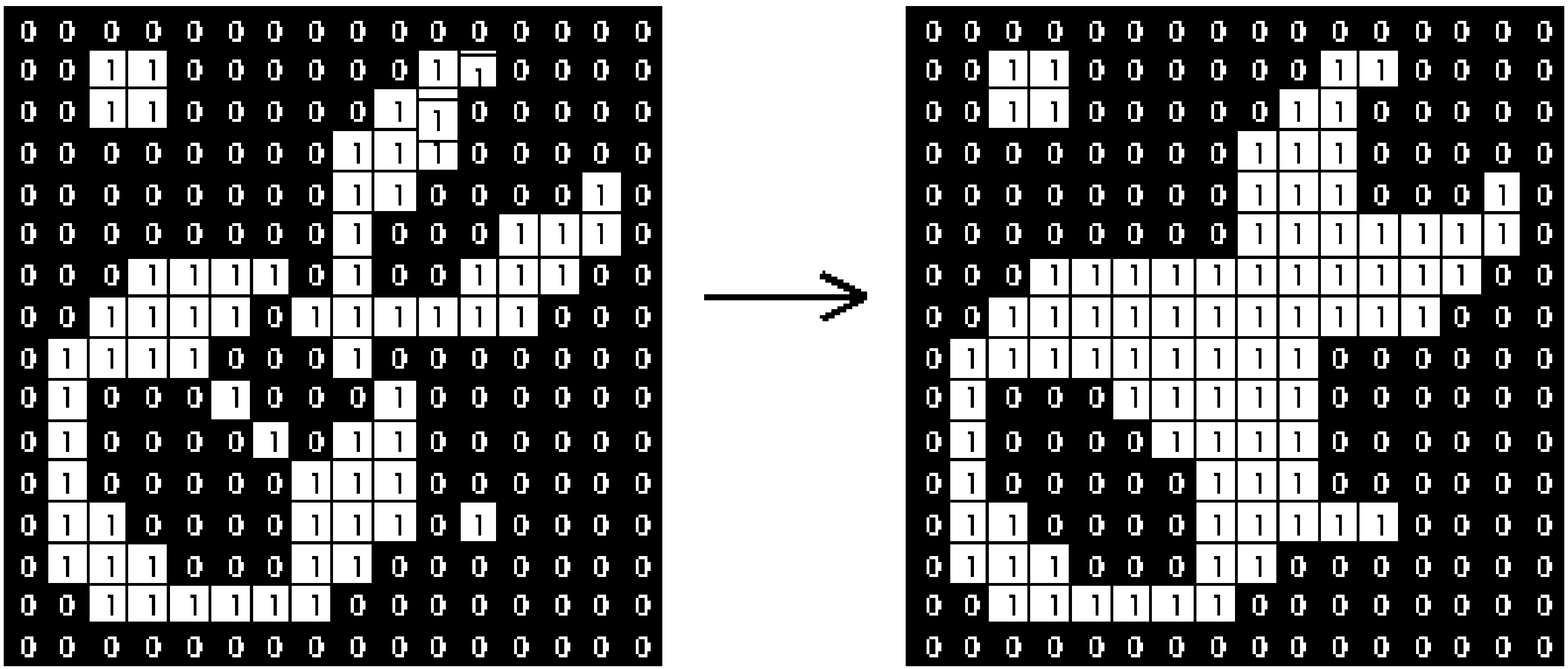
Opening

- Example using a 3x3 morphological kernel



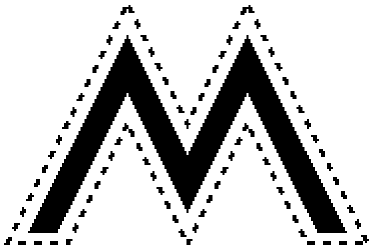
Closing

- Example using a 3x3 morphological kernel



Core morphological operators

Dilation

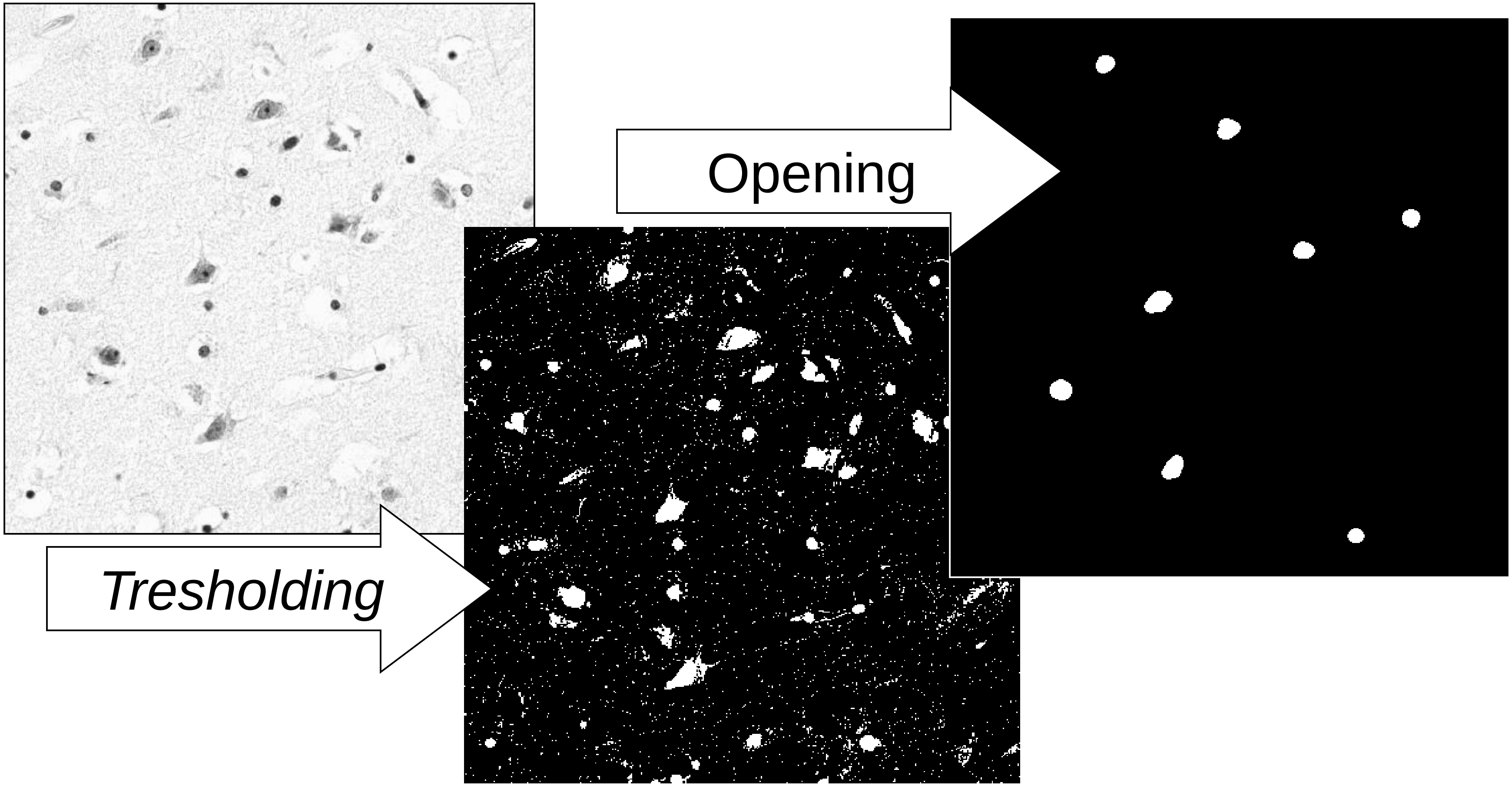


Erosion

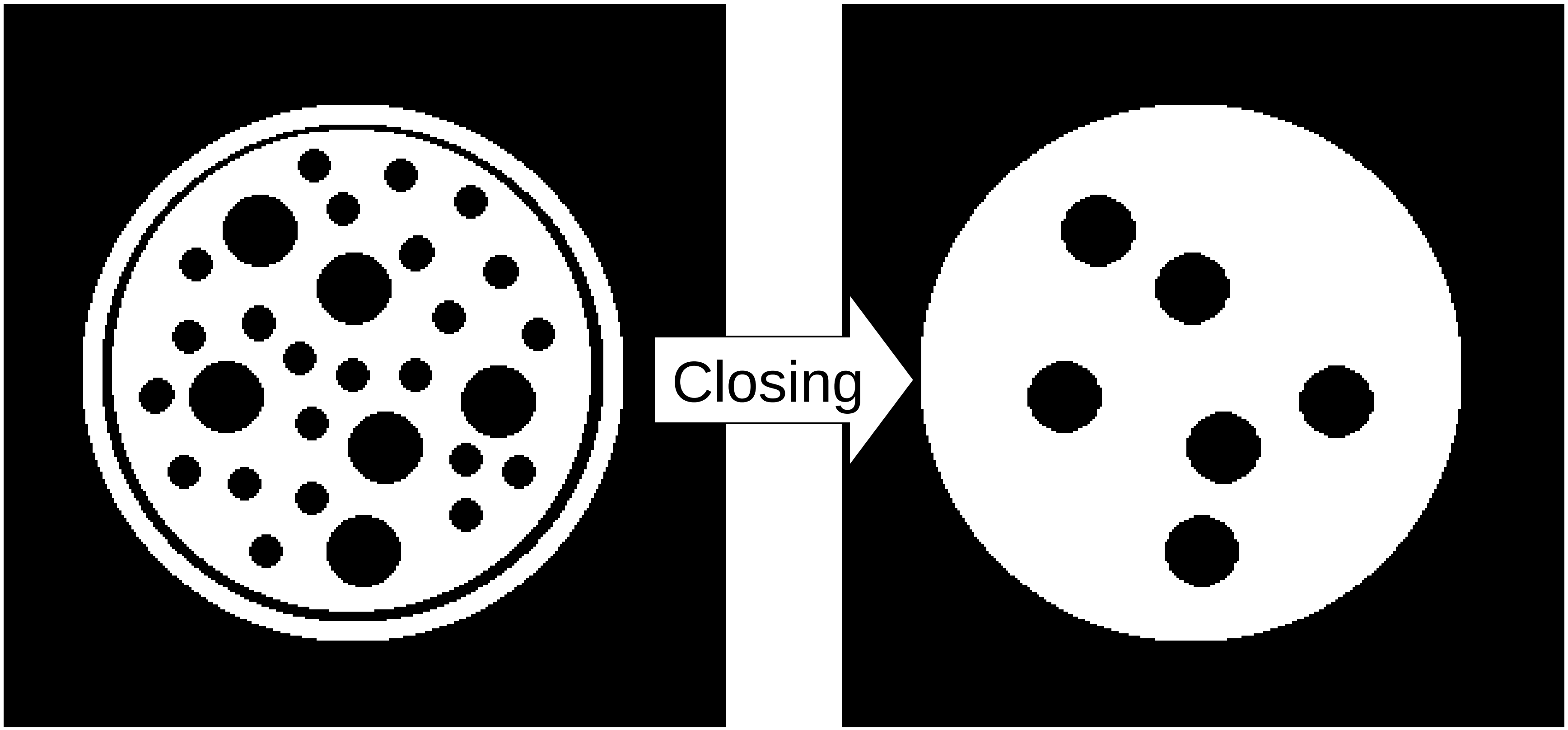
Closing

Opening

Example: Opening

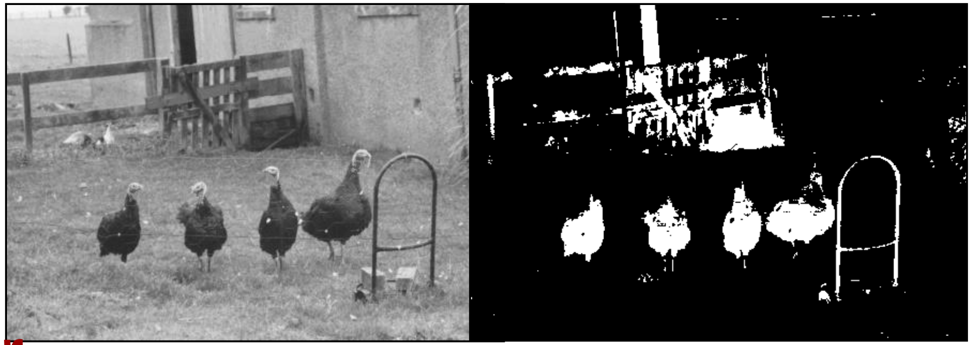


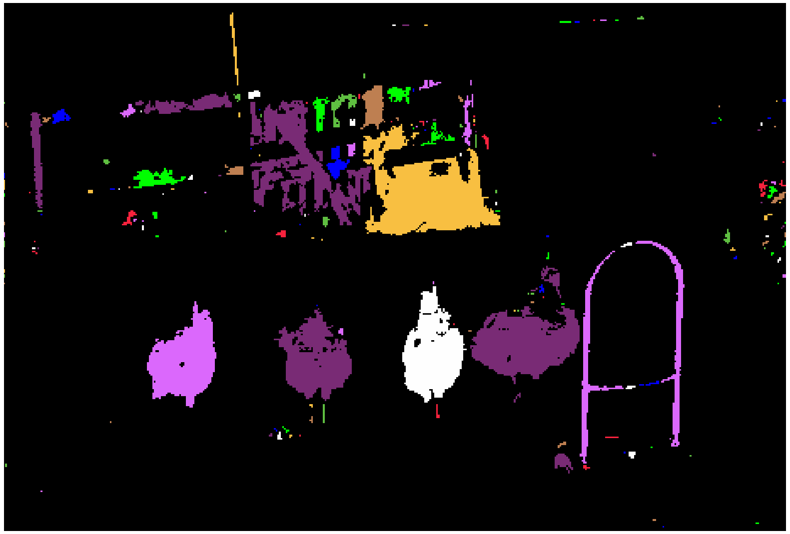
Example: Closing



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