UNIVERSITAT DE BARCELONA

>>> IMAGE PROCESSING AND COMPUTATIONAL PHOTOGRAPHY

SESSION 4b: BINARY IMAGE ANALYSIS.

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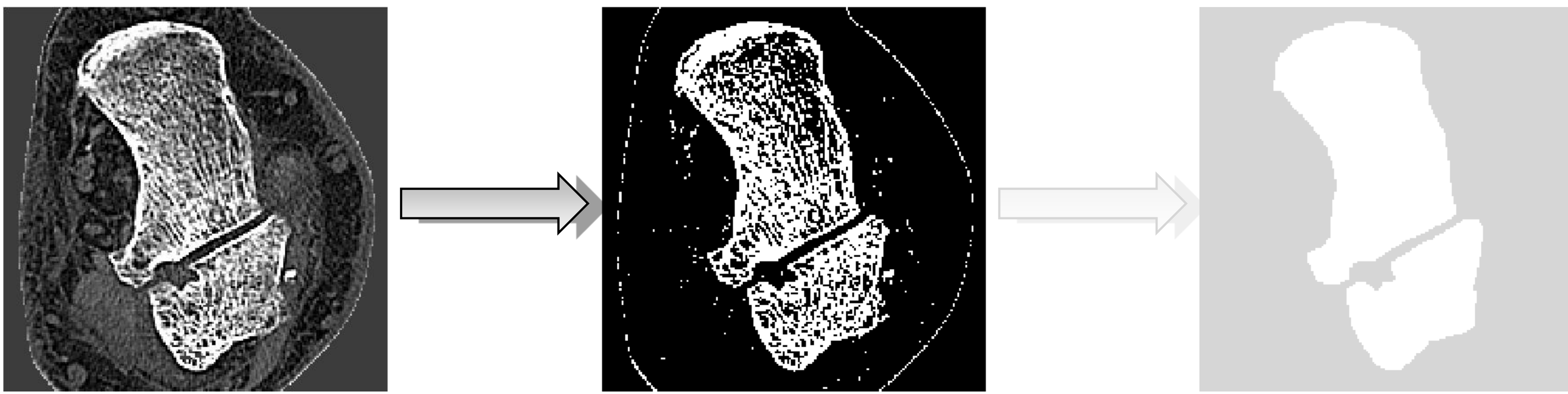
BINARY IMAGES

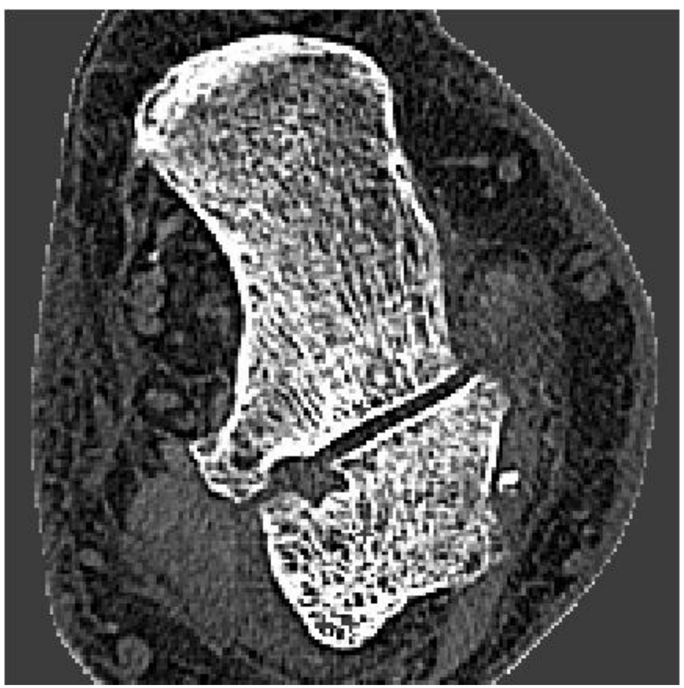


Creation

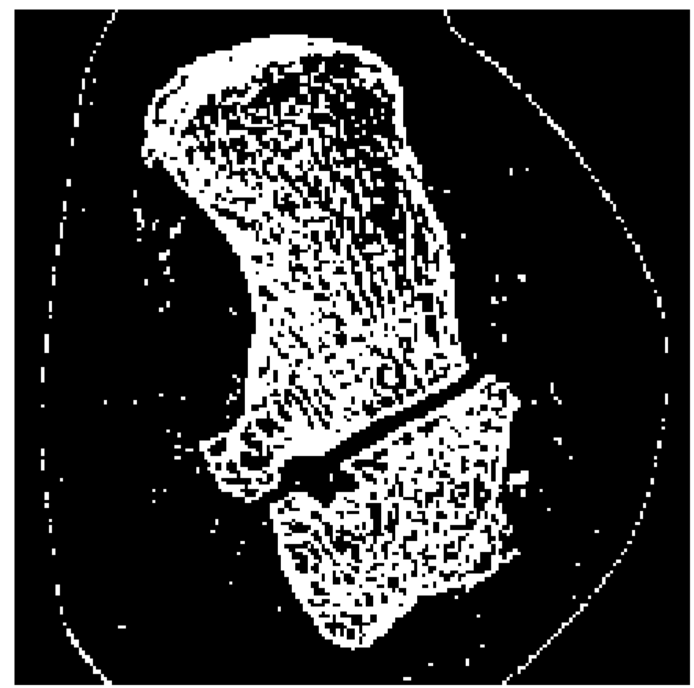
Processing

SEGMENTATION

- Separating object from background in a grayscale picture
  - A simple method: thresholding by pixel (voxel) color
    - All pixels (voxels) with color above a threshold are set to 1



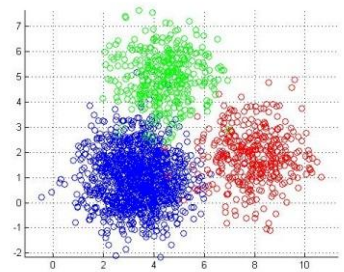
Grayscale picture

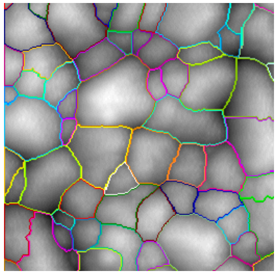


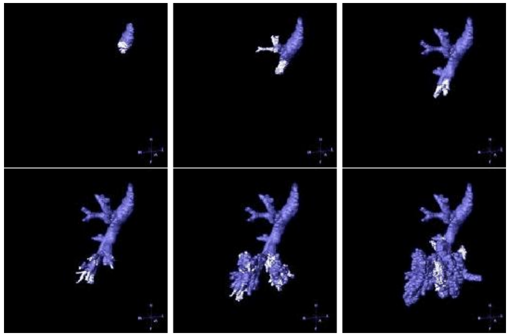
Thresholded binary picture

SEGMENTATION

- Separating object from background in a grayscale picture
  - A simple method: thresholding by pixel (voxel) color
  - Other methods:
    - K-means clustering
    - Watershed
    - Region growing
    - Snakes and Level set
    - Graph cut
    - …







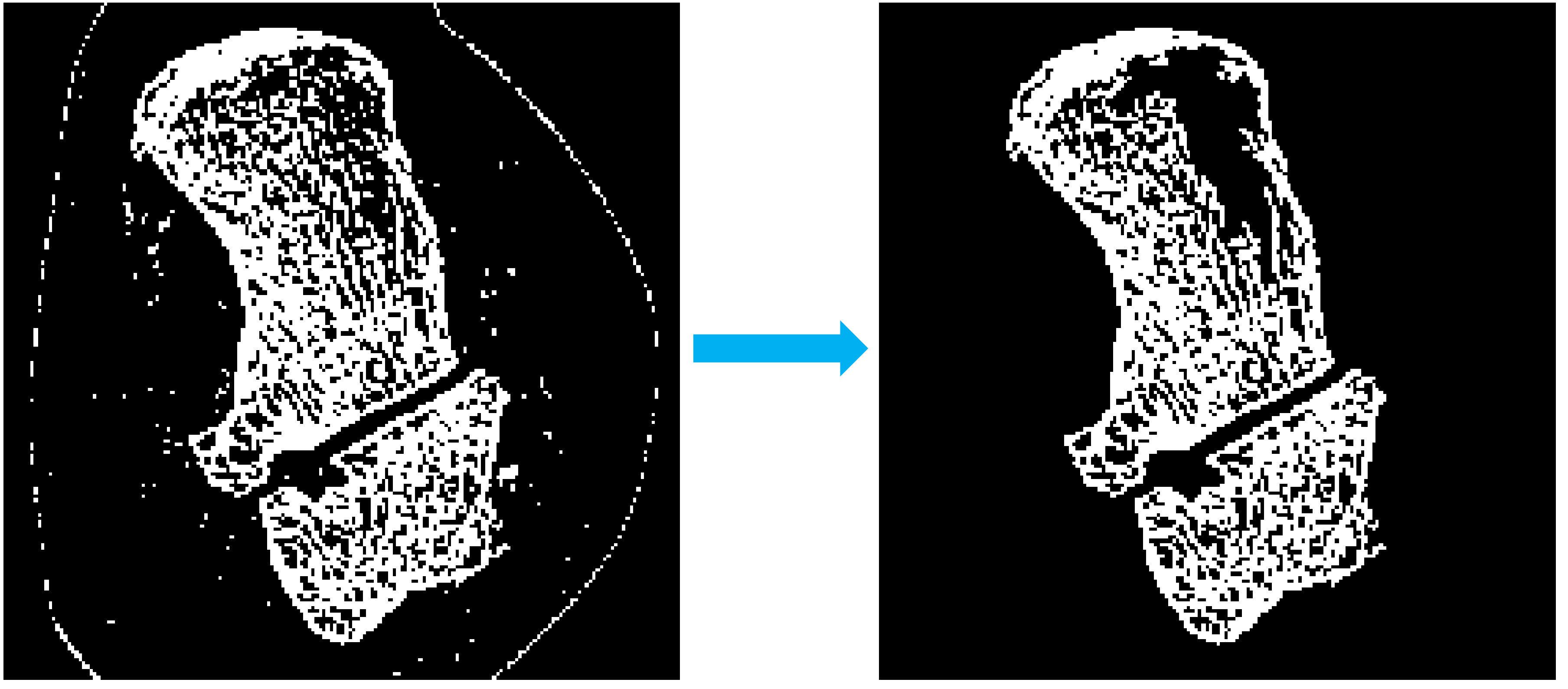
OTSU'S METHOD

$$\text{minimize}_t \quad p_+(t)\sigma_+^2(t) + p_-(t)\sigma_-^2(t)$$

Goal: Reduce the intra-class variance. The best thresholding should divide the image evenly such that a similar amount of pixels goes to each region. We can do that by weighting each variance by the amount of pixels considered.

P+ is the number of pixels in the positive region.
Sigma+ is the standard deviation of the pixels of the positive region

Connected Components



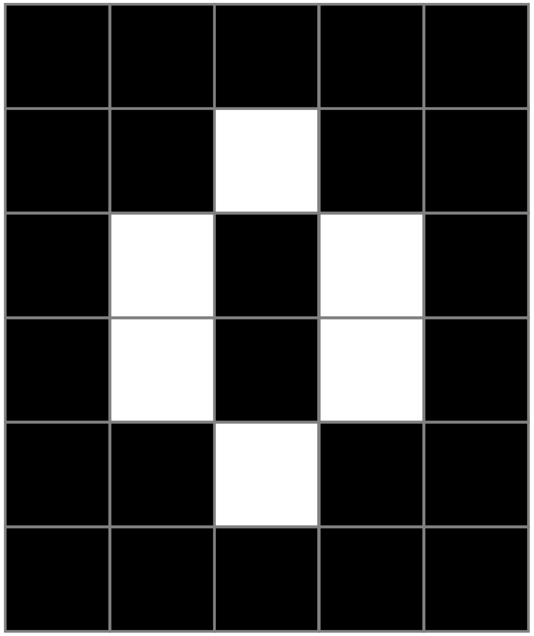
Take the largest 2 components of the object

CONNECTIVITY

We talk about connectivity referring to the definition of the neighbors of a Pixel. We may find 2 kinds of connectivity, either 4 or 8.

This allows to define the blob.

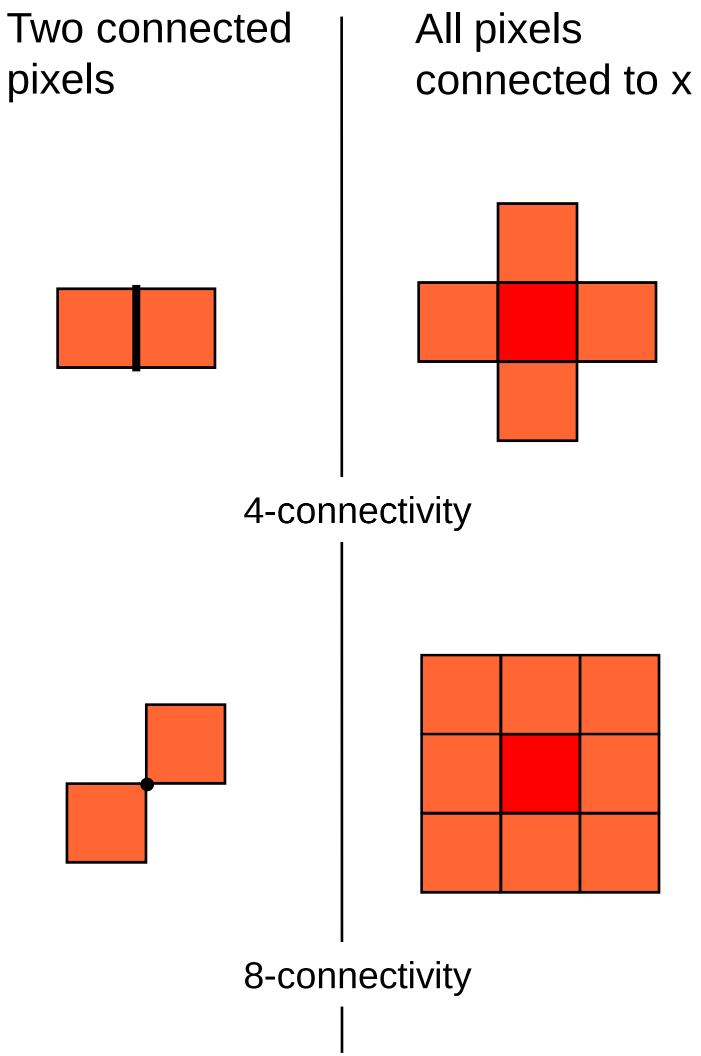
Connected Components



How many connected components are there in the object?

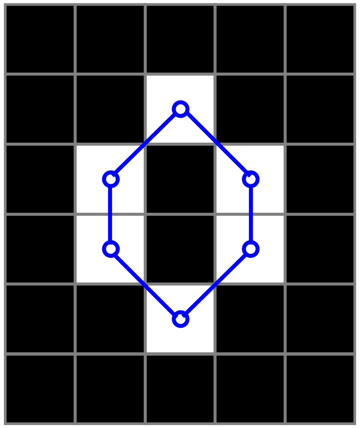
Connectivity (2D)

- Two pixels are connected if their squares share:
  - A common edge
    - 4-connectivity
  - A common vertex
    - 8-connectivity

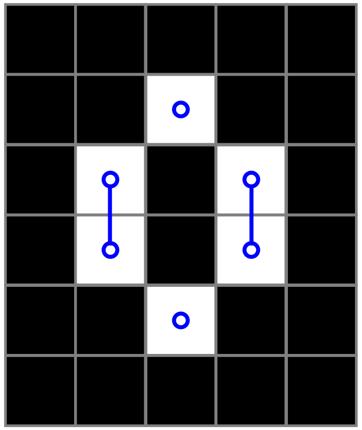


Connectivity (2D)

- Connected component
  - A maximum set of pixels (voxels) in the object or background, such that any two pixels (voxels) are connected via a path of connected pixels (voxels)



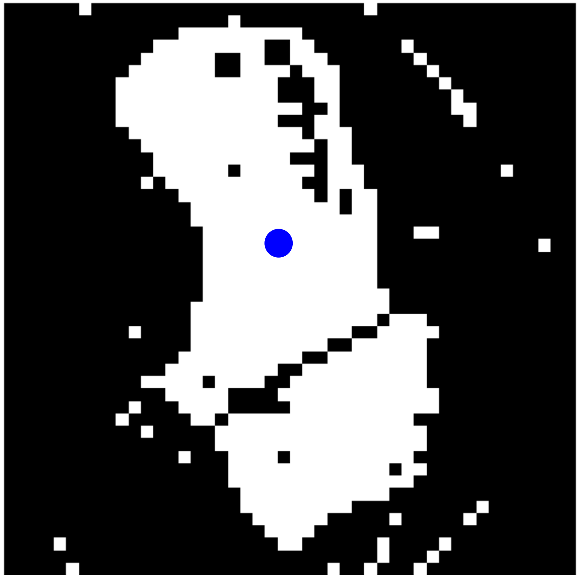
8-connected object
(1 component)

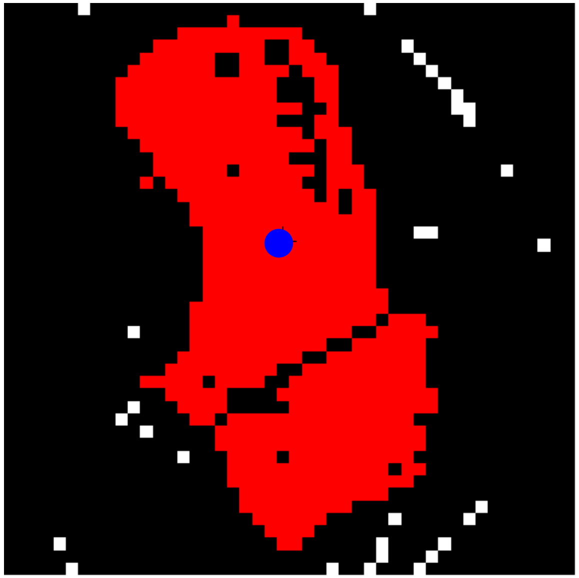


4-connected object
(4 components)

Connectivity (2D)

- What is the component connected to the blue pixel?



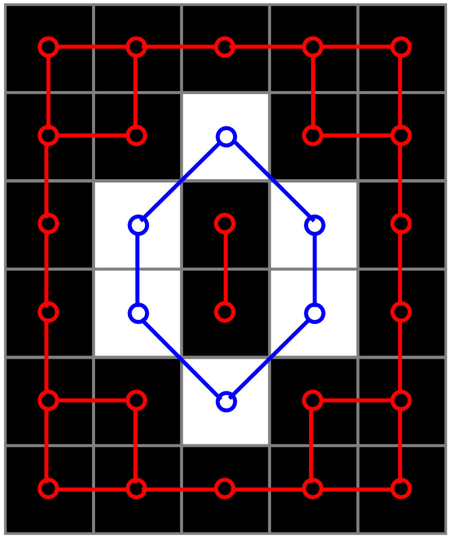


8-connectivity

4-connectivity

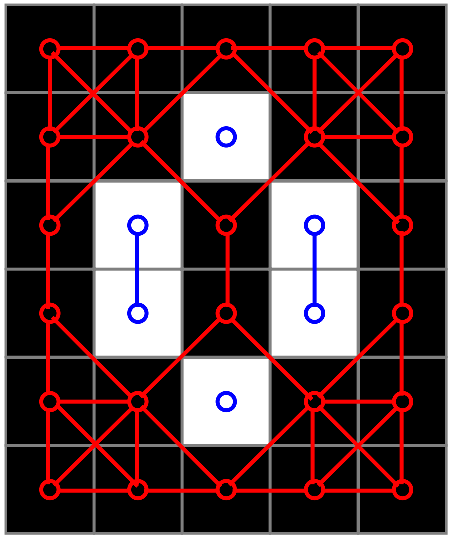
Connectivity (2D)

- Different connectivity for object (O) and background (B)
  - 2D pixels: 4- and 8-connectivity respectively for O and B (or B and O)



Object: 8-connectivity (1 comp)

Background: 4-connectivity (2 comp)

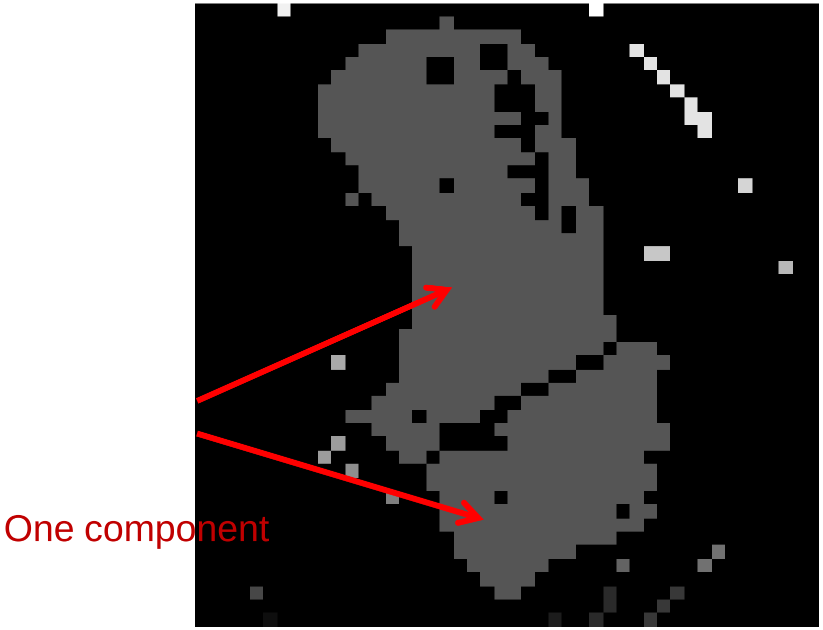


Object: 4-connectivity (4 comp)

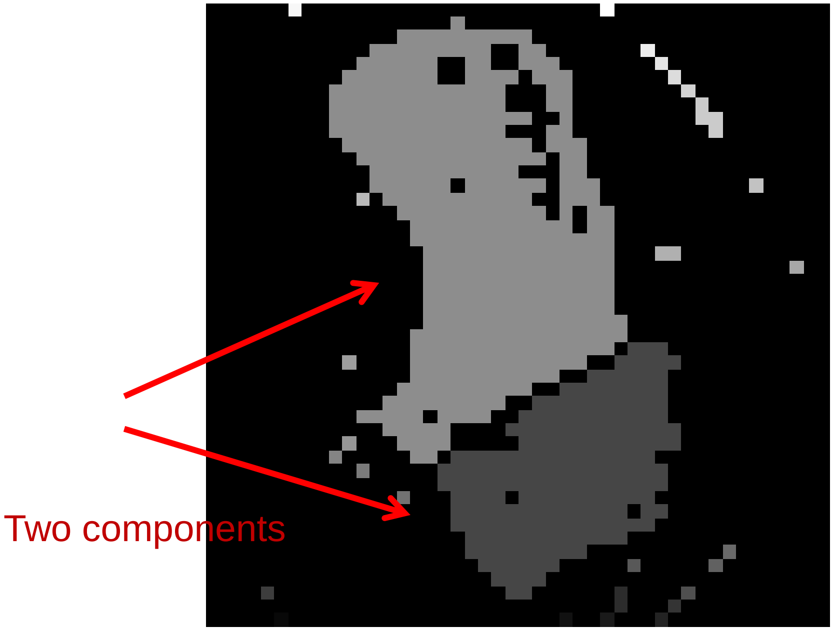
Background: 8-connectivity (1 comp)

Finding Connected Components

- Labeling all components in an image:
  - Loop through each pixel (voxel). If it is not labeled, find its connected component, then label all pixels (voxels) in the component.

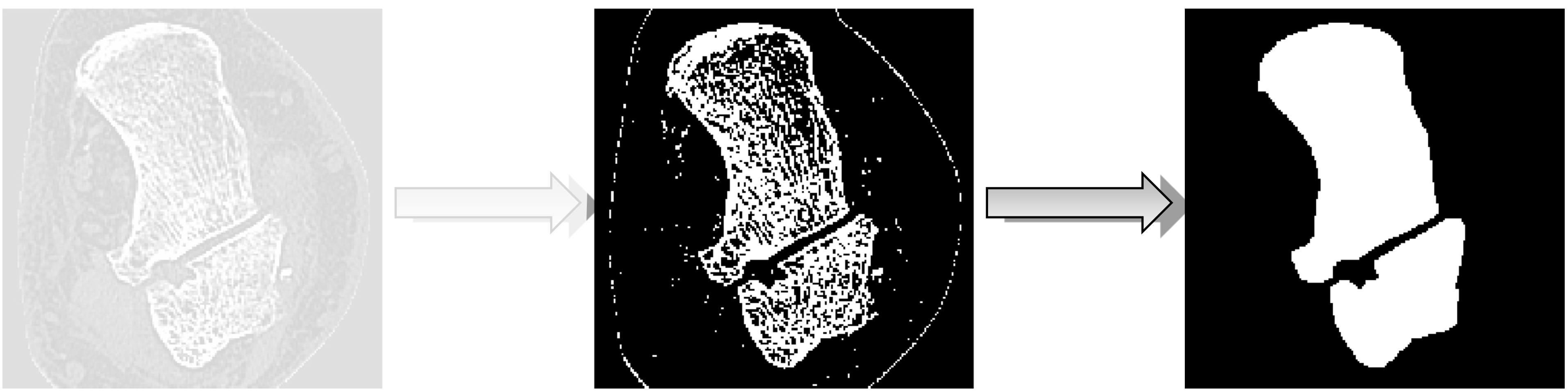


8-connected object



4-connected object

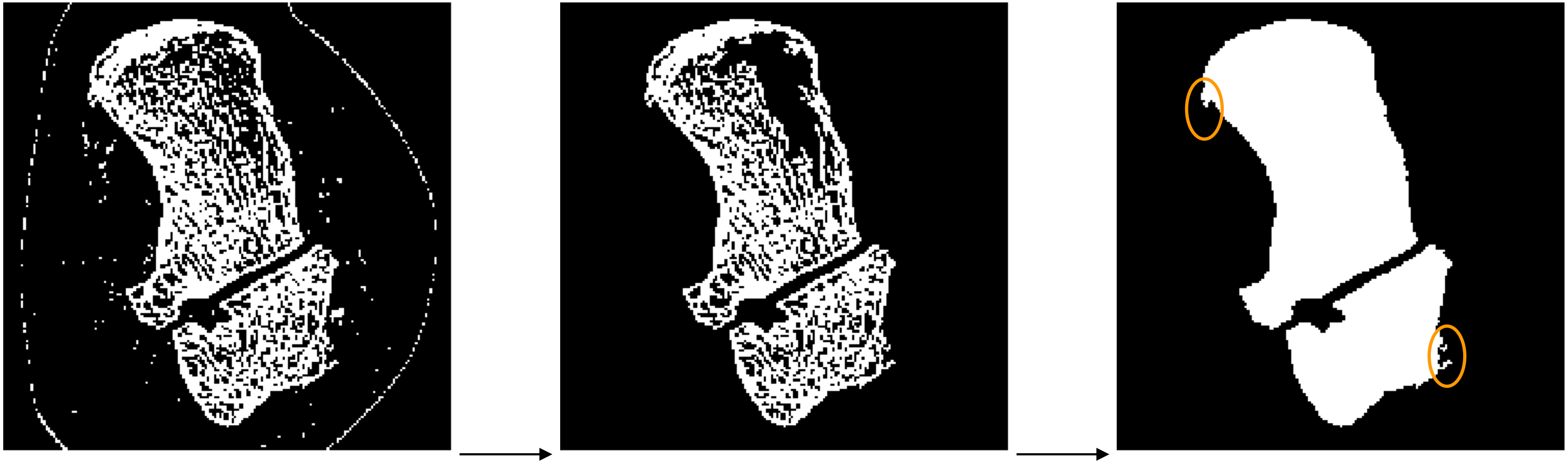
Binary Pictures



Creation Processing

Using Connected Components

- Pruning isolated islands from the main object
- Filling interior holes of the object

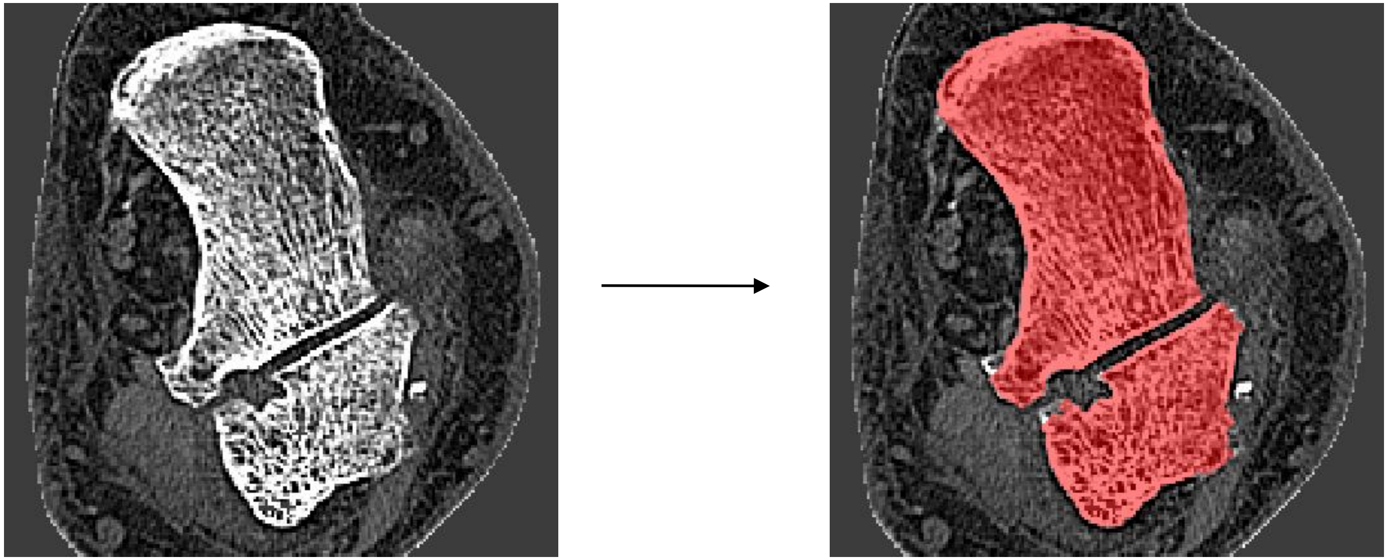


Take the largest 2 components of the object

Invert the largest component of the background

EXAMPLE

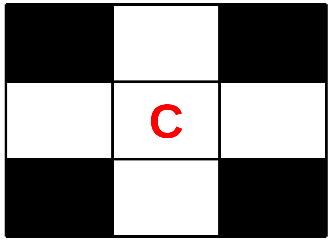
- A simple 2D segmentation routine
  - Initial segmentation using thresholding
  - Using connected components and opening/closing to “clean up” the segmentation.

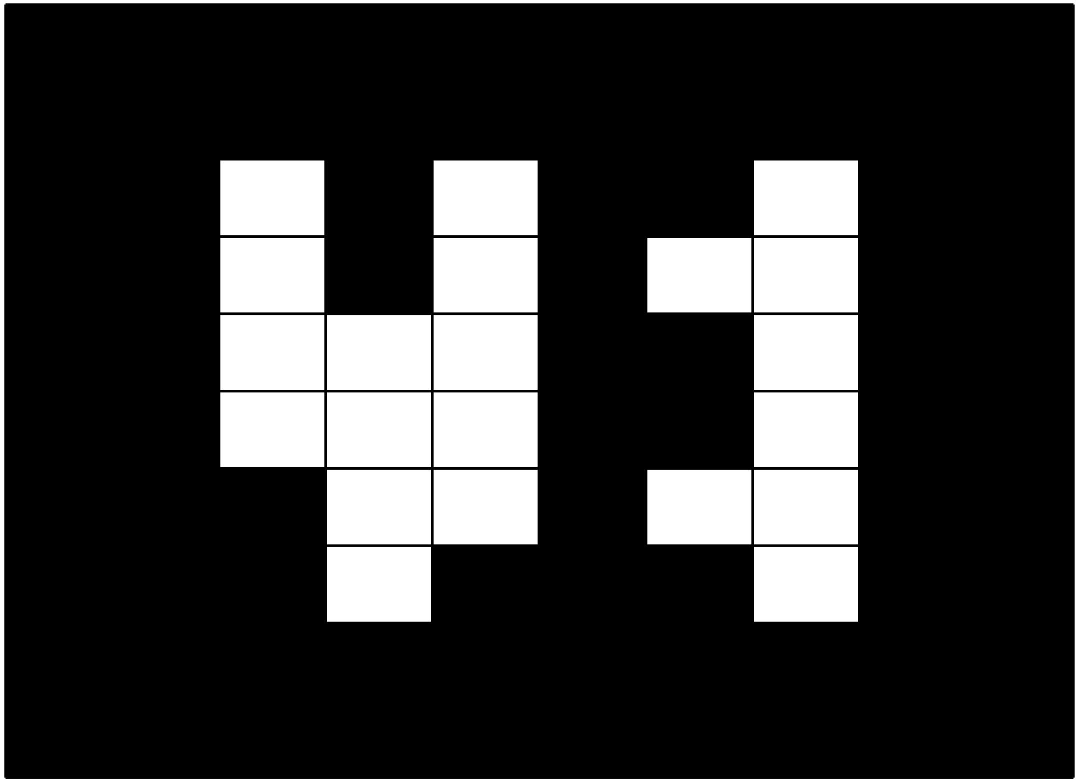


Mathematical morphology operations

Operations are defined by an structuring element and the image we want to process

Structuring element is defined by a neighborhood and a center



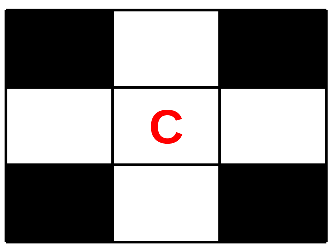


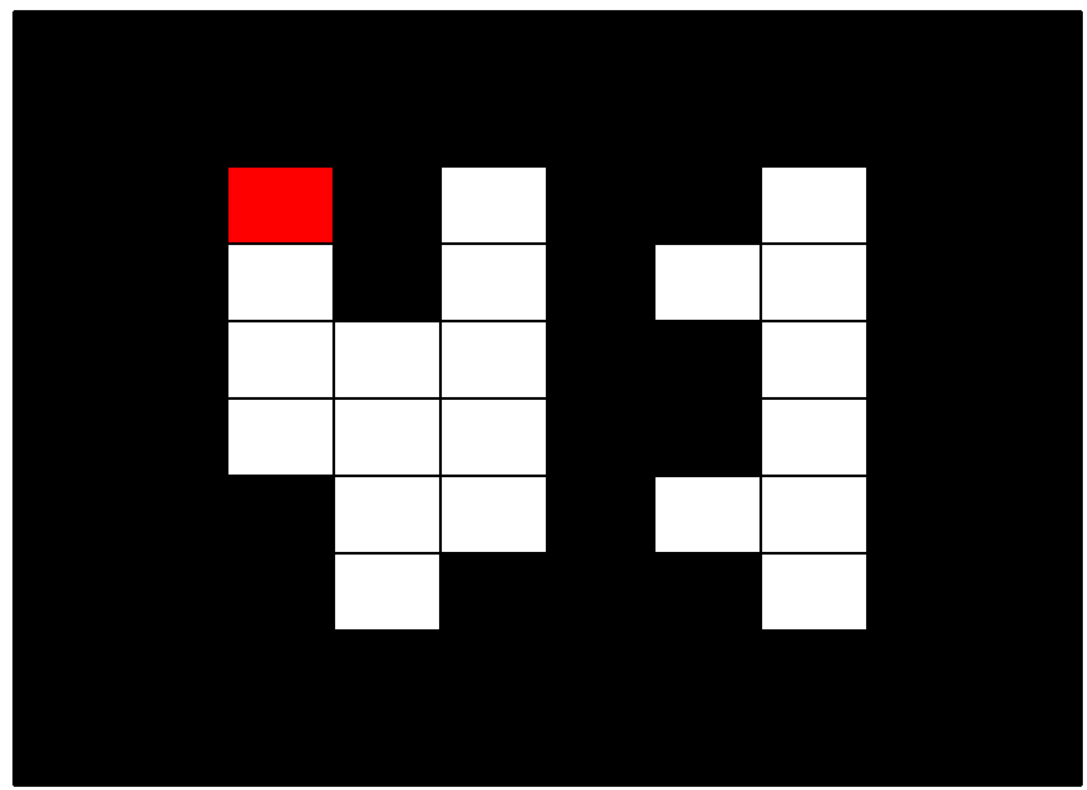
Basic operations: Dilation

Let p=(p_x,p_y) the coordinates of all white pixels in image I and s=(s_x,s_y) the coordinates of a white pixel in the structuring element with respect to the center:

The dilation is defined as the union of the translations p + s for all s in the structuring element.

$$D = \{p + s,\ \forall s \in S,\ \forall p \in P\}$$





Example:
S = {(0,-1),(0,0),(-1,0),(0,+1),(+1,0)}

p = (3,3)

Basic operations: Dilation

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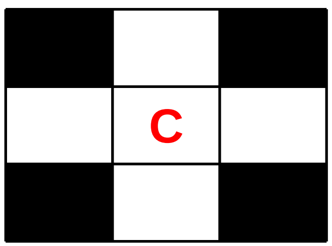
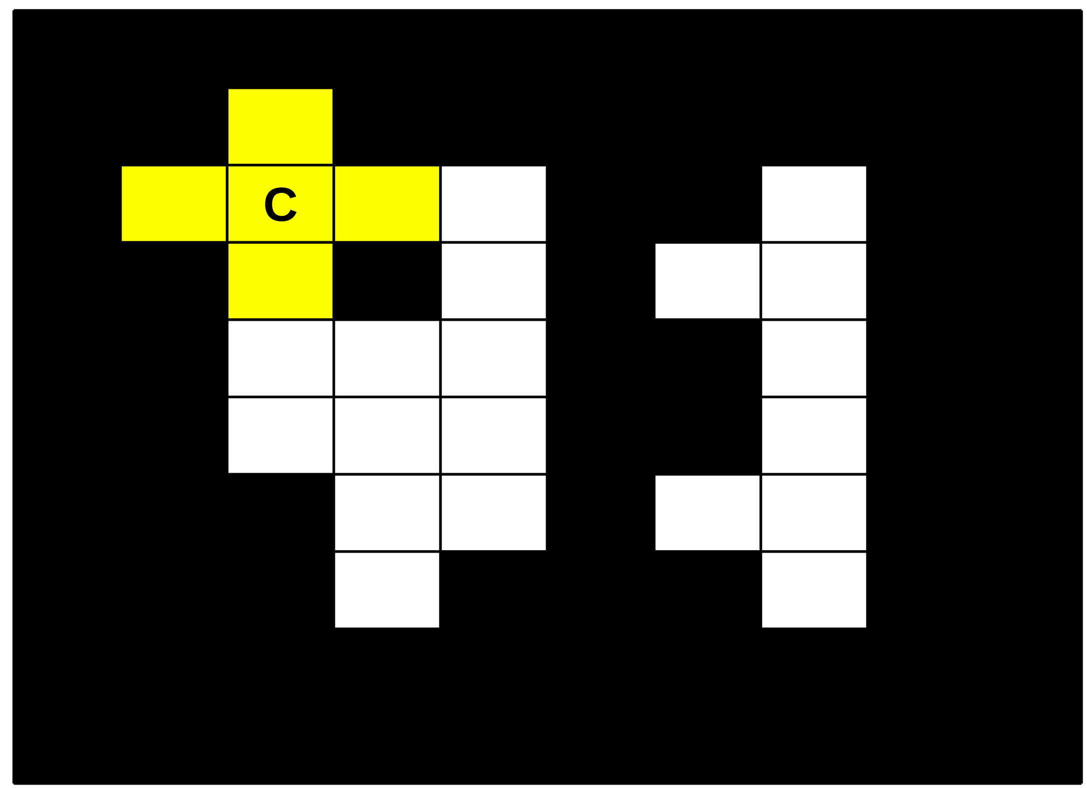




Example:
S = {(0,-1),(0,0),(-1,0),(0,+1),(+1,0)}

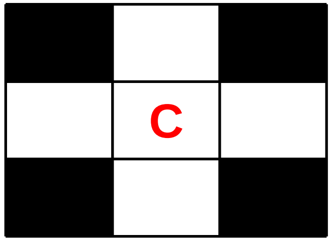
p = (3,3)

p+s = {(3,2),(3,3),(2,3),(3,4),(4,3)}

Basic operations: Dilation in practice

Put the SE over all white pixels of the image

$$D = \{p + s,\ \forall s \in S,\ \forall p \in P\}$$



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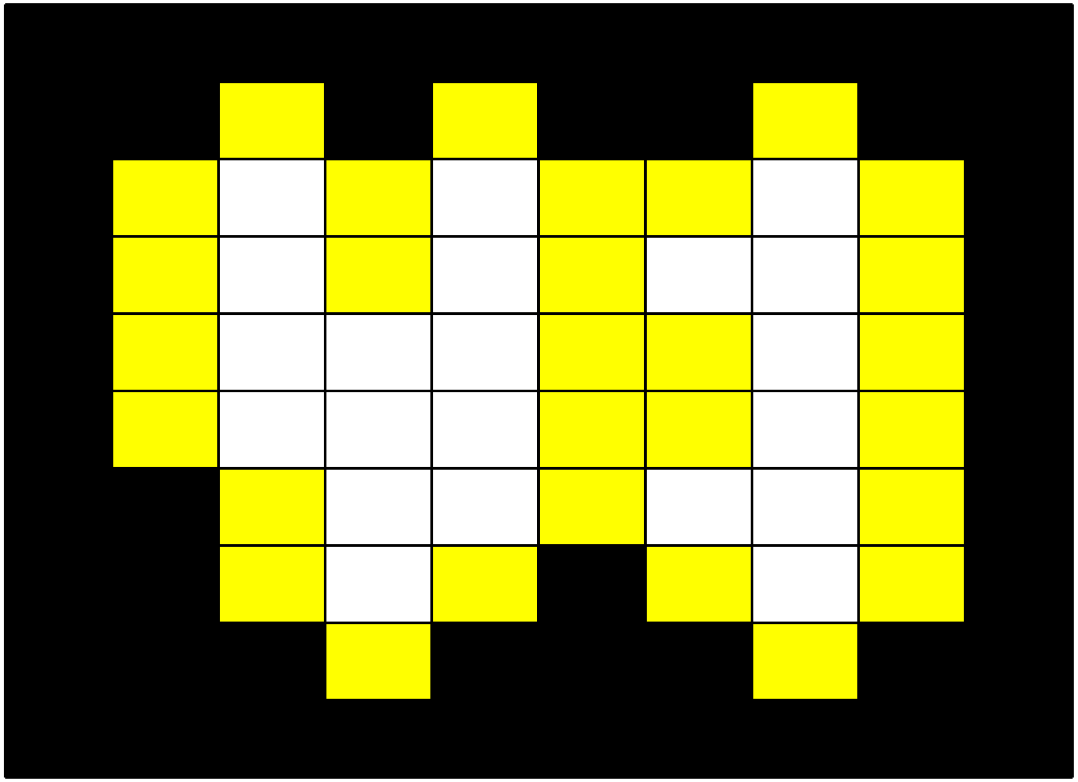
p = (3,3)

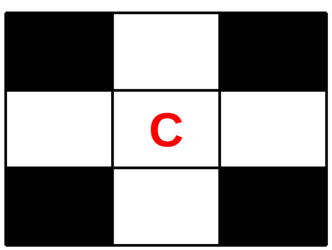
p+s = {(3,2),(3,3),(2,3),(3,4),(4,3)}

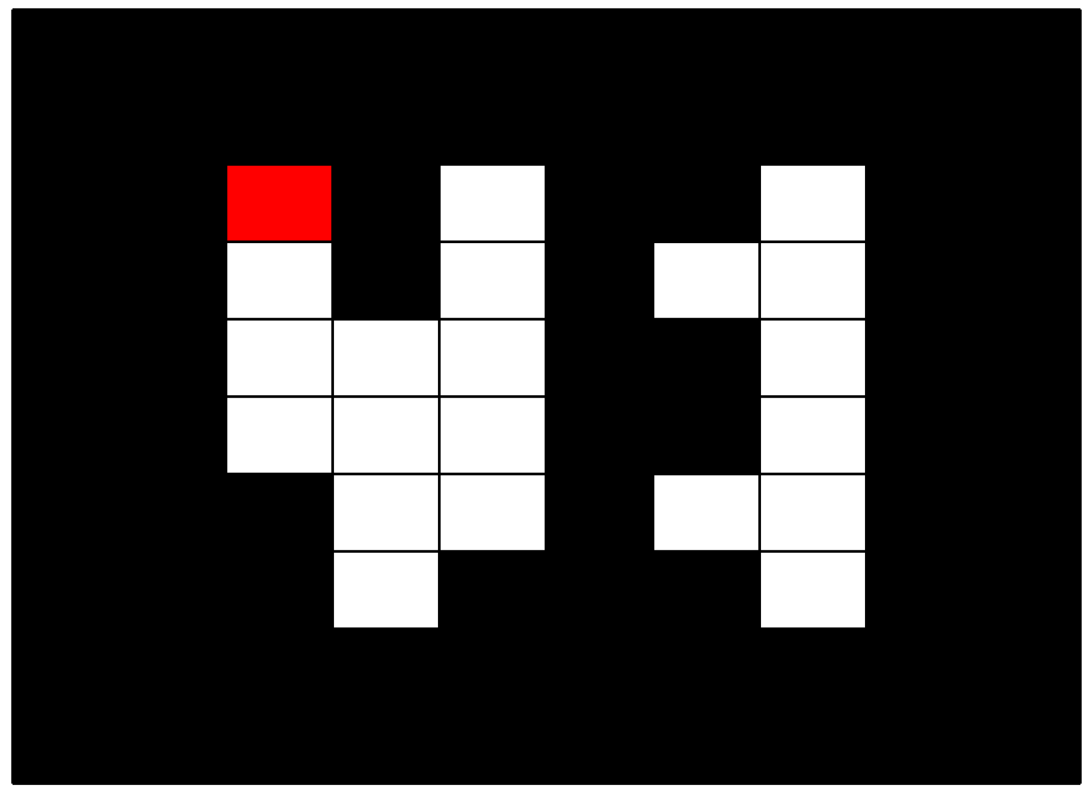


Basic operations: Erosion

Let p=(p_x,p_y) the coordinates of a pixel in the image and P the set of the coordinates of all white pixels in image I. Let s=(s_x,s_y) the coordinates of pixel in the structuring element and S the set of the coordinates of all white pixel in the structuring element with respect to the center:

The erosion is defined as the elements $E = \{p|\ p + s \in P,\ \forall s \in S\}$





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p = (3,3)

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Let p=(p_x,p_y) the coordinates of a pixel in the image and P the set of the coordinates of all white pixels in image I. Let s=(s_x,s_y) the coordinates of pixel in the structuring element and S the set of the coordinates of all white pixel in the structuring element with respect to the center:

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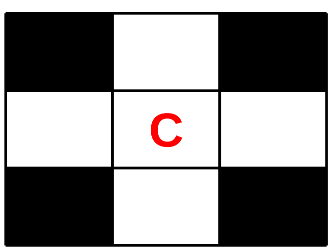
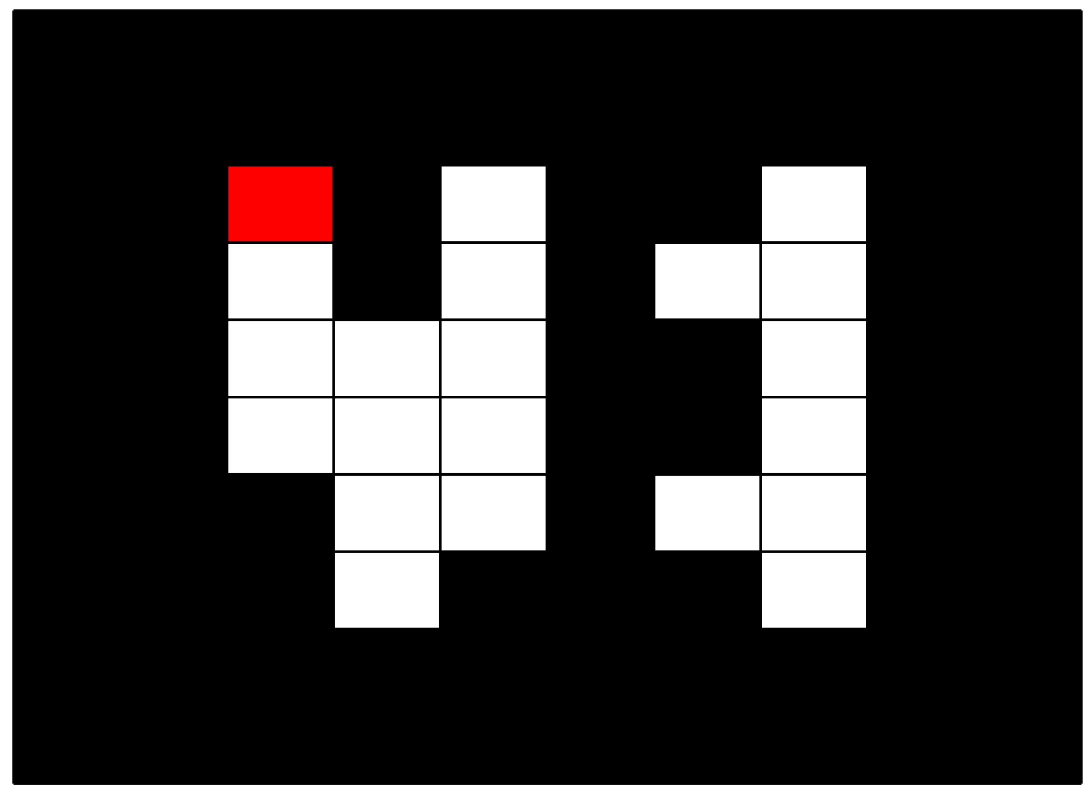




Example:
S = {(0,-1),(0,0),(-1,0),(0,+1),(+1,0)}

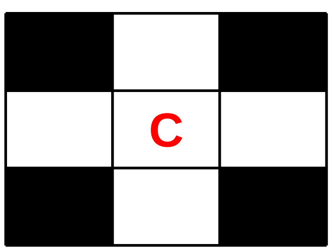
p = (3,3)

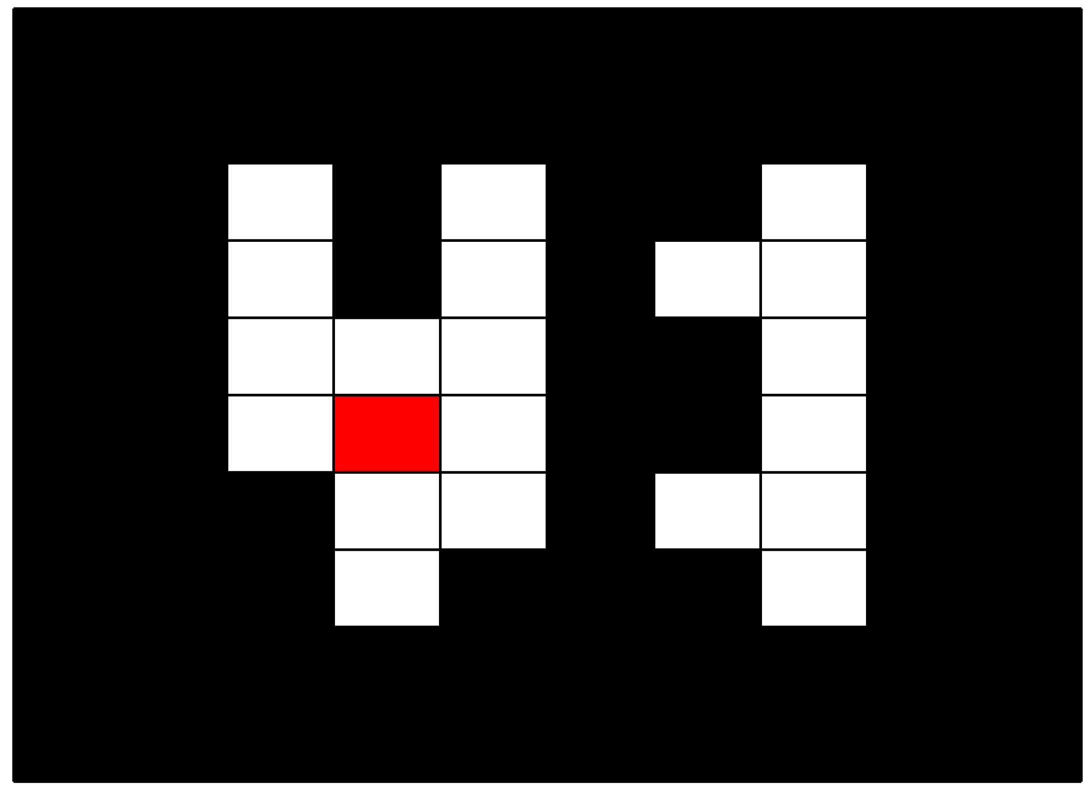
p+s = {(3,2),(3,3),(2,3),(3,4),(4,3)} pertanyen a P?

Basic operations: Erosion

Let p=(p_x,p_y) the coordinates of a pixel in the image and P the set of the coordinates of all white pixels in image I. Let s=(s_x,s_y) the coordinates of pixel in the structuring element and S the set of the coordinates of all white pixel in the structuring element with respect to the center:

The erosion is defined as the elements $E = \{p |\, p + s \in P,\ \forall s \in S\}$





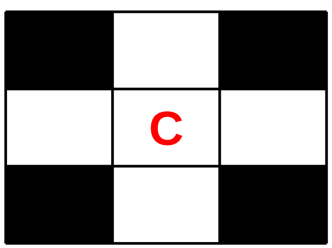
Example:
S = {(0,-1),(0,0),(-1,0),(0,+1),(+1,0)}

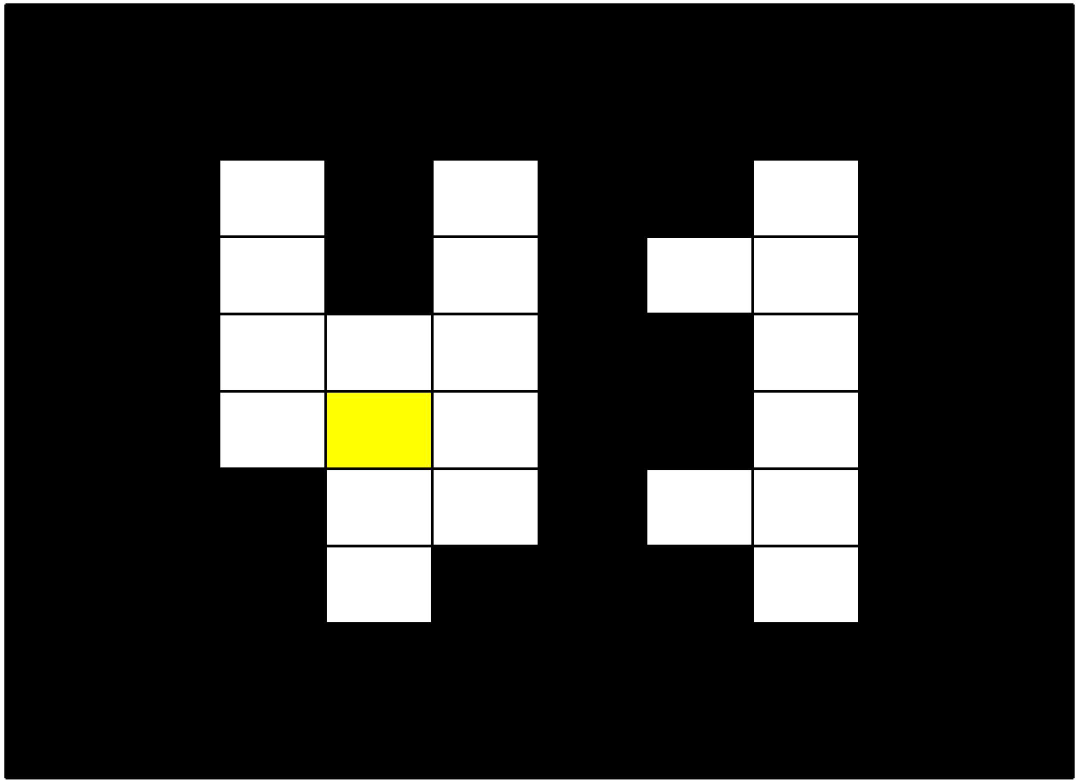
p = (6,4)

p+s = {(6,3),(6,4),(5,4),(6,5),(7,4)} pertanyen a P?

Basic operations: Erosion in practice

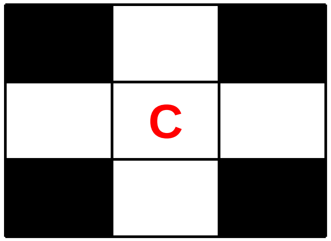
“Keep all the points in which the structuring element fits in the white region”
(only true if the center belongs to the inside of the structuring element)

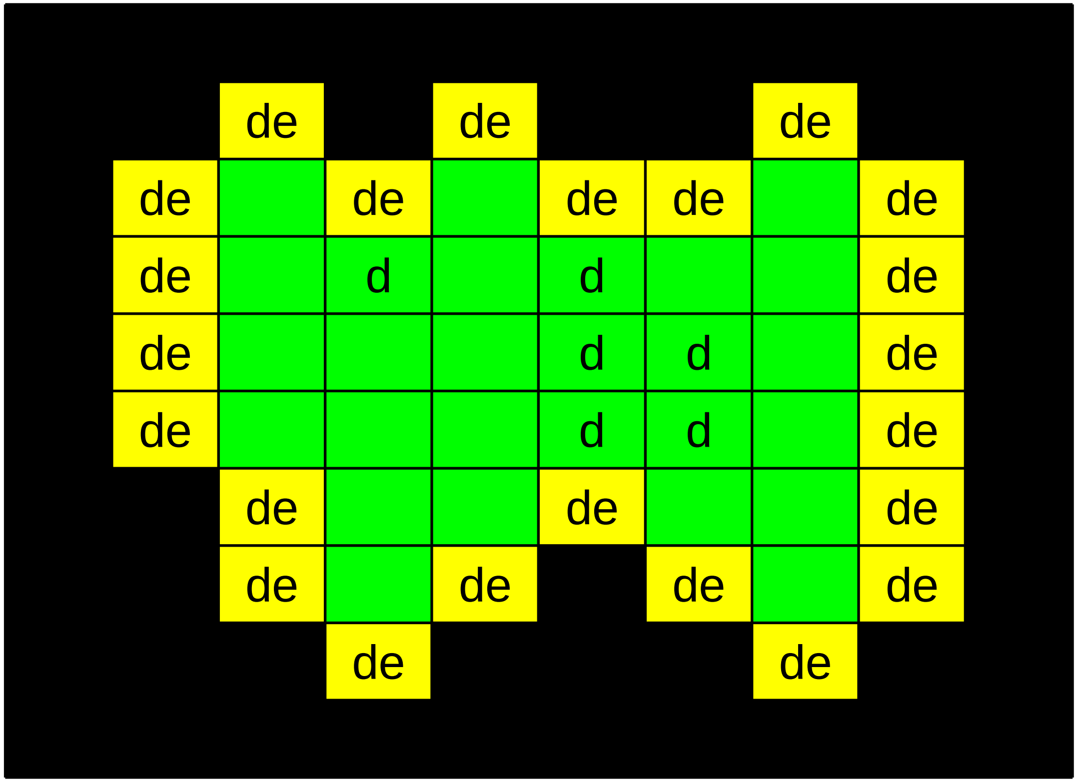




Composing operations:
Closing = Dilation + Erosion

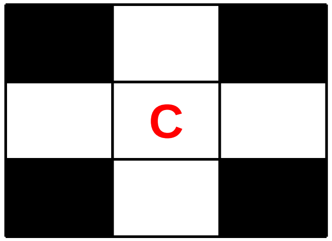
Recovers the original objects closing holes, and joining structures smaller than the SE

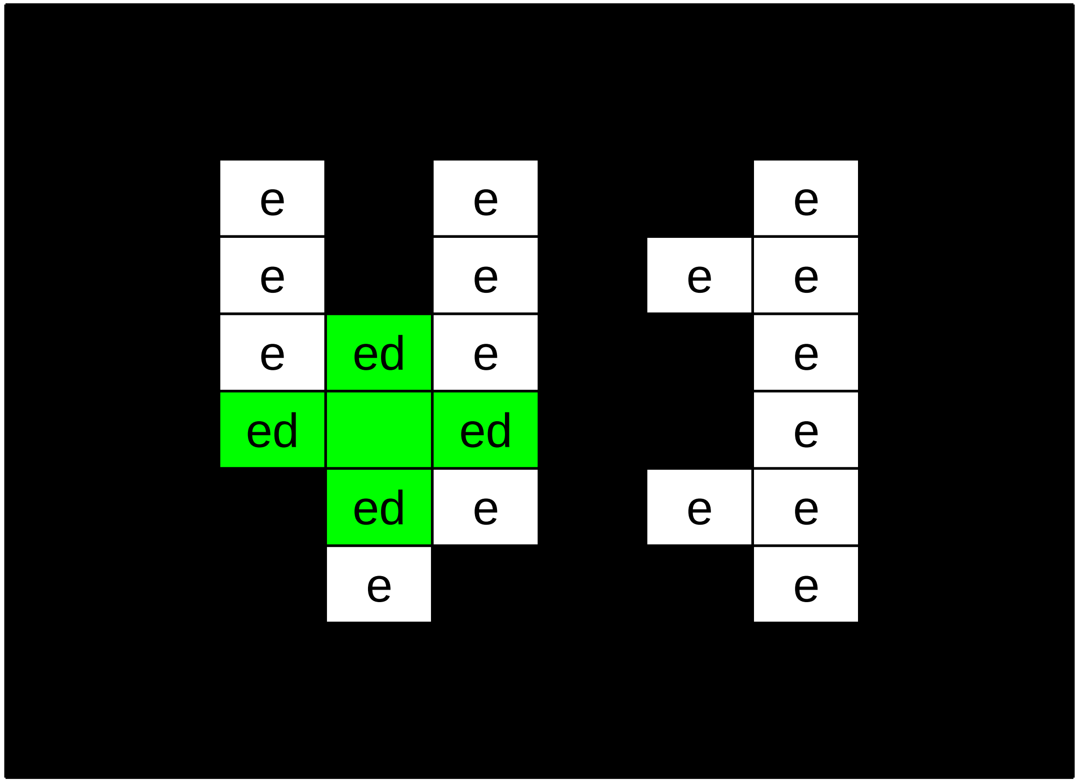




Composing operations:
Opening = Erosion + Dilation

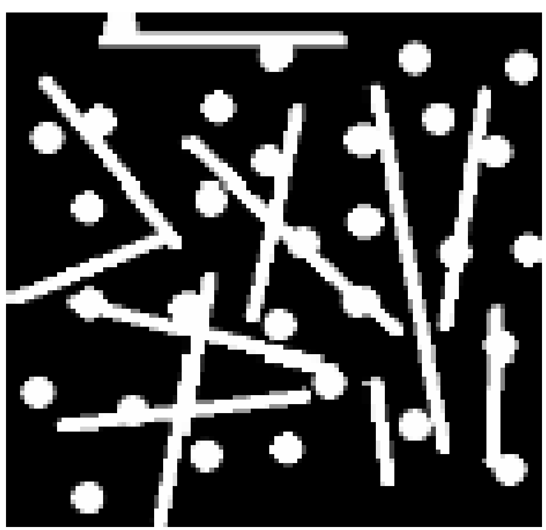
Removes parts of the elements not conforming the SE shape

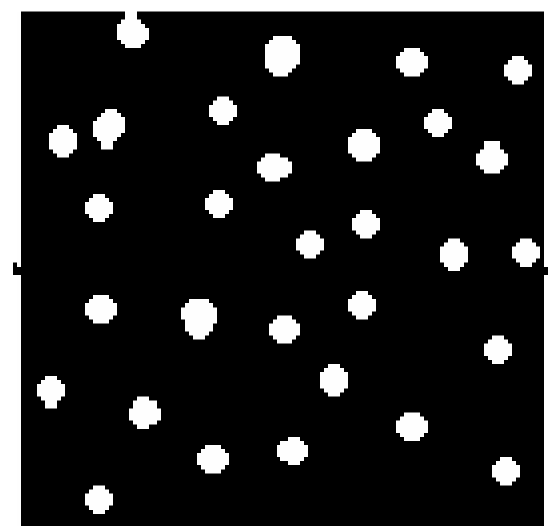




Aplicacions

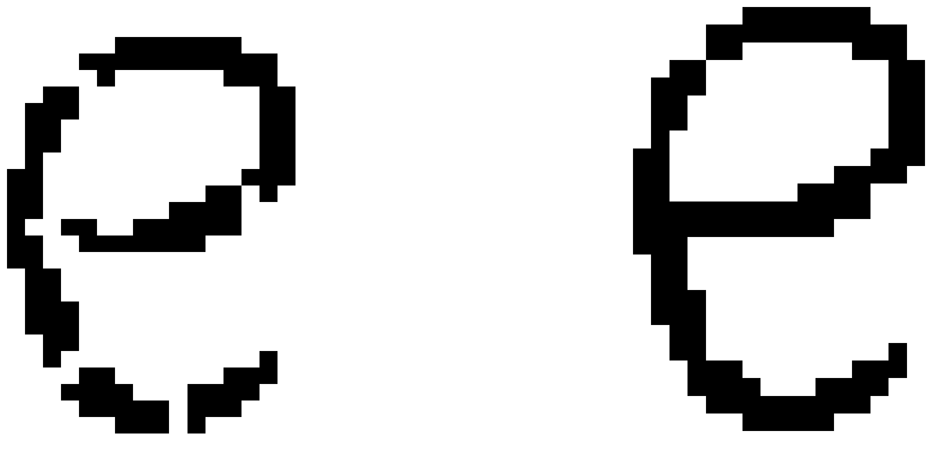
Separation of structures: If we know that we are looking for disk structures of 7 pixels of diameter, which operation would you use?





Aplicacions

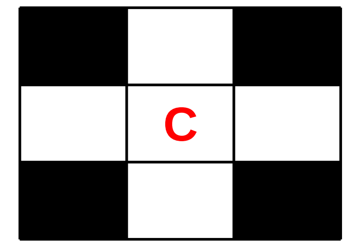
Restauration of binary scanned letters.



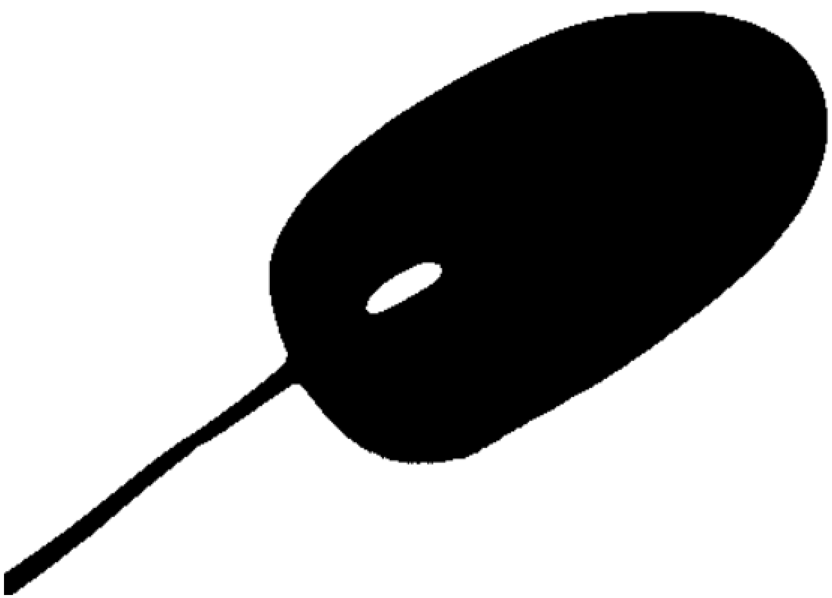
Which operation did I use?

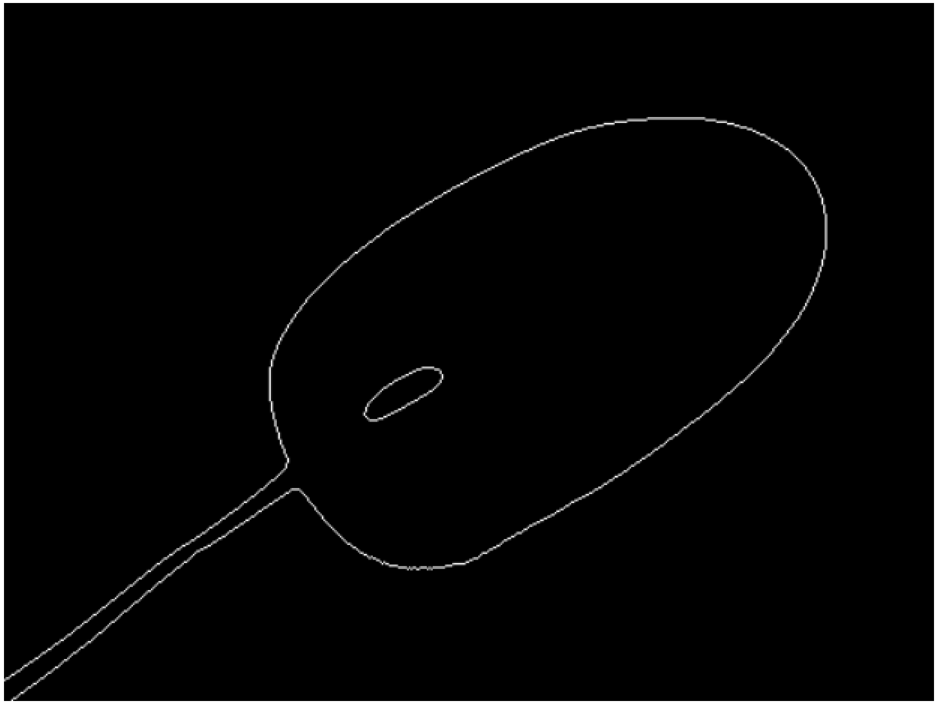
Morphological Gradient: Contour detection

Dilation(I)-I External contour
I – erosion(I) Internal contour
Dilation(i)-Erosion(i) Both contours



Inversa de I





Morphological Gradient: Contour detection

Dilation(I)-I External contour
I – erosion(I) Internal contour
Dilation(i)-Erosion(i) Both contours