Computer Vision

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Summary

- Morphological operations
  - Dilation, erosion
  - Opening, closing
- Segmentation
  - Thresholding
  - Region growing

Summary

- Morphological operations
  - Dilation, erosion
  - Opening, closing
- Segmentation
  - Thresholding
  - Region growing

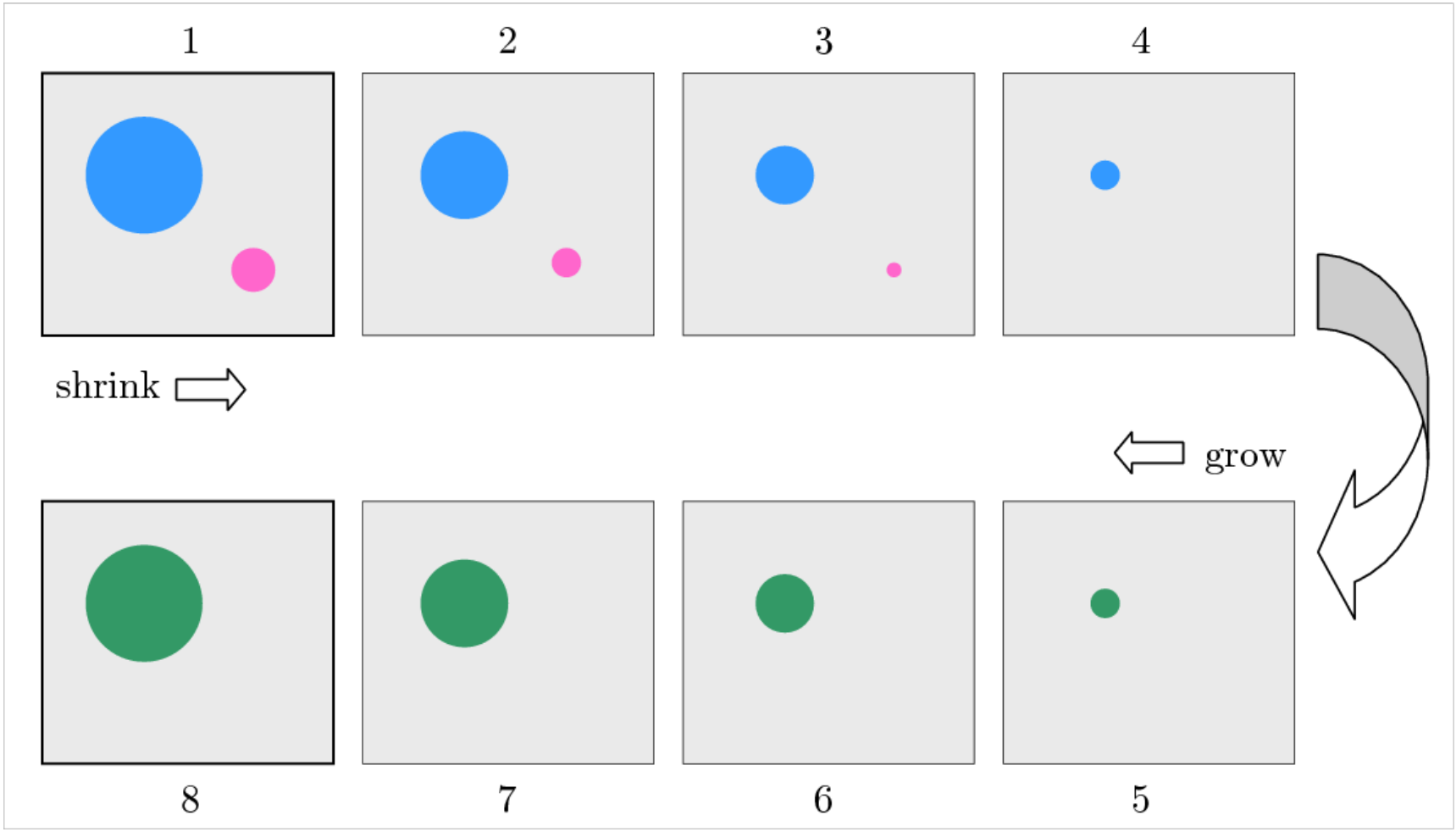
Morphological operations

- Morphological mathematics operates on images as a set of points
- Modify in a control way the structure/morphology of an image
- Typically used in binary images
- Can be used in graylevel ou colour image as well

- Used in Image Processing for
  - Filtering
  - Segmentation
  - Object description

Morphological operations

- Main idea

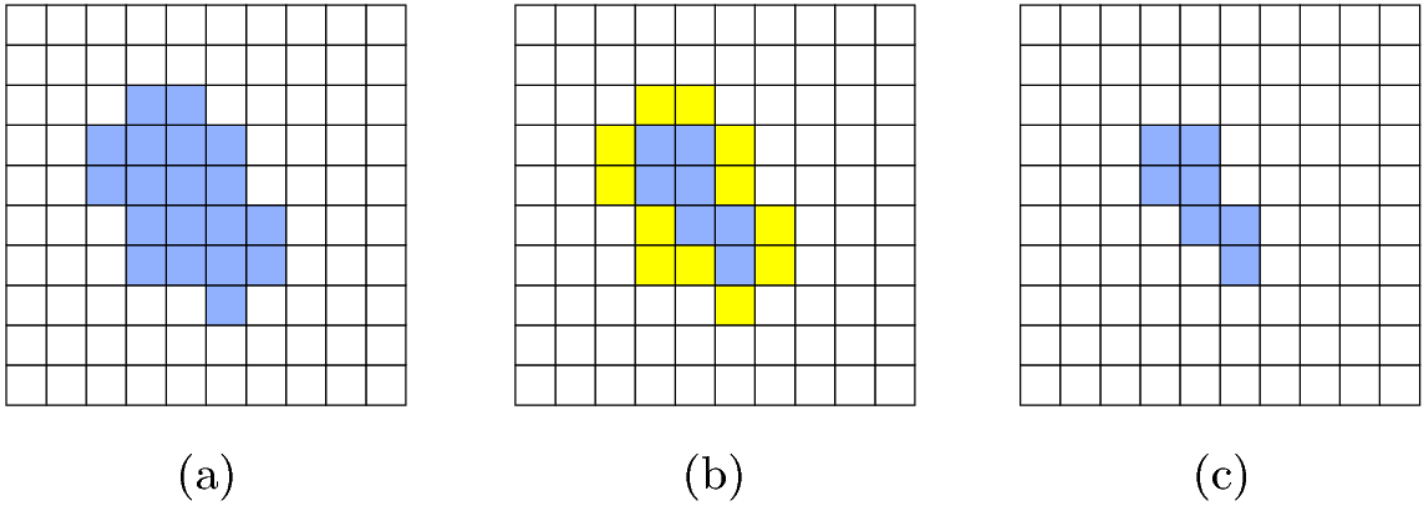


Burger and Burge

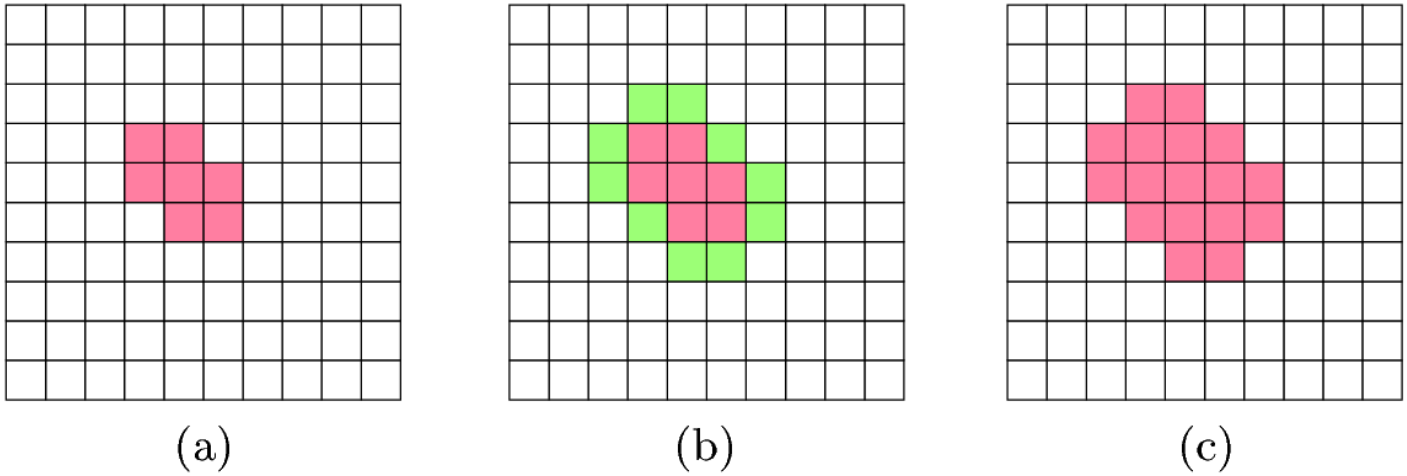
Morphological operations

- Main idea

Erosion



Dilation

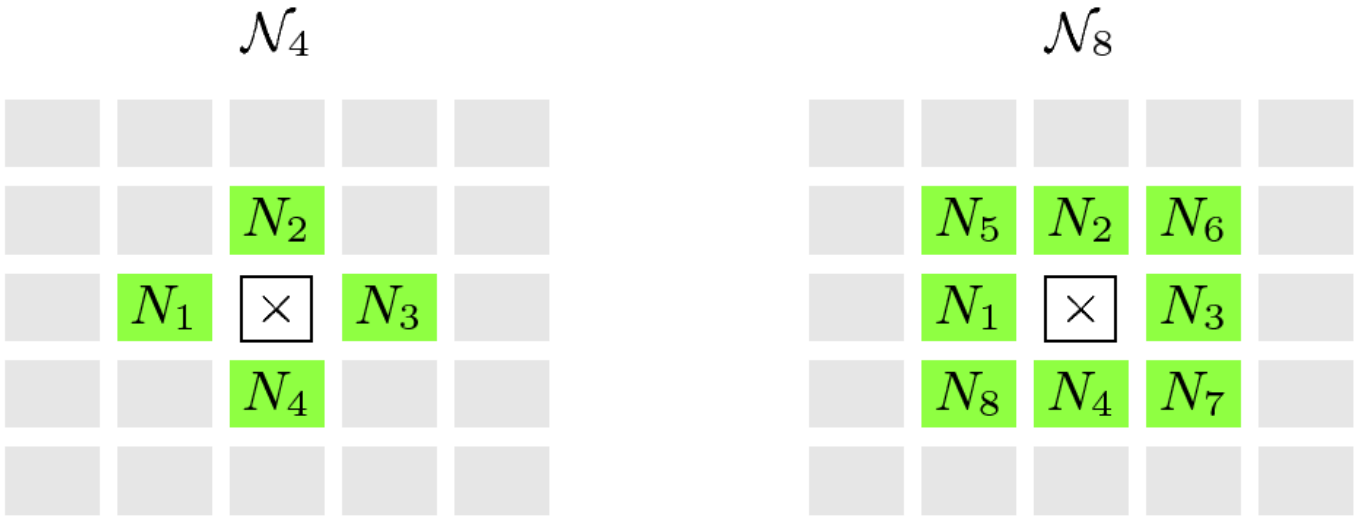


Burger and Burge

Morphological operations

- Structuring element

- Neighbourhood



Burger and Burge

Morphological operations

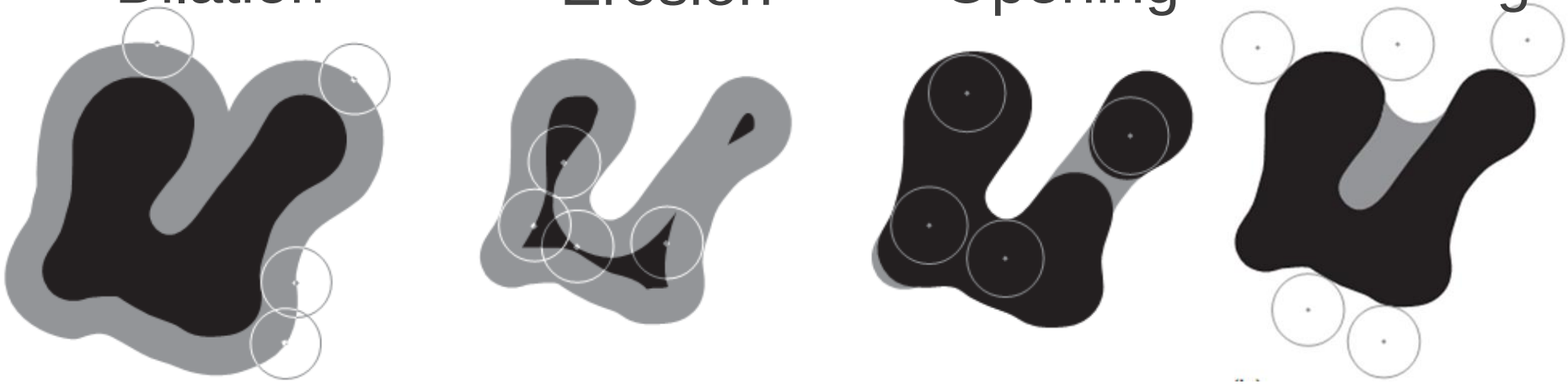
- Main Morphological operations
  - Dilation
  - Erosion

  } Basic Operations

  - Opening
  - Closing

  } Composed Operations

Dilation Erosion Opening Closing



Morphological operations - Dilation

- Dilation
  - gradually enlarge the boundaries of regions
  - small holes and gaps are filled

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

Original image

1	1

Structuring element

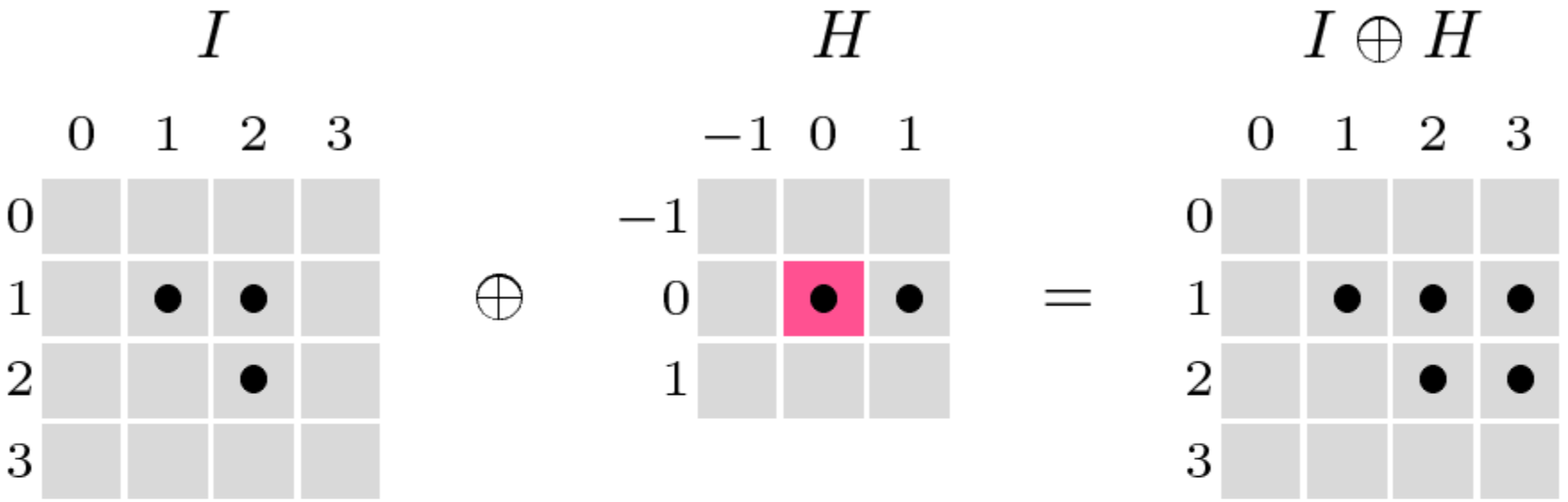
0	1	1	0	0
0	1	1	0	0
0	1	1	0	0
0	1	1	1	1
0	0	0	0	0

Dilation

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

$I \oplus X$

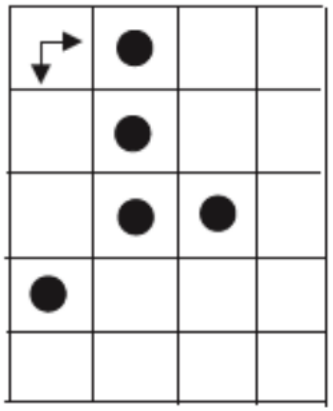
Morphological operations - Dilation



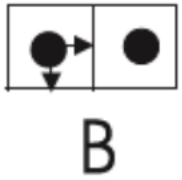
$$I \equiv \{(1,1),(2,1),(2,2)\},\ H \equiv \{(\mathbf{0},\mathbf{0}),(\mathbf{1},\mathbf{0})\}$$

$$\begin{aligned} I \oplus H \equiv \{ & (1,1)+(\mathbf{0},\mathbf{0}),\ (1,1)+(\mathbf{1},\mathbf{0}), \\ & (2,1)+(\mathbf{0},\mathbf{0}),\ (2,1)+(\mathbf{1},\mathbf{0}), \\ & (2,2)+(\mathbf{0},\mathbf{0}),\ (2,2)+(\mathbf{1},\mathbf{0}) \} \end{aligned}$$

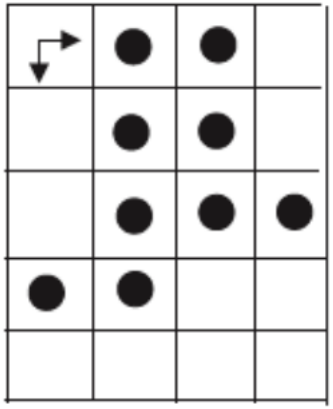
Morphological operations - Dilation



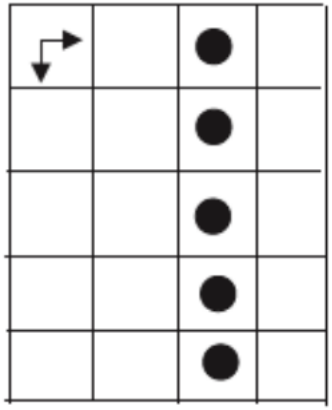
A



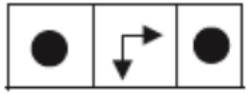
B



A ⊕ B



A



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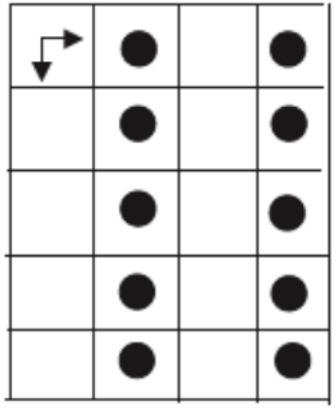


A ⊕ B

05:00

Morphological operations - Erosion

- Erosion
  - Dual of the dilation operation
  - Erode away the boundaries of regions of foreground
  - holes and gaps are increased

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

Original image

1	1

Structuring element

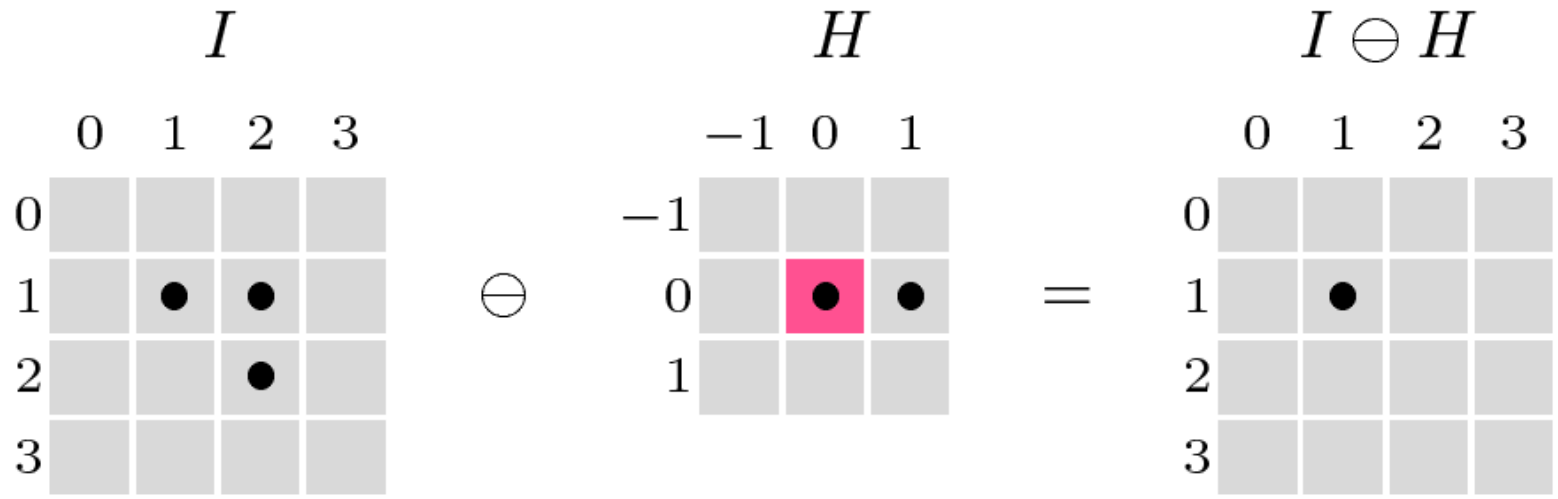
0	1	0	0	0
0	1	0	0	0
0	1	0	0	0
0	1	1	1	0
0	0	0	0	0

Erosion

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

$I \ominus X$

Morphological operations - Erosion



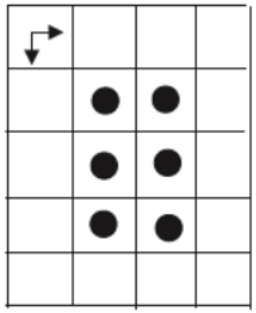
$$I \equiv \{(1,1),(2,1),(2,2)\},\ H \equiv \{(\mathbf{0},\mathbf{0}),(\mathbf{1},\mathbf{0})\}$$

$$I \ominus H \equiv \{\,(1,1)\,\} \text{ because}$$

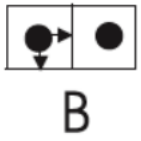
$$(1,1)+(\mathbf{0},\mathbf{0}) = (1,1) \in I \quad \textbf{and} \quad (1,1)+(\mathbf{1},\mathbf{0}) = (2,1) \in I$$

Morphological operations - Erosion

05:00



A



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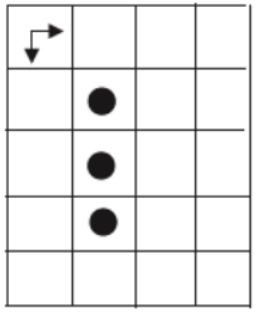
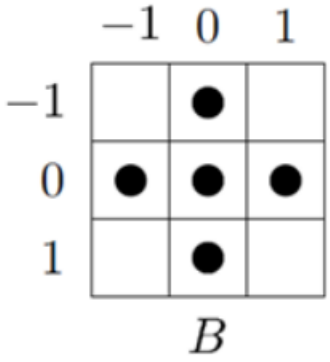
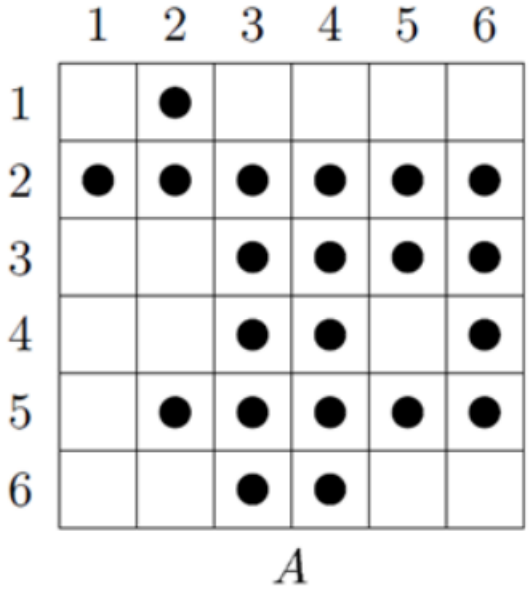


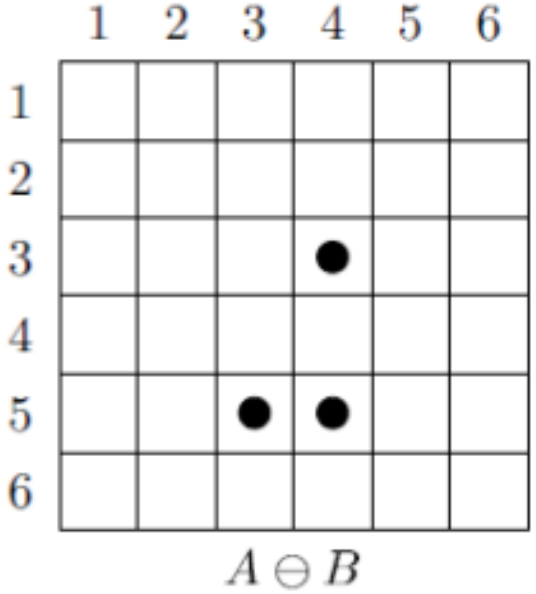
A⊖B



B



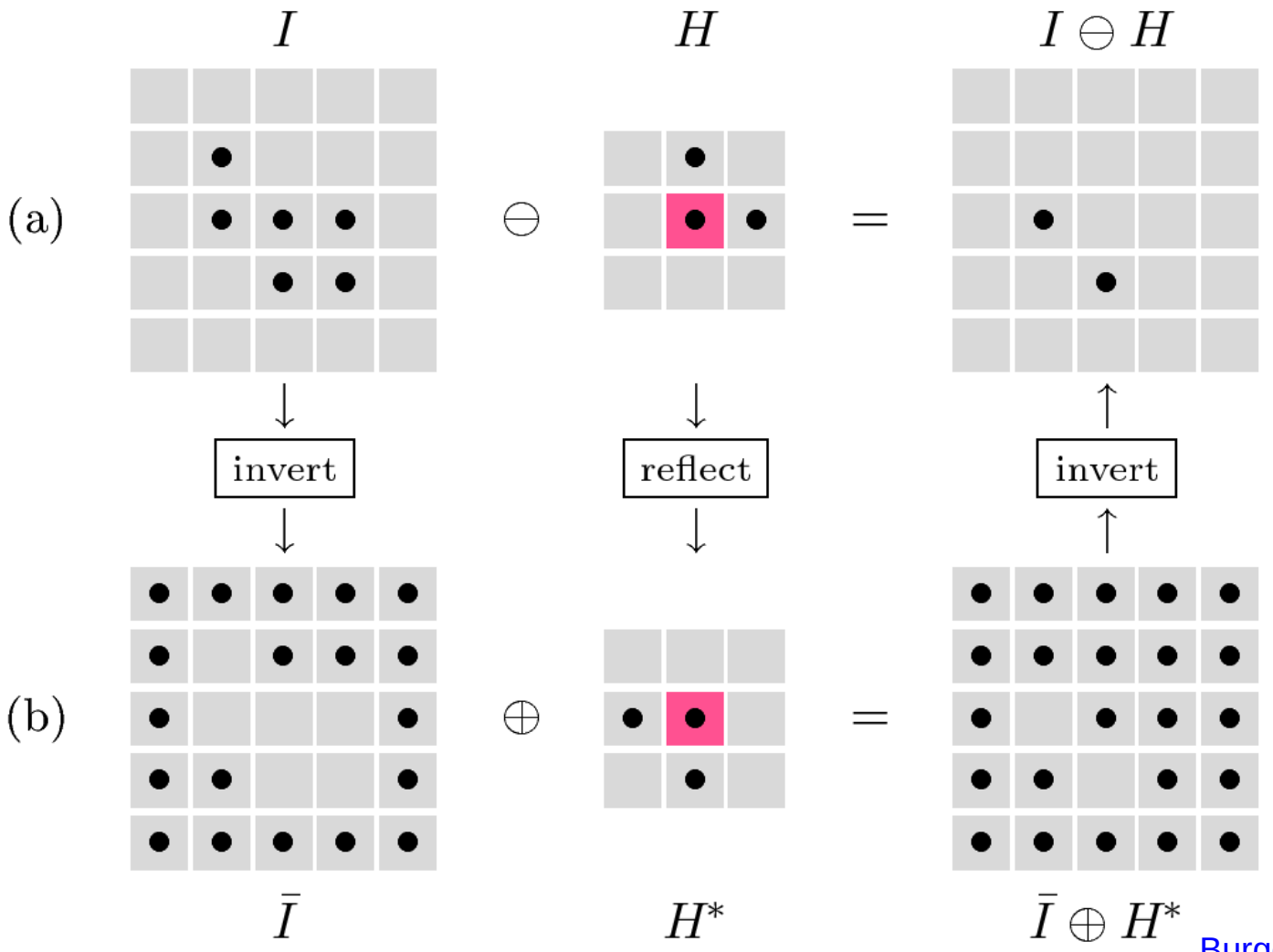
A



$A \ominus B$

Morphological operations

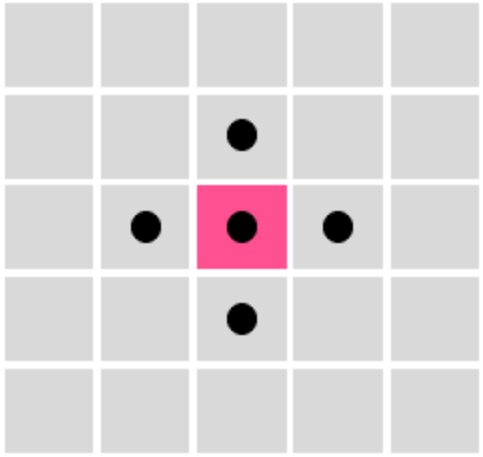
- Dilation and Erosion are dual operations

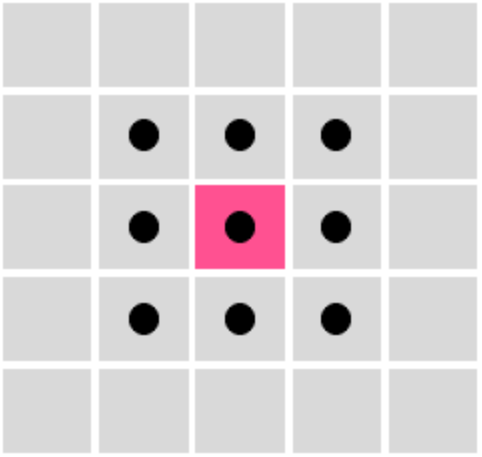


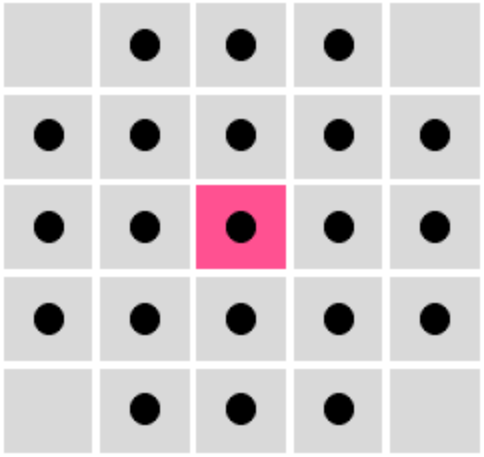
Burger and Burge

Morphological operations

- Typical structuring elements







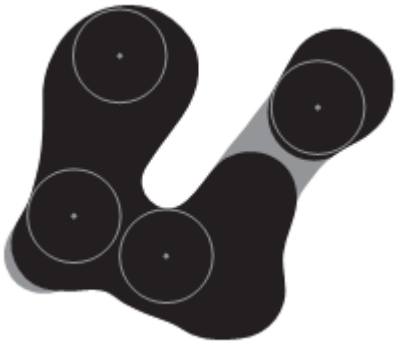
Burger and Burge

Summary

- Morphological operations
  - Dilation, erosion
  - Opening, closing
- Segmentation
  - Thresholding
  - Region growing

Morphological operations - Opening

- Opening
  - Erosion followed by dilation
  - Idempotent operation
    - Results will not change applied multiple time
  - Union of all objects that fit in Structuring Element
  - Circular kernel:
    - Smooth edges of object
    - Broke thin connections



$$I \bigcirc X = (I \ominus X) \oplus X$$

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

Original image

1	1

Structuring element

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

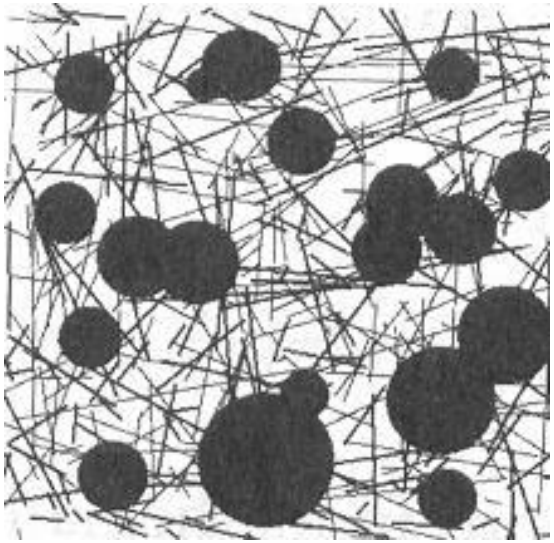
Opening

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

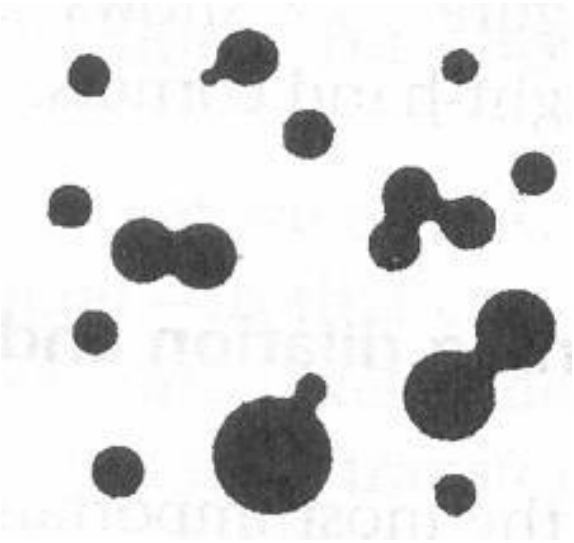
$I \bigcirc X$

Morphological operations - Opening

- Opening example
  - Circular structuring element
  - Radius of structuring element must be larger than subsets to remove



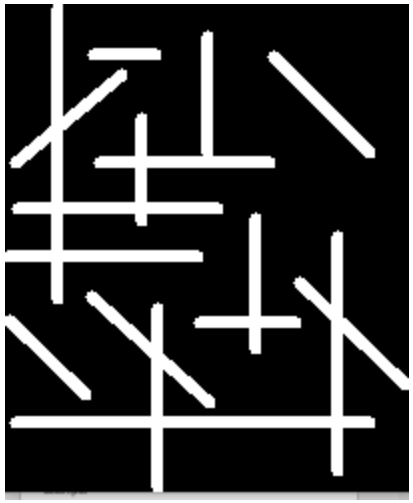
Original image

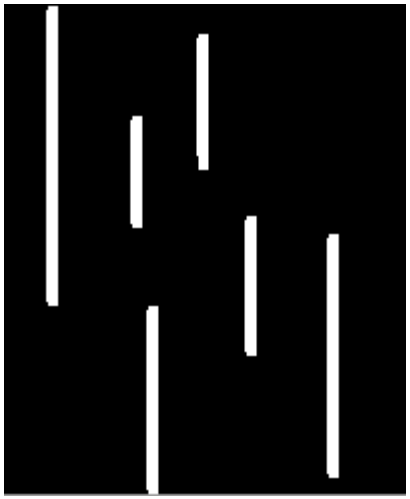


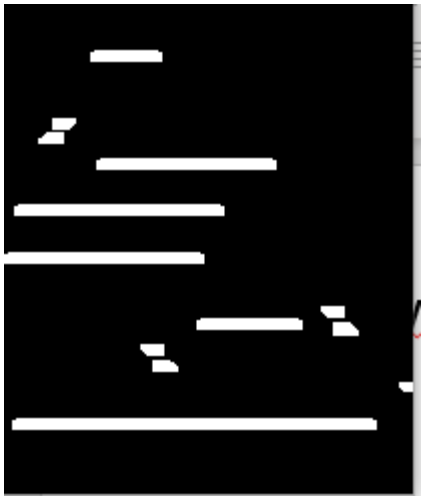
After erosion

After dilation

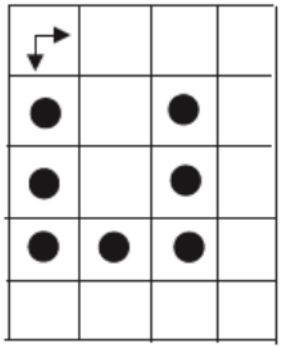
Opening with different structuring elements



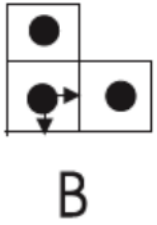




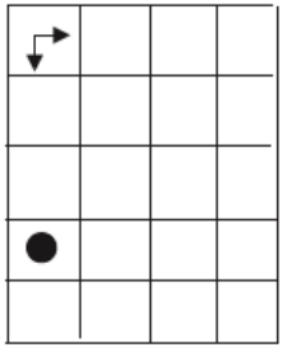
Opening



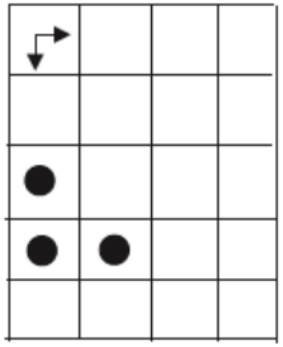
A



B

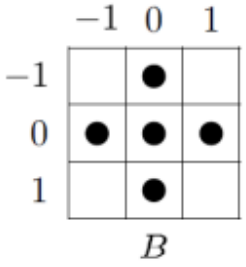


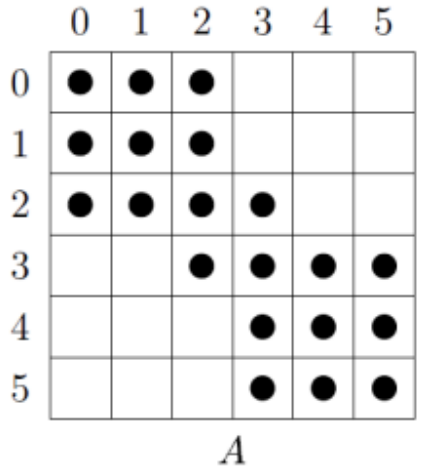
A⊖B



(A⊖B)⊕B

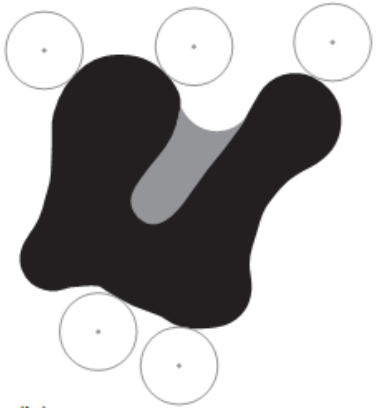
05:00





Morphological operations - Closing

- Closing
  - Dilation followed by erosion
  - Dual to opening
  - Idempotent operation
    - Results will not change applied multiple time



$$I \bullet X = (I \oplus X) \ominus X$$

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

Original image

1	1

Structuring element

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

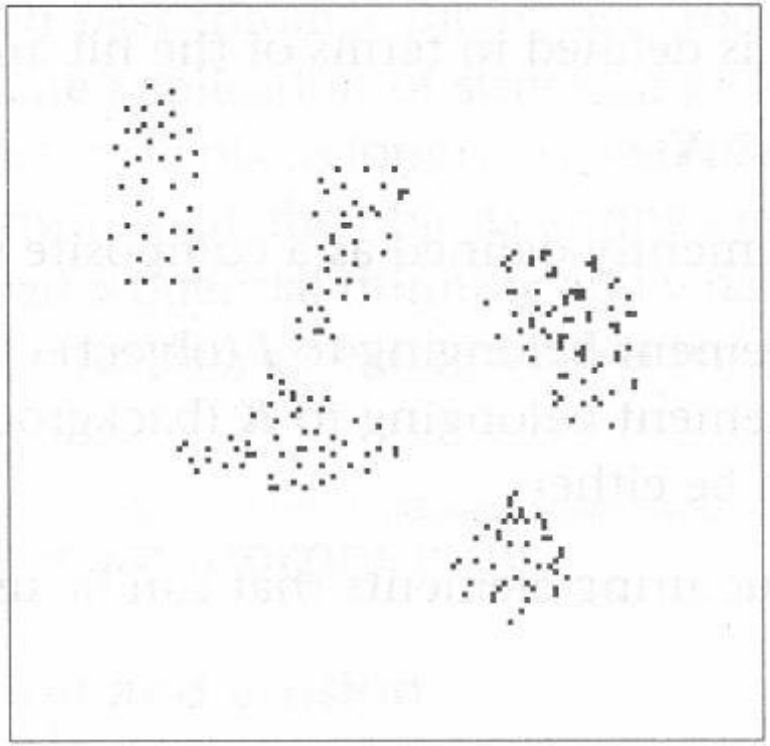
Closing

?

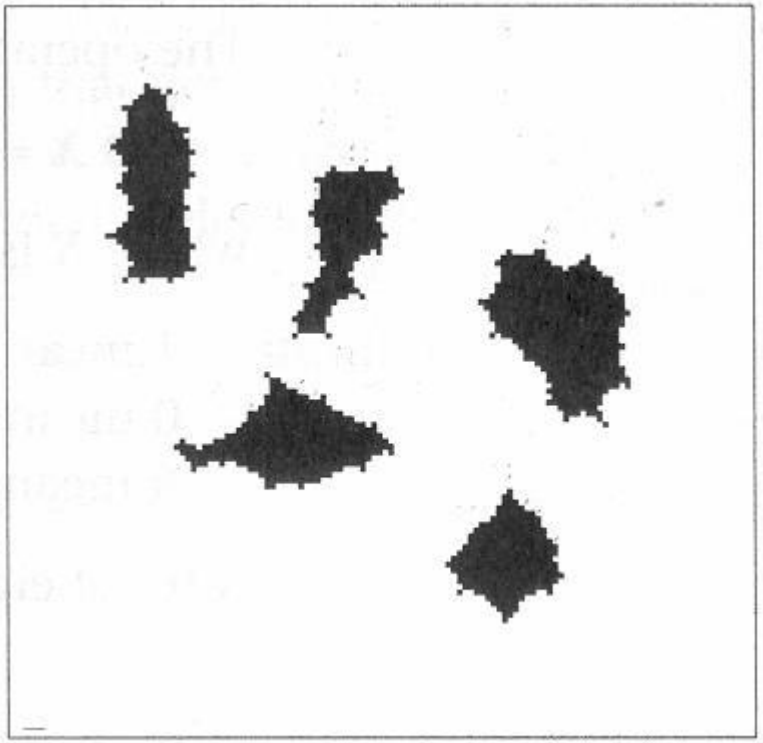
$I \bullet X$

Morphological operations - Closing

- Closing example

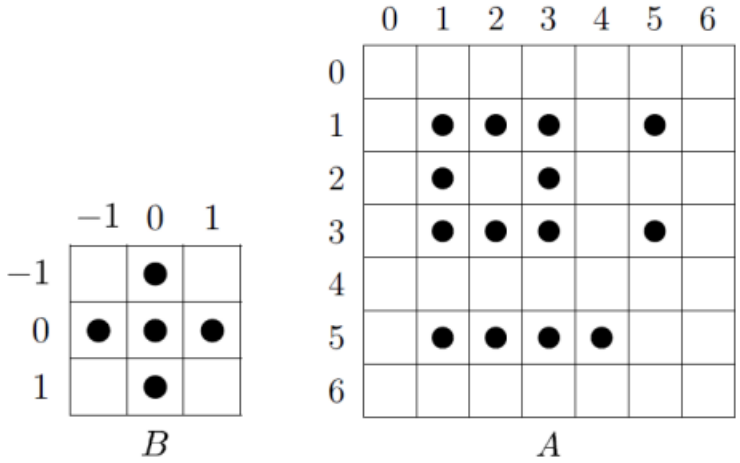


Original image



After closing

Morphological operations - Closing



05:00

Morphological operations

- Edge detection with morphology (outlining)
  - Since erosion results in an isotropic contraction of images, can be used for edge detection:

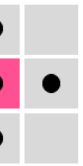
$$Edge = I - (I \ominus X)$$

  - Erosion of objects and then subtraction from original (using 3x3 or 5x5 structuring element)
  - Size of structuring element will have impact of contour thickness

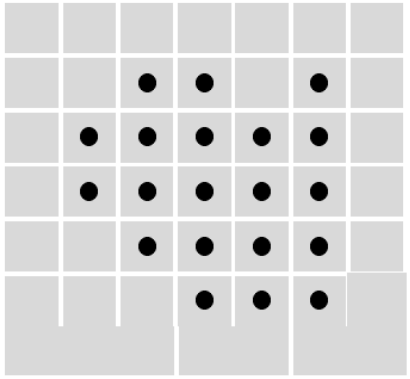
Morphological operations

- Edge detection with morphology (outlining)

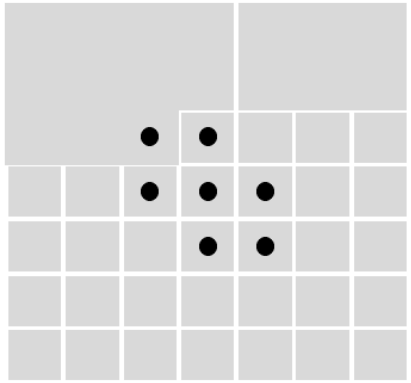
$H_n =$



I



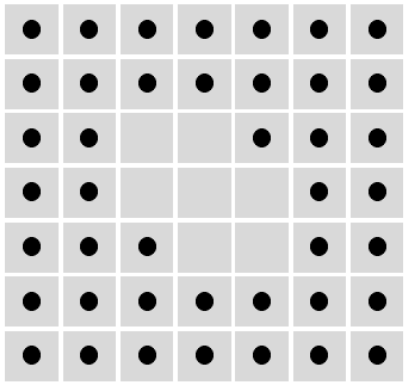
$I \ominus H_n$



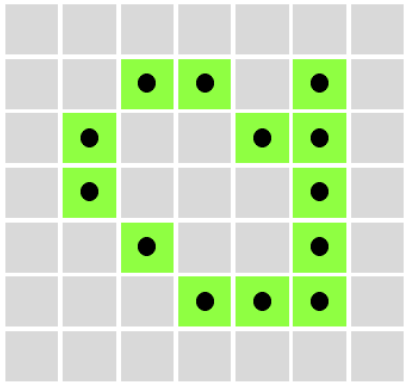
$$I' = I \ominus H_n$$

$$B = I \cap \overline{I'} = I \cap \overline{(I \ominus H_n)}$$

$\overline{I \ominus H_n}$



$B = I \cap \overline{I \ominus H_n}$



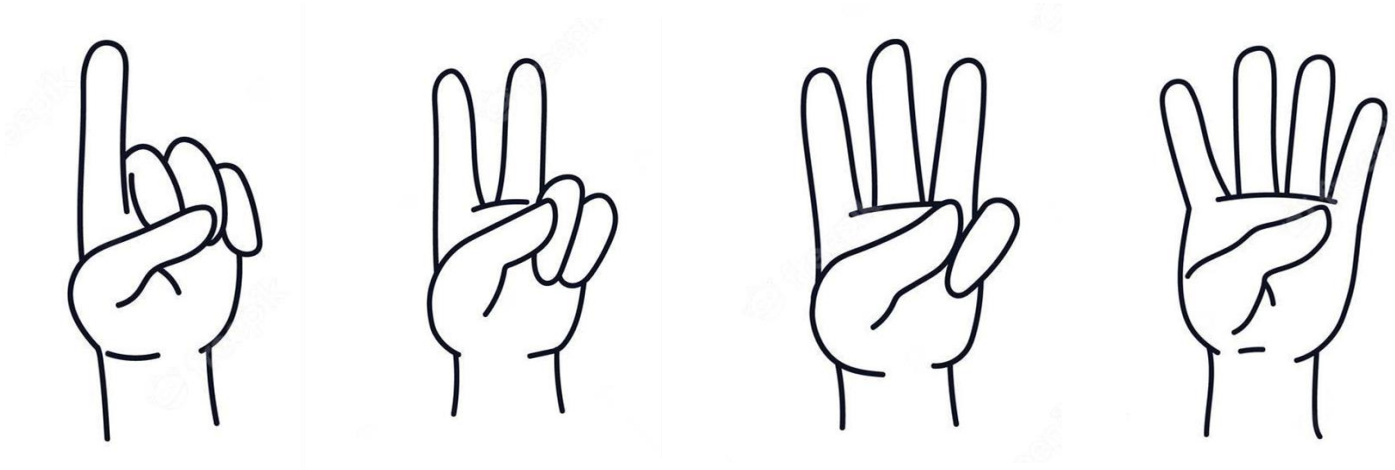
Finger Question

Which method is more adequate to ensure you do not loose any pixel in a binary region you wish to segment?

1. Open
2. Close
3. Dilation
4. Erosion

Finger Question

When timer ends…

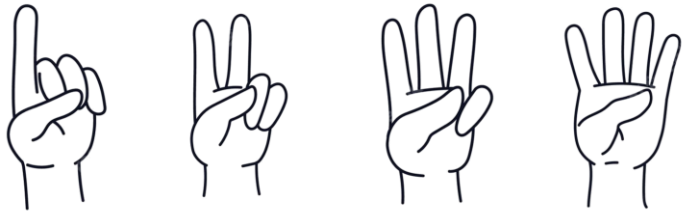


Finger Question

Which method is more adequate to ensure you do not loose any pixel in a binary region you wish to segment?

03:00

1. Open
2. Close
3. Dilation
4. Erosion



Summary

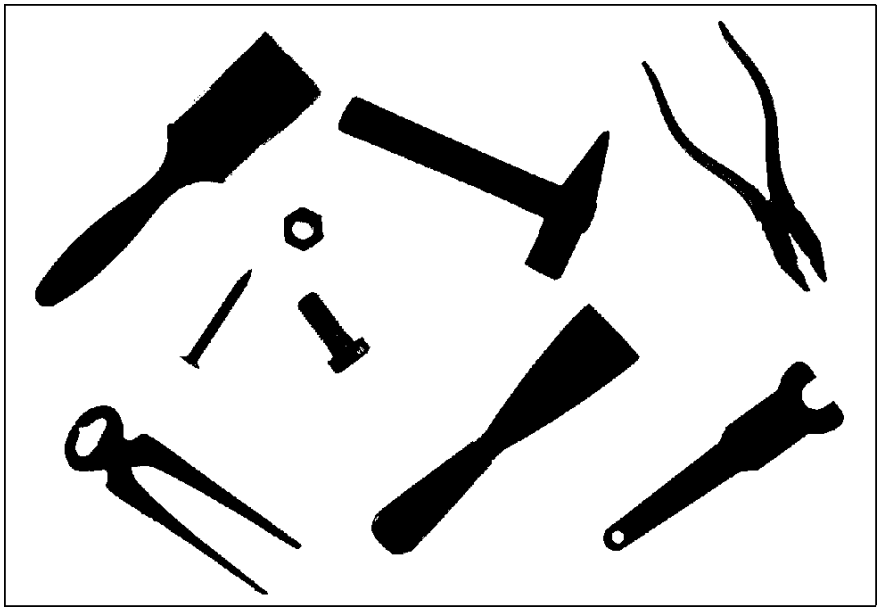
- Morphological operations
  - Dilation, erosion
  - Opening, closing
- Segmentation
  - Thresholding
  - Region growing

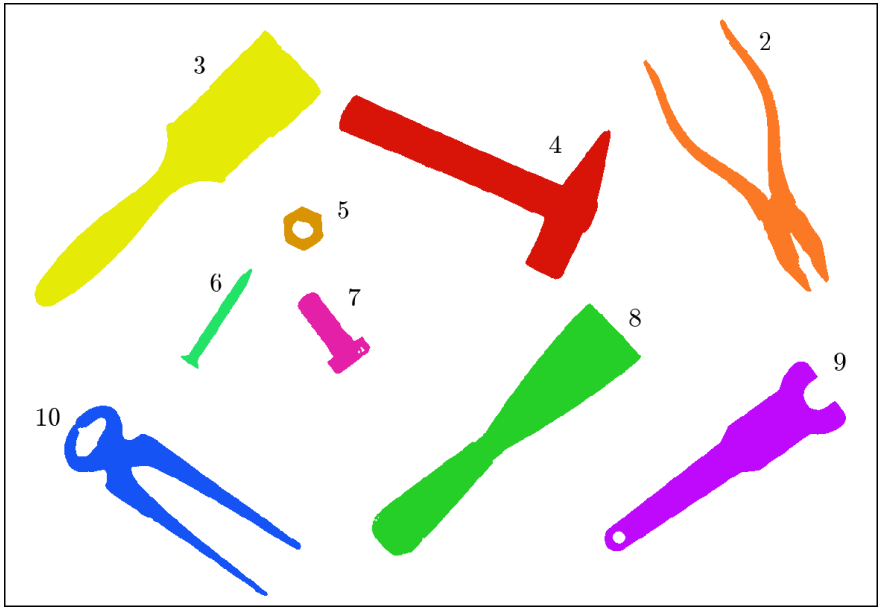
Segmentation

- Segmentation means dividing image in regions
- Often applied before image analysis
- Typical approach is to group pixels with similar properties

Segmentation

- Examples





Burger and Burge

Segmentation

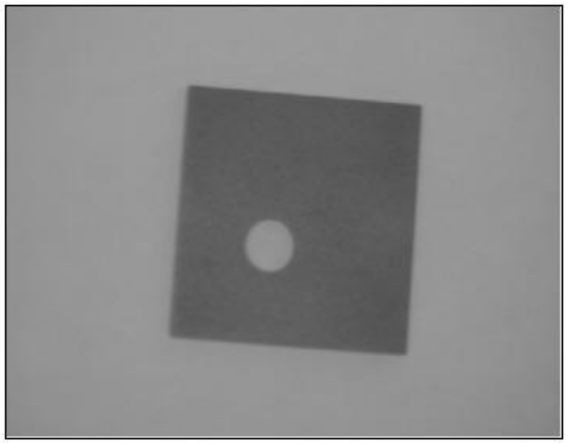
- No segmentation methods that can be used in every case
- No “perfect” segmentation method
- Typical segmentation are based in:
  - pixel intensity
  - regions
  - edges

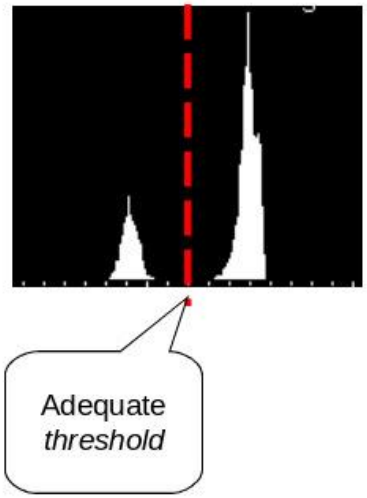
Summary

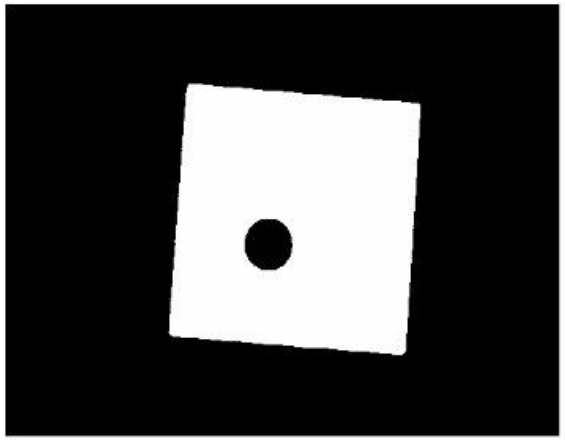
- Morphological operations
  - Dilation, erosion
  - Opening, closing
- Segmentation
  - Thresholding
  - Region growing

Segmentation - Thresholding

- Thresholding
  - Oldest segmentation method
  - Appropriate when object of interest have homogeneous intensity different from background
  - Not easy to find the adequate value



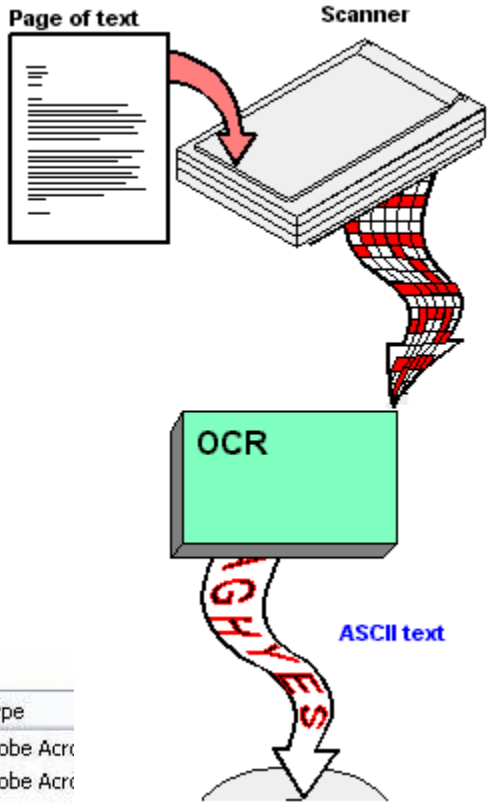


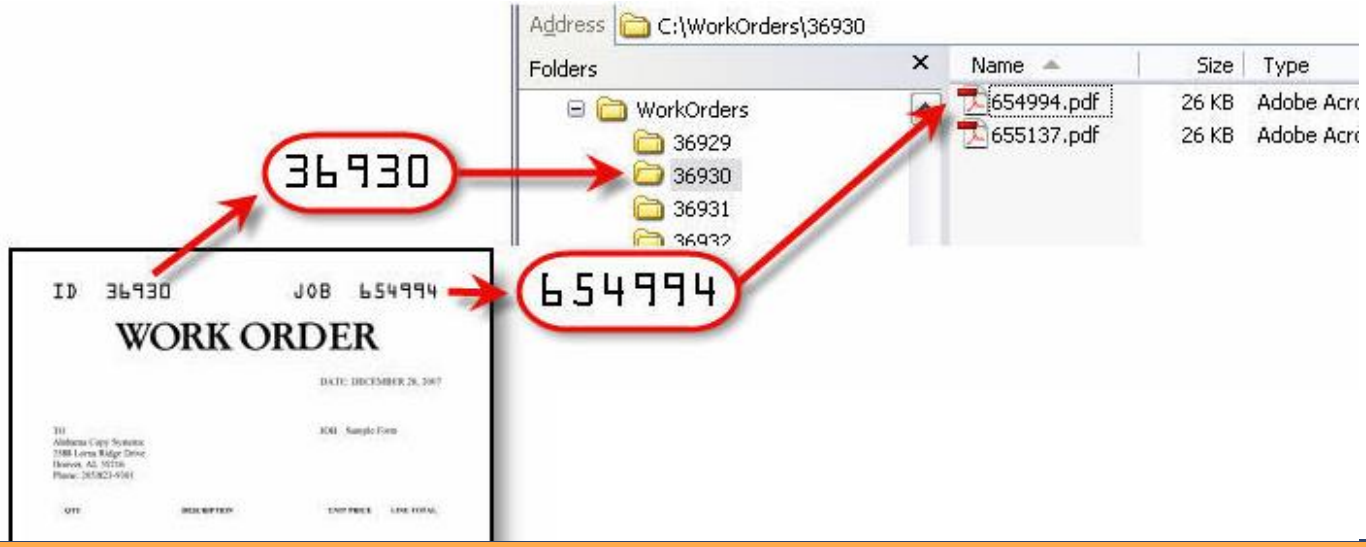


Segmentation - Thresholding

- Oldest segmentation approach
- Appropriate whenever the intensity of the objects of interest is homogeneous and they are different from the background

  Example: OCR (*Optical Character Recognition*)

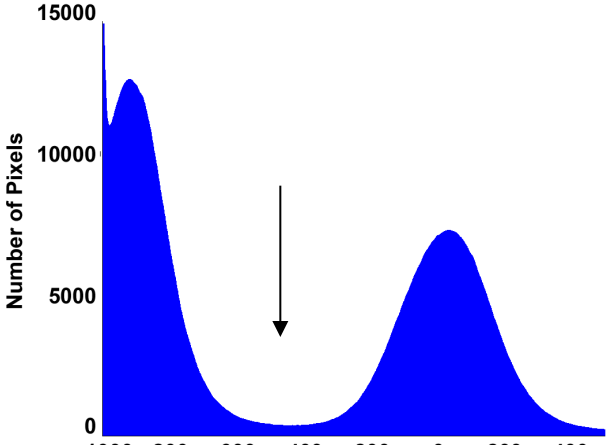


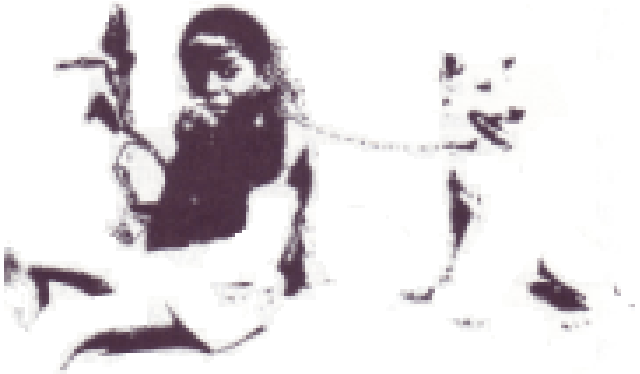


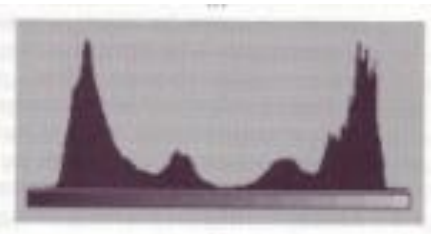
Segmentation - Thresholding

- If the threshold value is unknown, analyze the histogram to choose an adequate threshold value

- For a bimodal histogram, the threshold value corresponds to the valley between the peaks



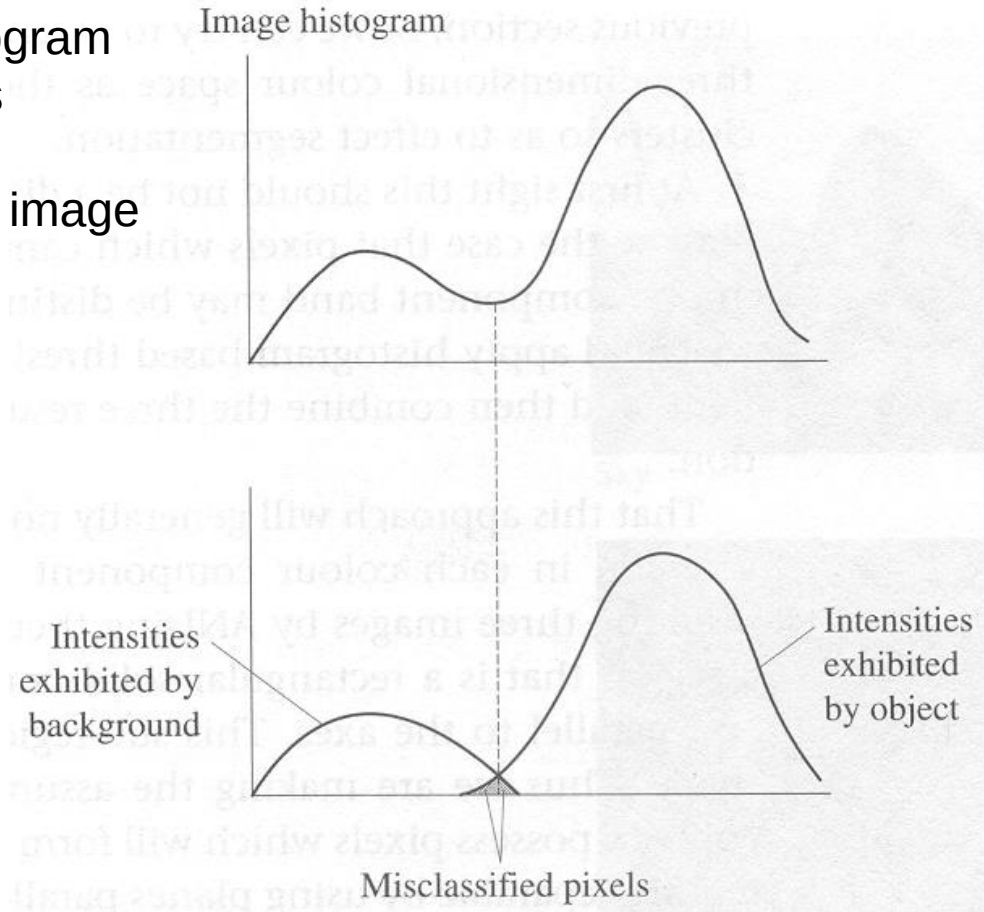




Segmentation - Thresholding

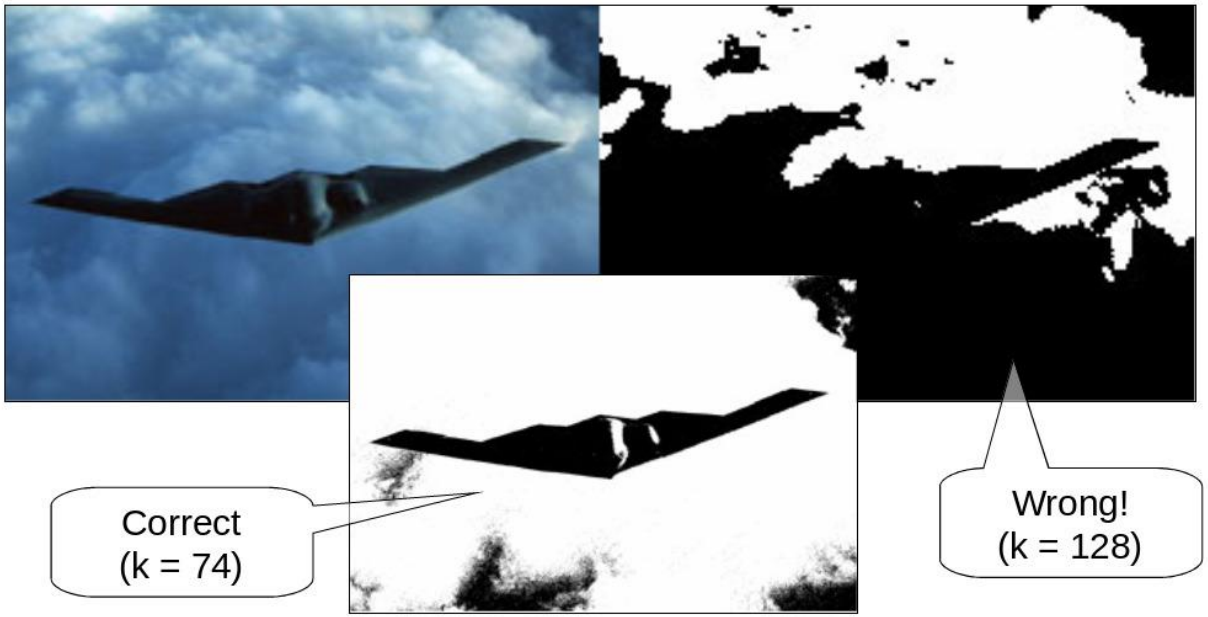
- This approach can produce "classification errors", depending on the image histogram and the intensity values of the objects

- The *thresholding* can be applied to image sub-regions



Segmentation - Thresholding

- Several approaches for threshold selection
  - Global
  - Variable
    - Local - depends on properties of neighbouring pixels
    - Adaptive – depends on spatial coordinates
    - Otsu's method – based on probabilistic analysis obtained from histogram



Summary

- Morphological operations
  - Dilation, erosion
  - Opening, closing
- Segmentation
  - Thresholding
  - Region growing

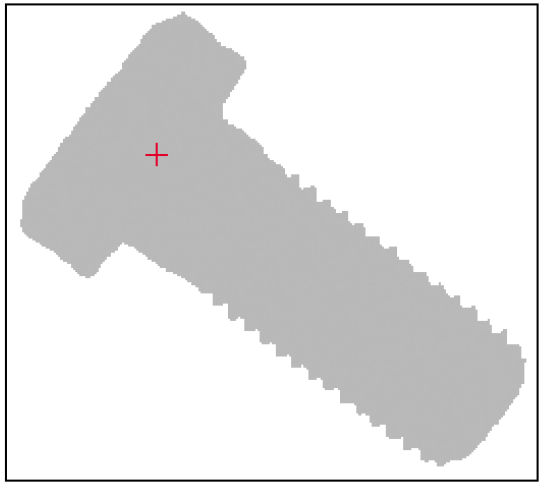
Segmentation – Region growing

- Grow region by aggregation of pixels starting at a seed point
- All neighbouring pixels that comply the rule are labelled as belonging to the region
- A problem is to obtain “good” seed pixels
- Seed can be obtained using
  - Histograms
  - Interactively
  - …

Segmentation – Region growing

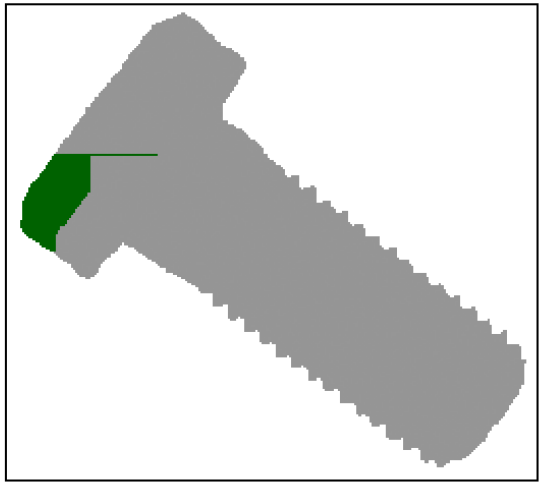
- Flood-Filling

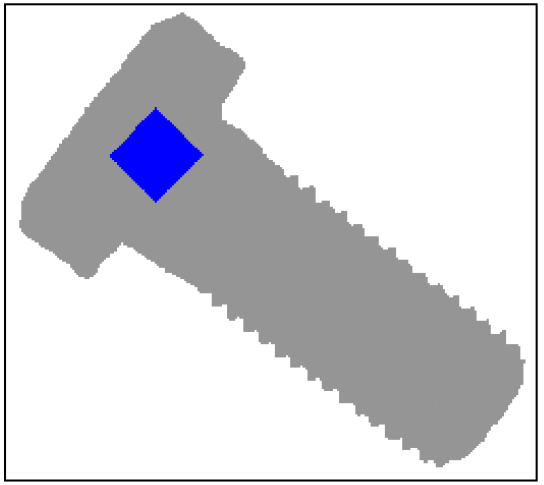
(a)
Original



depth-first **breadth-first**

(b)
$K = 1.000$

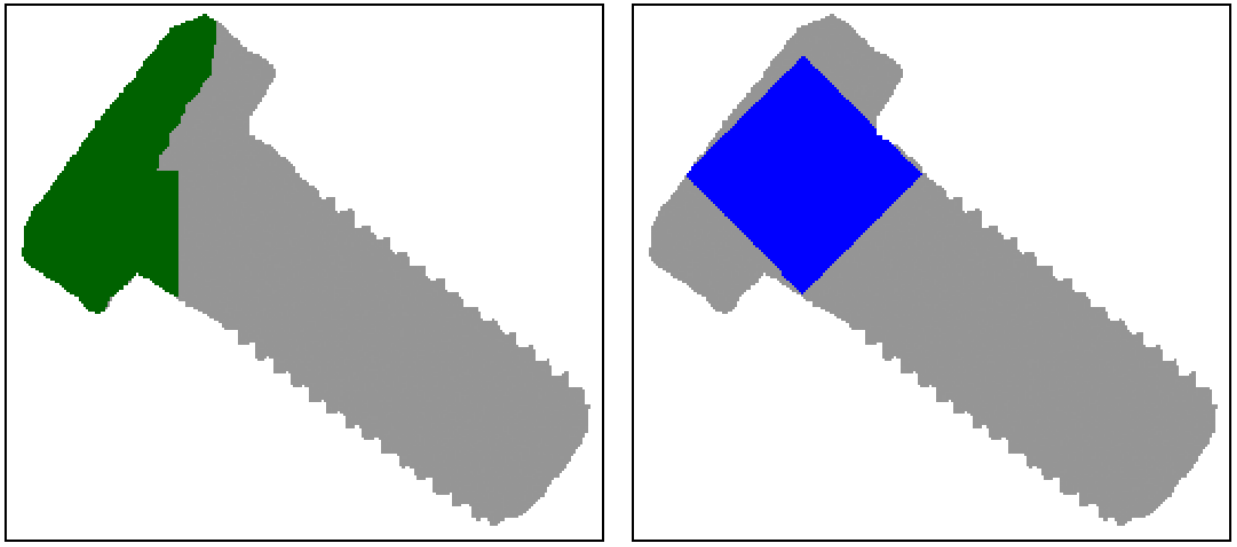




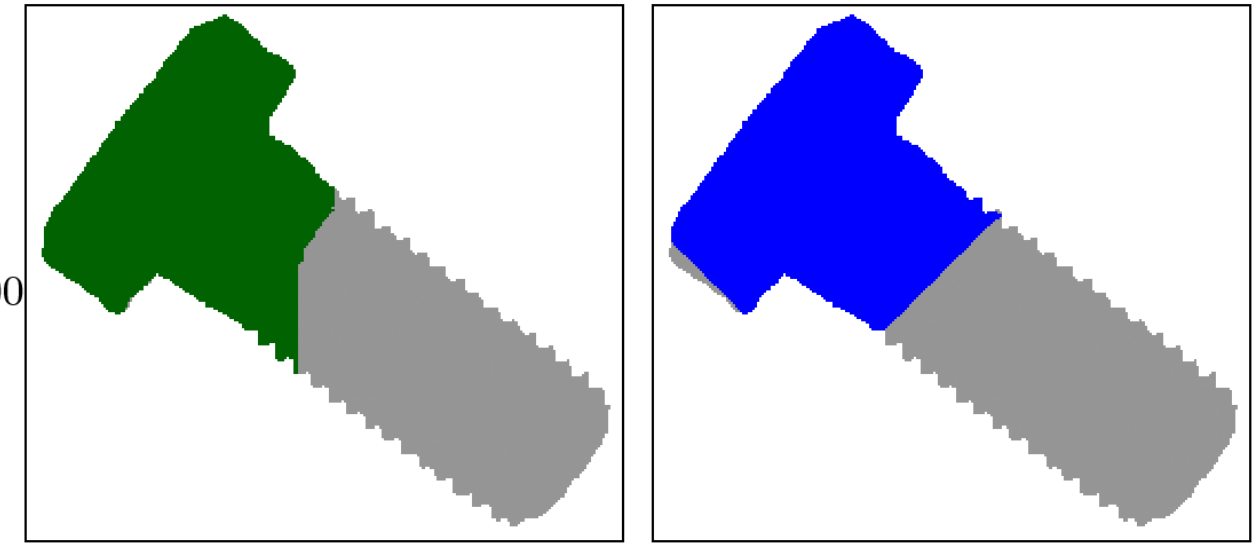
Segmentation – Region growing

- Flood-Filling

(c)
$K = 5.000$



(d)
$K = 10.000$



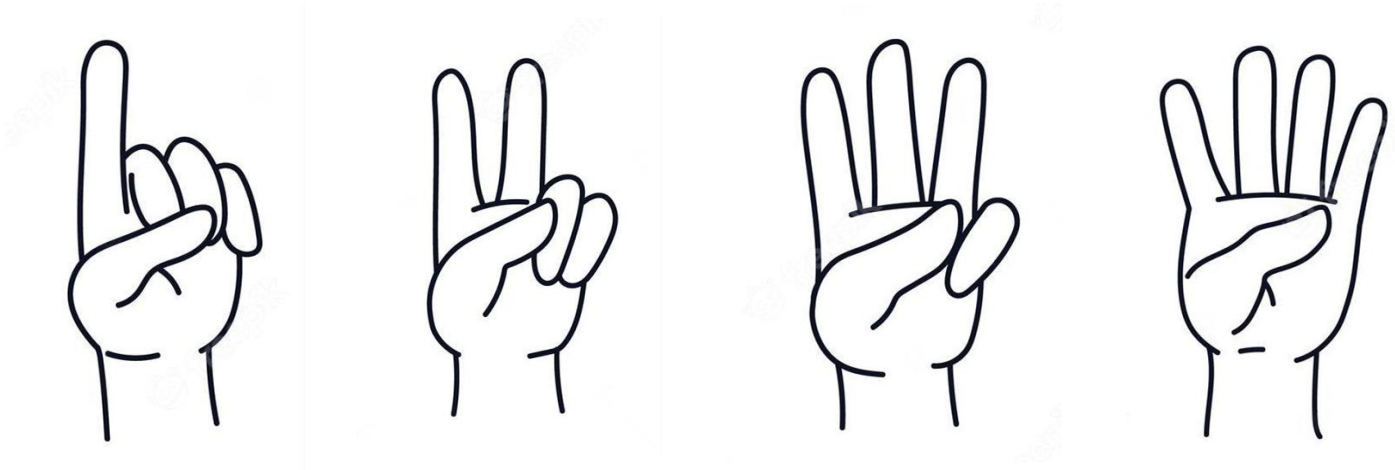
Finger Question

Which method is more adequate to ensure you do not loose any pixel in a binary region you wish to segment?

1. Open
2. Close
3. Dilation
4. Erosion

Finger Question

When timer ends…



Finger Question

Which method is more adequate to ensure you do not loose any pixel in a binary region you wish to segment?

03:00

1. Open
2. Close
3. Dilation
4. Erosion