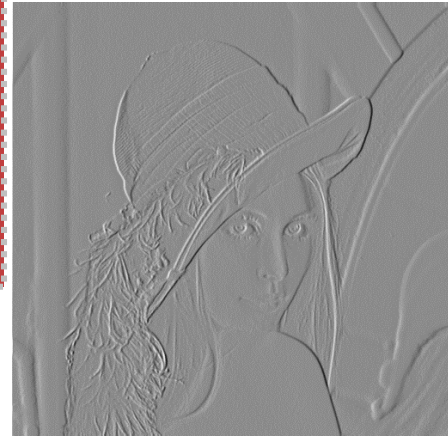
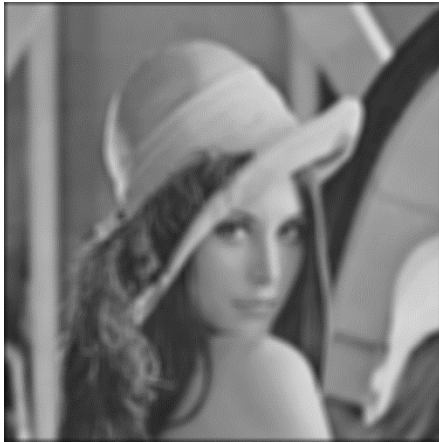
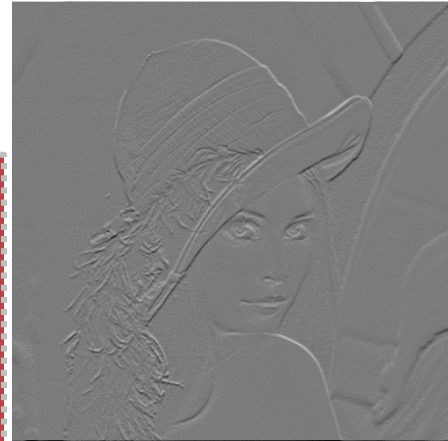




## Solution Exercise 4: Spatial Filtering



# Chapter 5: Morphology

## Definition

- Morphology is originally Greek for “concerning the shape”.
- It provides basic operations to improve images, extract features or detect shapes.

## Application

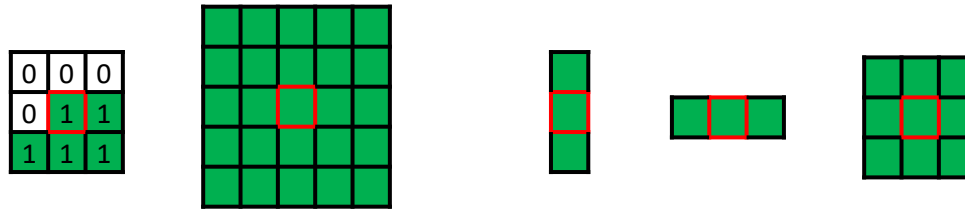
- Change shapes
- Extraction of shape features
- Edge detection
- Counting objects in an image
- Noise reduction
- Filtering

## Assumption for this lecture & exercise

- only binary images  
(extension to greyscale images is possible)

## Masks / Structure Elements (SE)

- Main form: rectangular mask



- A structure element (SE) is defined by its shape and size.
- The SE in morphological operations is similar to the filter kernel in the application of mathematical convolution (see chapter 4 Spatial Filtering).
- The shape is usually displayed as a binary matrix. Entries with one (green) belong to the SE, zeroes (white) do not.
- The reference point (red border) is similar to the hot spot in spatial filtering.

## Often used shapes

- Square
- Rectangle
- Line
- Octagon
- Diamond
- Disk
- every other shape is possible

There are only two morphological base operations, dilation and erosion.  
All other operations consist of a combination of those two.

## 1. Dilation

Definition:

$$F \oplus M = \{ \underline{p} : M_p \cap F \neq \emptyset \}$$



dilation operator

$F$  – set of all foreground pixels (binary image: white)

$M$  – set of all mask pixels with grey value greater than zero

$\underline{p}$  – current pixel in the image

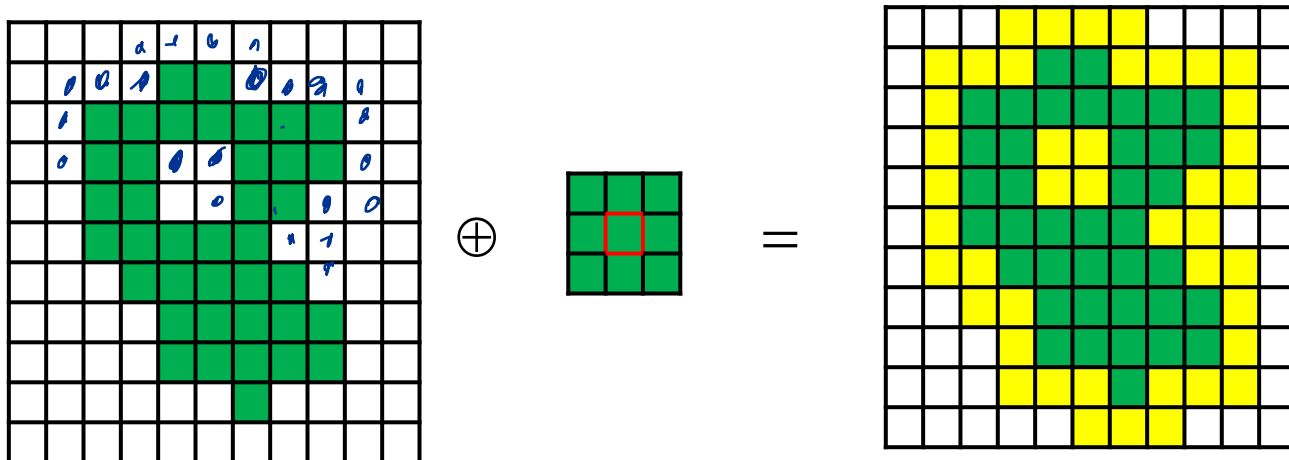
$M_p$  – shifted mask with the reference point moved to pixel  $\underline{p}$

Dilation of an image  $F$  with a mask  $M$  is the same as the set of all pixels  $\underline{p}$ , where the intersection of  $M_p$  and  $F$  is not empty. This means, there has to be at least some overlap.

Properties:

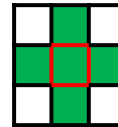
- enlarge objects
- connect structures
- fill gaps

Dilation working scheme:



Example of dilation:

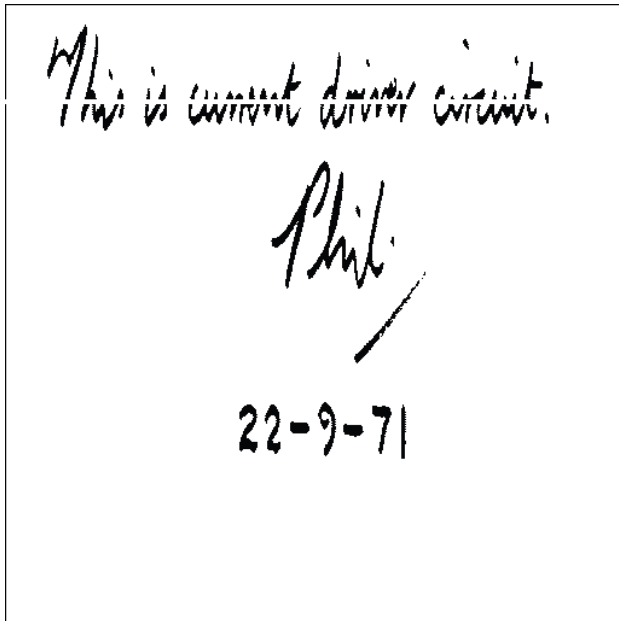
Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.



Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.

[Source: Tönnies, „Grundlagen der Bildverarbeitung“]

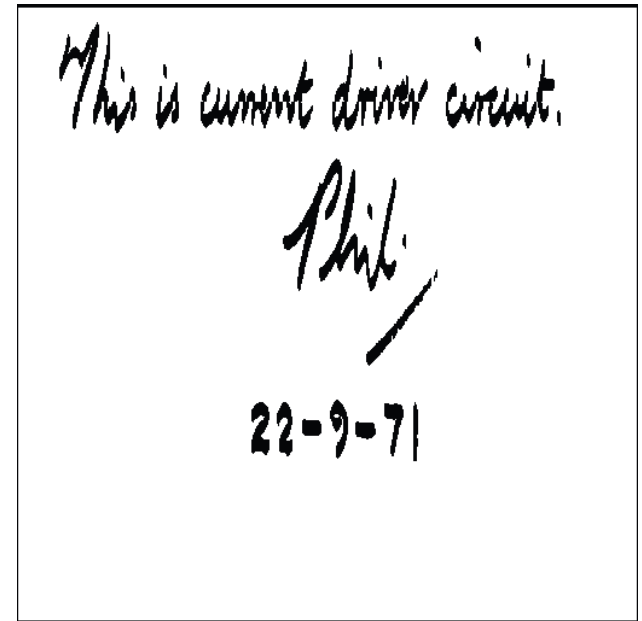
Example of dilation:



$\oplus$



=



[Source: Tönnies, „Grundlagen der Bildverarbeitung“]



## 2. Erosion

Definition:

$$F \ominus M = \{ \underline{p} : M_p \subseteq F \}$$

Erosion of an image  $F$  with a mask  $M$  is the same as the set of all pixels  $\underline{p}$ , where  $M_p$  is a subset of  $F$ . This means, there has to be a complete overlap.

Properties:

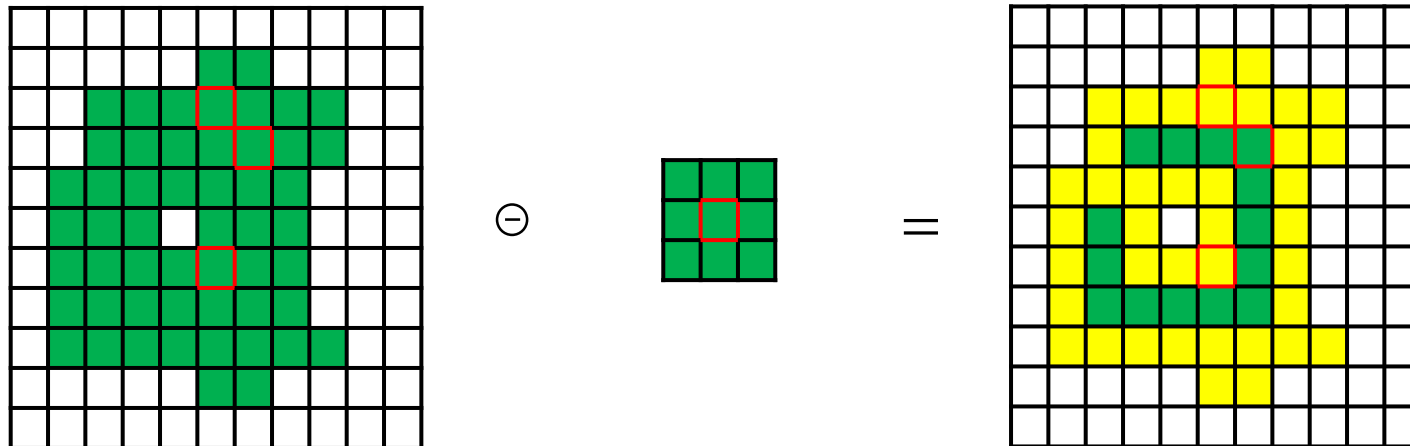
- Shrinks objects
- Removes structures, that are smaller than mask size
- Enlarges gaps/holes

Duality of erosion and dilation (valid for binary images):

$$\overline{F \ominus M} = \overline{F} \oplus \overline{M}$$

$$\overline{F \oplus M} = \overline{F} \ominus \overline{M}$$

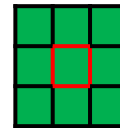
Erosion working scheme:



Examples for erosion:



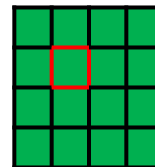
$\ominus$



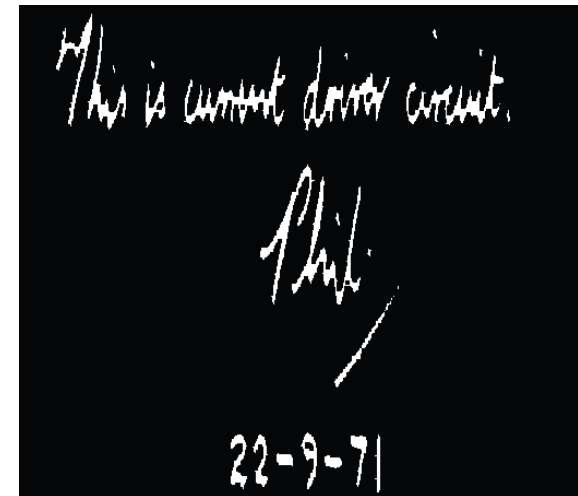
=



$\ominus$



=



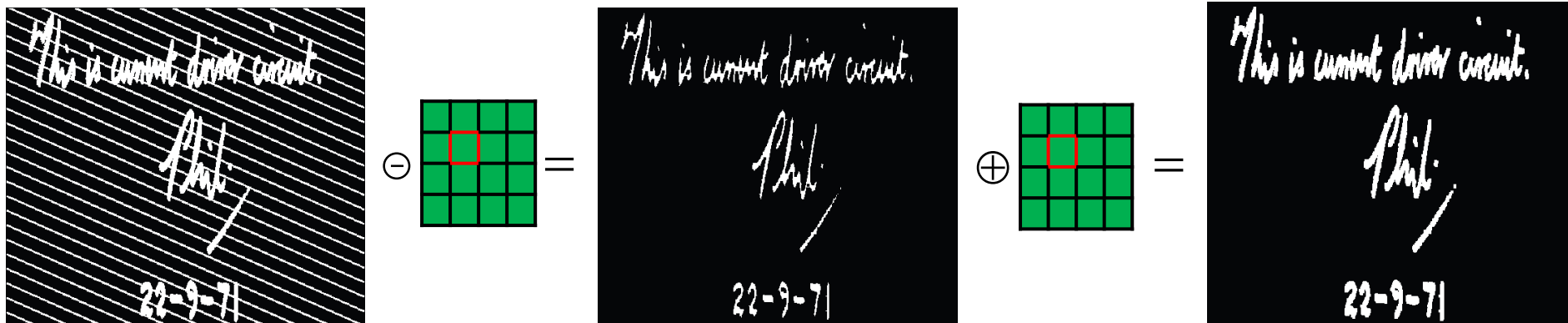
[Source: Gonzales, „Digital Image Processing“]

## Opening

$$F \circ M = (F \ominus M) \oplus M$$

first erosion, then dilation

- deletes small segments in image
- does not change object size



[Source: Gonzales, „Digital Image Processing“]

## Closing

$$F \bullet M = (F \oplus M) \ominus M$$

first dilation, then erosion

- fills small gaps in objects
- does not change object size

This is current driver circuit.

Phil:

22-9-71

$\oplus$



=

This is current driver circuit.

Phil:

22-9-71

$\ominus$



=

This is current driver circuit.

Phil:

22-9-71



$\oplus$



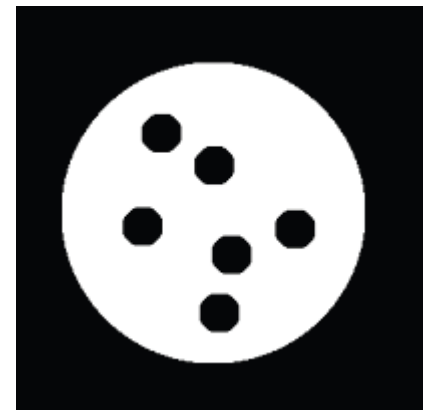
=



$\ominus$



=



[Source: Tönnies, „Grundlagen der Bildverarbeitung“]

## Boundary Extraction

Algorithm:

- (1) Erosion with either 3x3 mask (neighborhood of 4 or 8, see below)
  - Removes all pixels with at least one background pixel in the neighborhood
- (2) Boundary is given by the subtraction from the original image

$$B = F \setminus (F \ominus M)$$



set subtraction

Mask:

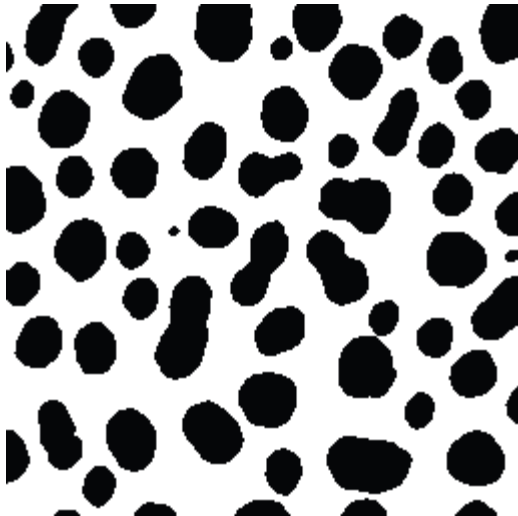
- with two different definitions of neighborhood

$$M_4 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$M_8 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Example Boundary Extraction:

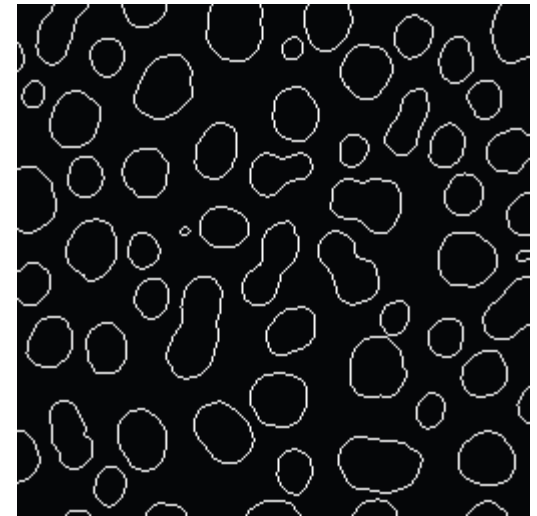
original segmentation



erosion



subtraction of the previous images

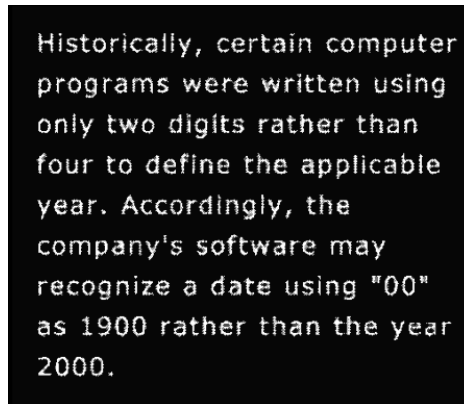


[Source:Dougherty, „*Digital Image Processing for Medical Applications*“]

## Fifth Exercise

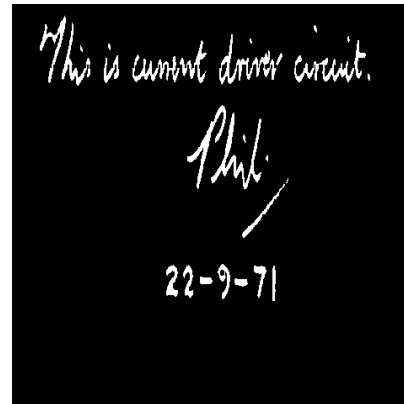
- Implement opening, closing and boundary extraction.

## Expected Output (1)



Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.

Closing #1



This is current driver circuit.  
Phil.  
22-9-71

Closing #2



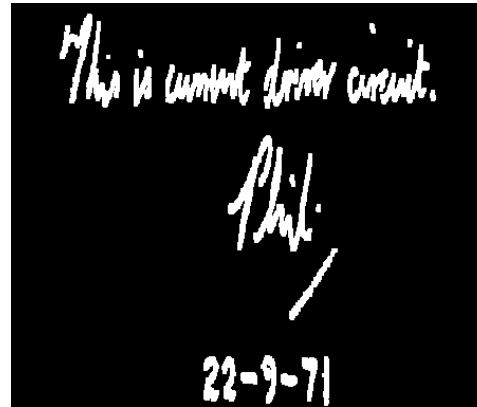
Closing #3



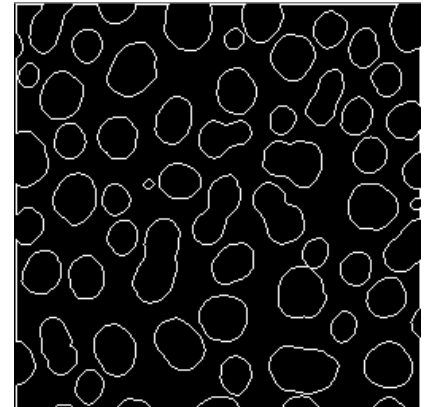
## Expected Output (2)



Opening #1



Opening #2



Boundary Extraction

**That is all for today.**

- Klaus D. Tönnies, „*Grundlagen der Bildverarbeitung*“, Pearson Studium, 1. Auflage, 2005
- Bernd Jähne, „*Digitale Bildverarbeitung*“, Springer, 6. Auflage, 2005
- Rafael C. Gonzales and Richard E. Woods, „*Digital Image Processing*“, Pearson International, 3. Edition, 2008
- Geoff Dougherty, „*Digital Image Processing for Medical Applications*“, Cambridge University Press, 1. Edition, 2009