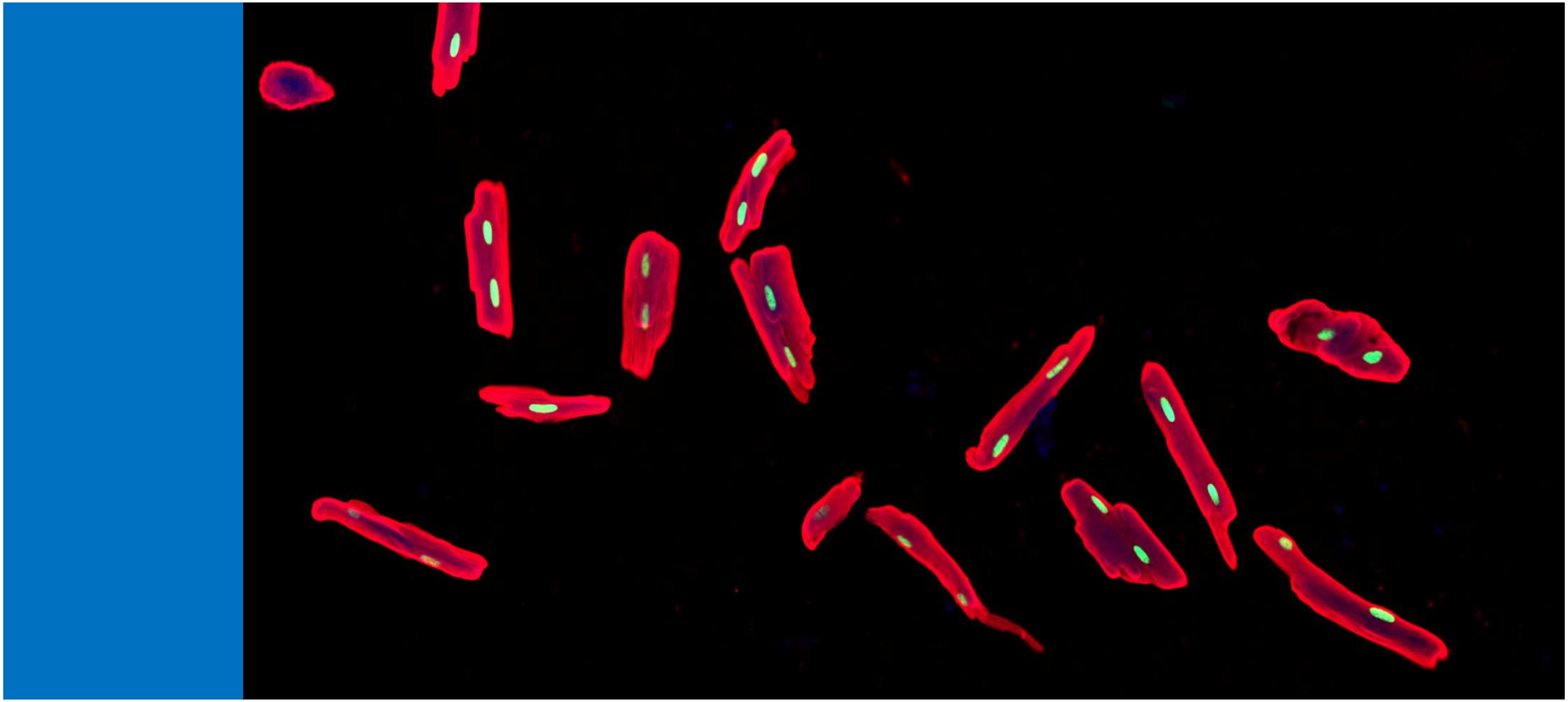


Week 5: Refining masks with morphological operators

MCDB-BCHM 4312-5312

Clarification about radius of curvature

- For a plane lens or mirror

$$ROC = \infty$$

General MATLAB tips

- Remember to read the documentation of functions

- Please feel free to email or come to office hours if you feel like you are stuck

- Do sanity checks of your answers

Homework Question 6

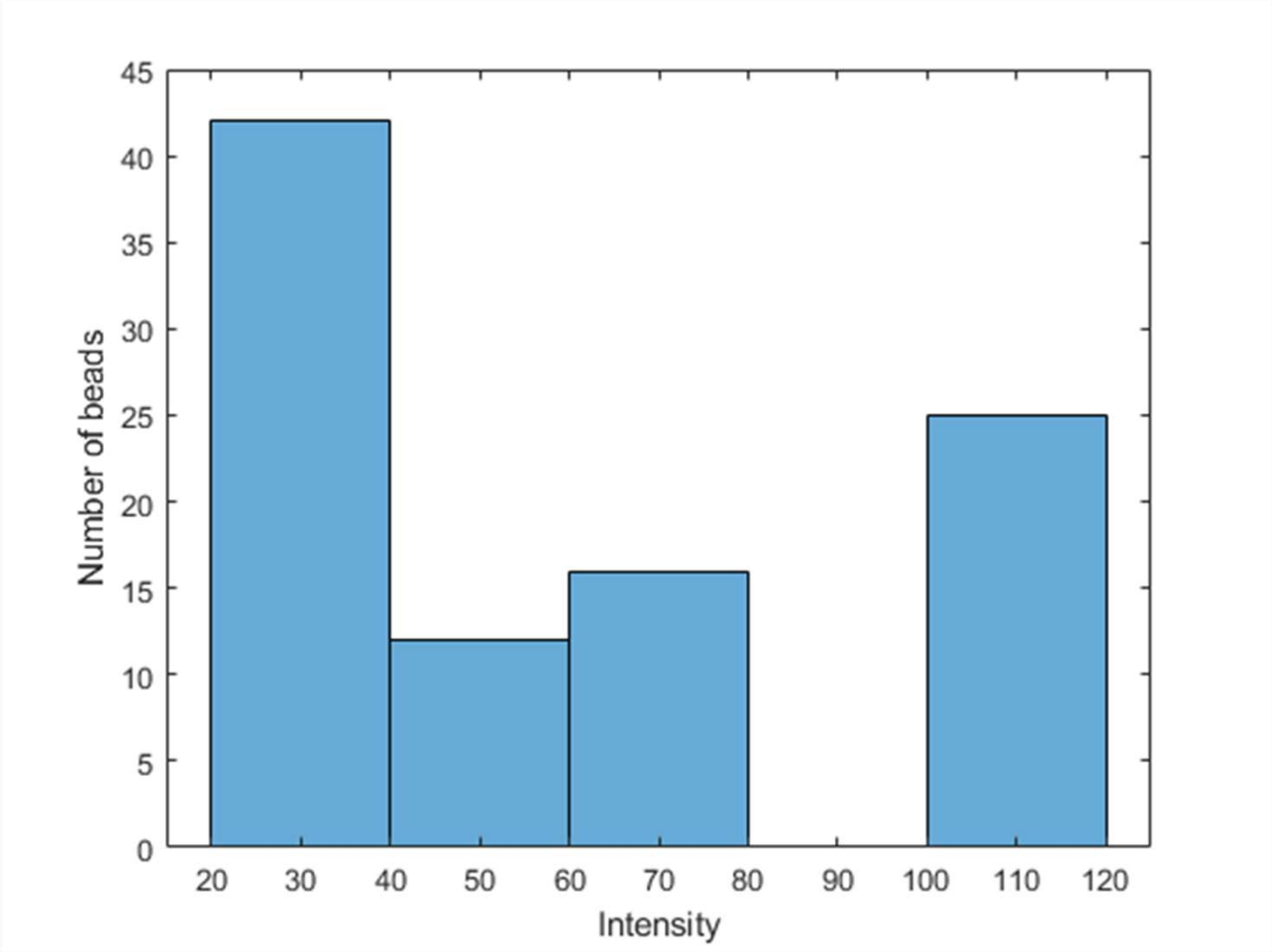
- To measure intensities, `regionprops` needs to have both the mask (so it knows where the objects are) and the image (so it can measure the intensity)

```
intensities = regionprops(mask, image, 'MeanIntensity')
```

Histograms

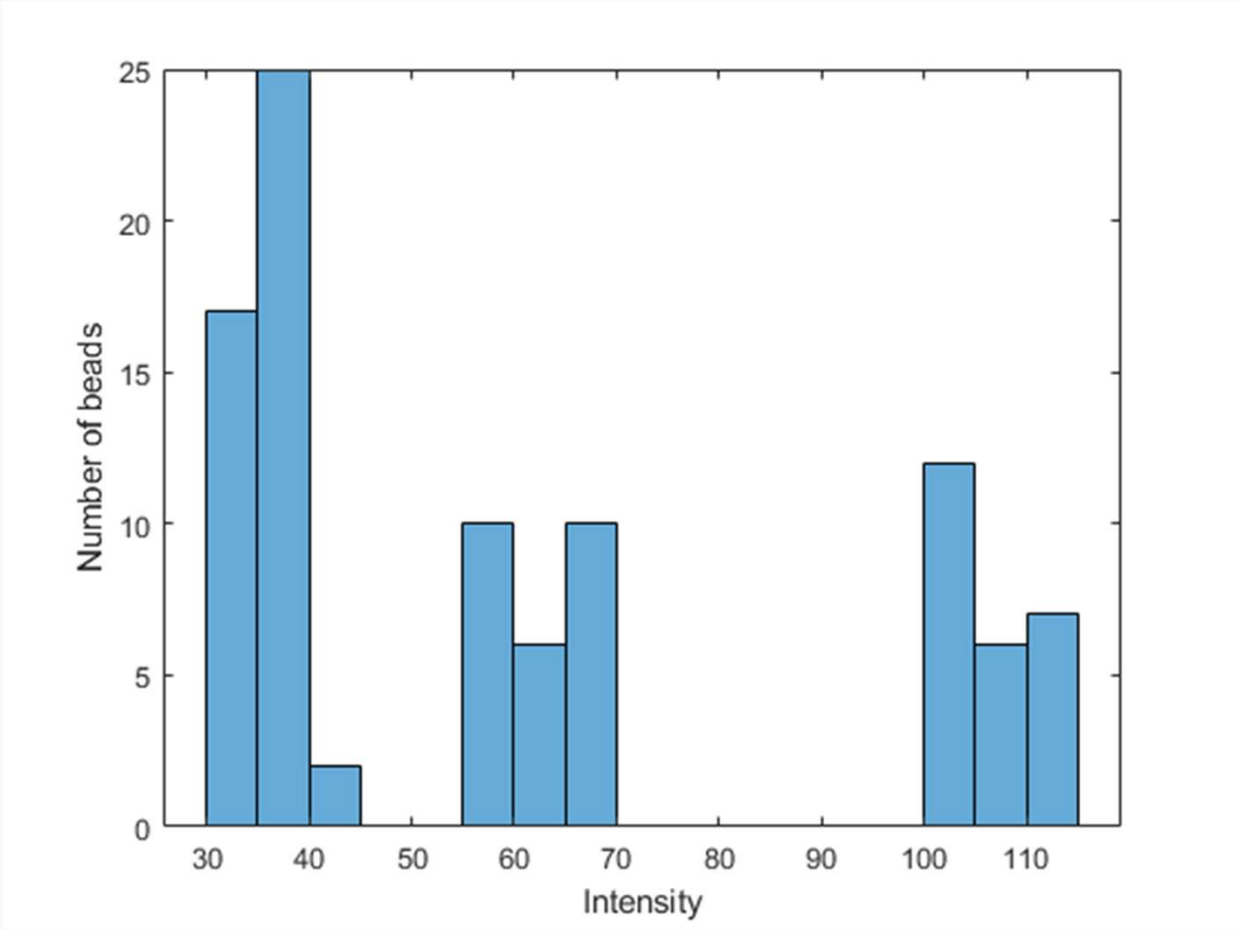
- I made this a homework question because I want you to start thinking about how to display your data

Histograms




```
histogram([beaddata.MeanIntensity])
```

Histograms




```
histogram([beaddata.MeanIntensity], 'BinWidth', 5)
```

Histograms

- I made this a homework question because I want you to start thinking about how to display your data

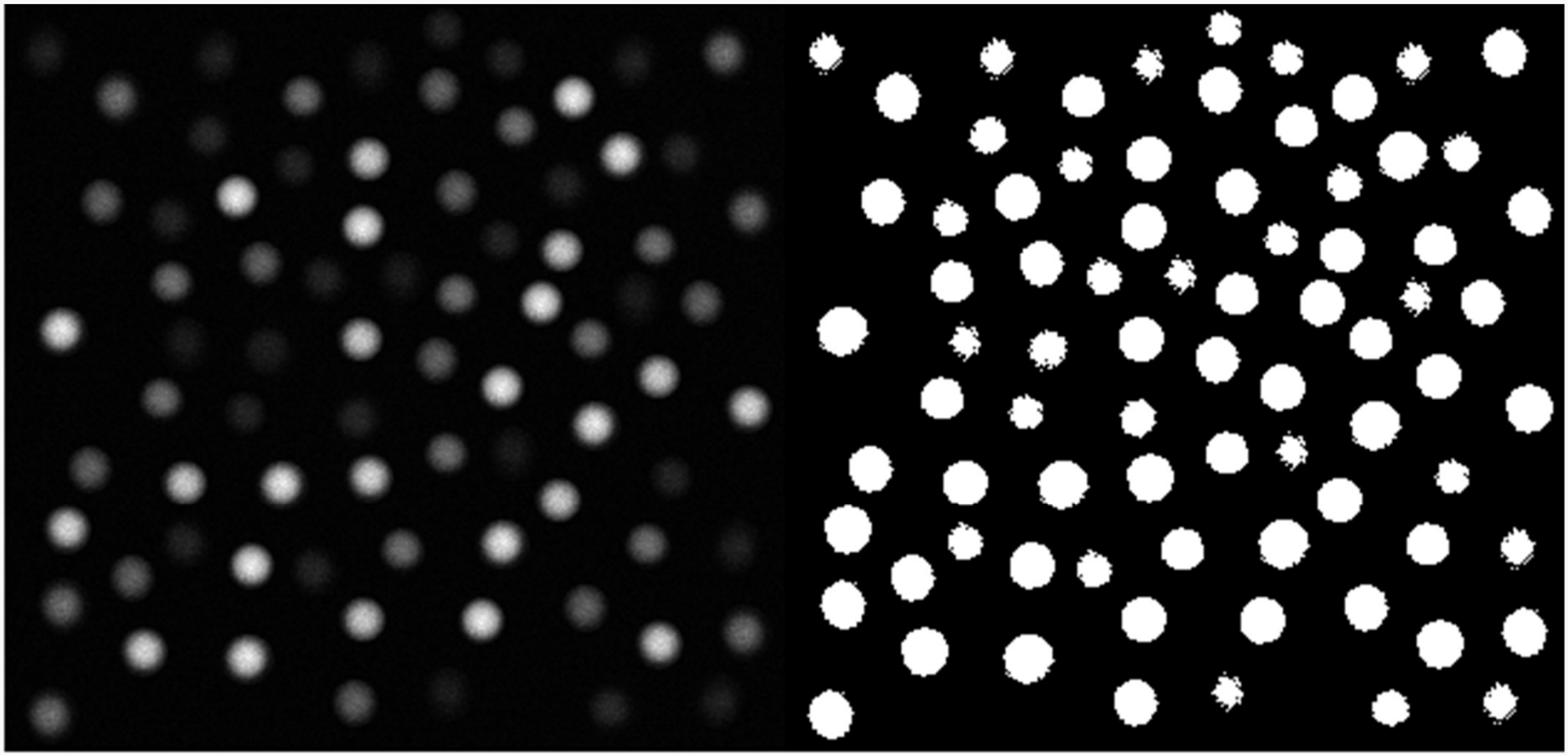
- The number of bins and width of the bins can greatly change how the data appears

> "There is no "best" number of bins, and different bin sizes can reveal different features of the data.
>
> Depending on the actual data distribution and the goals of the analysis, … **experimentation is usually needed** to determine an appropriate width"
>
> **Wikipedia**

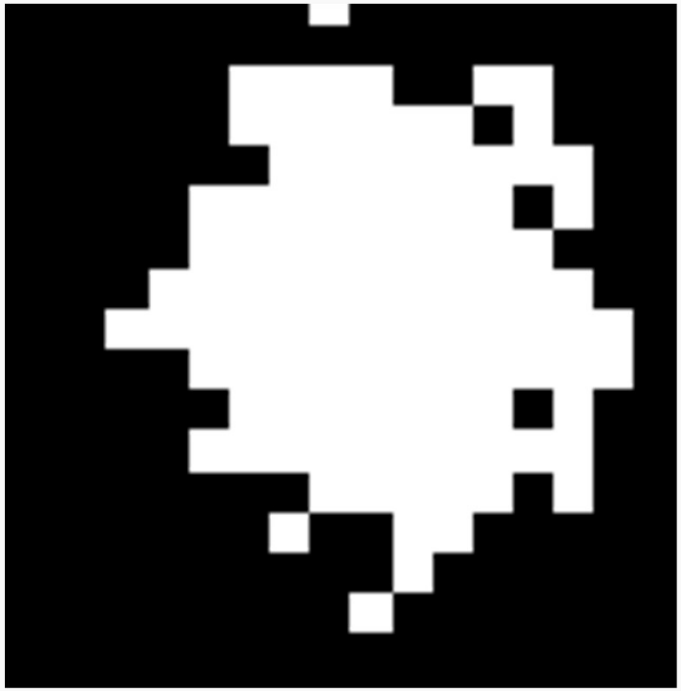
Learning goals

Refining masks using morphological operations

From homework last week



From homework last week



Issues:

- The edges of some of the beads are not very smooth
- Probably does not cover the whole area of the bead
- Did this matter for the measurement last week?

(A little – a different segmentation approach caused only about 10% change)

Morphological operations

- "Morphological" – "related to shape"

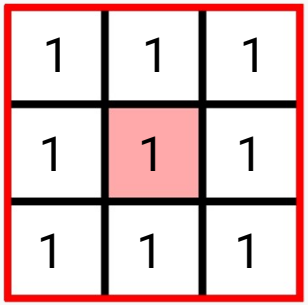
- These operations allow us to select/grow/shrink/refine masked objects by shape

- Two basic operations:
  - Dilation
  - Erosion

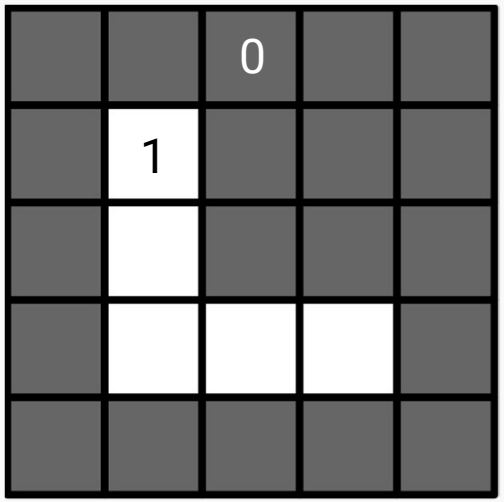
Morphological dilation

Basic principle

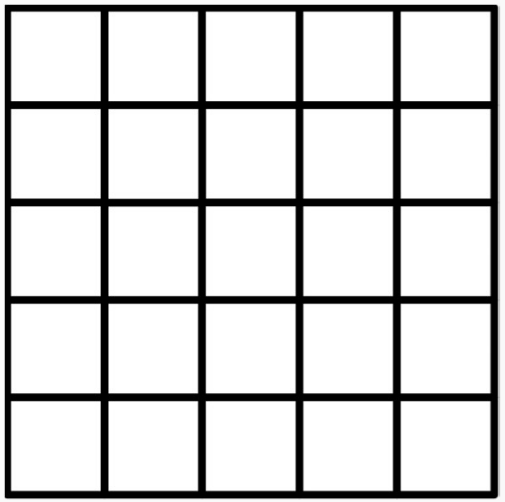
Structuring element



Input image



Output image



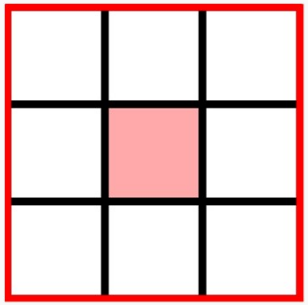
Usually small compared to image

Assume all images are binary (logical)

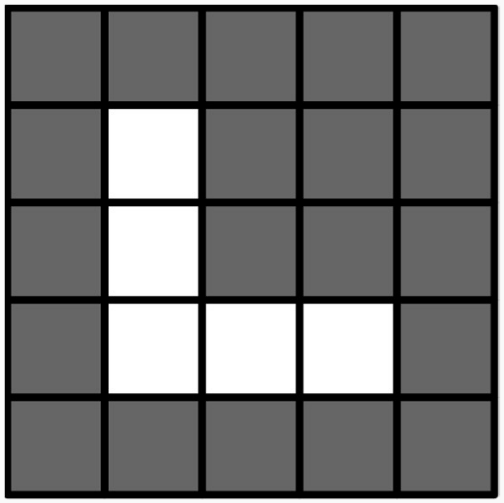
Morphological dilation

Basic principle

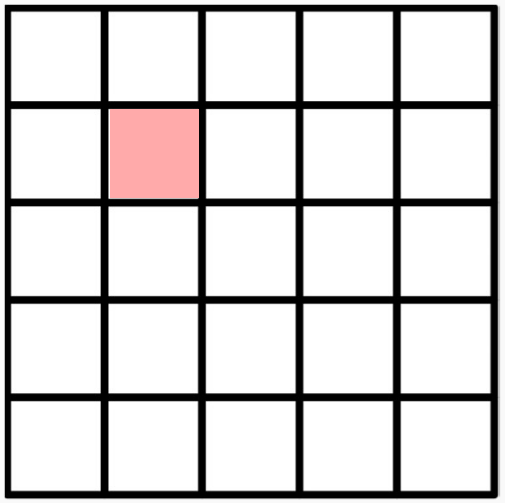
Structuring element



Input image



Output image



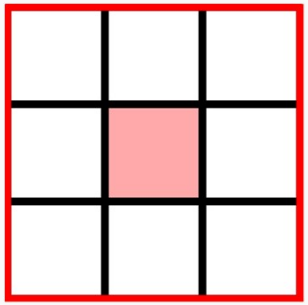
Place the structuring element over the input image

The pink square indicates the output pixel

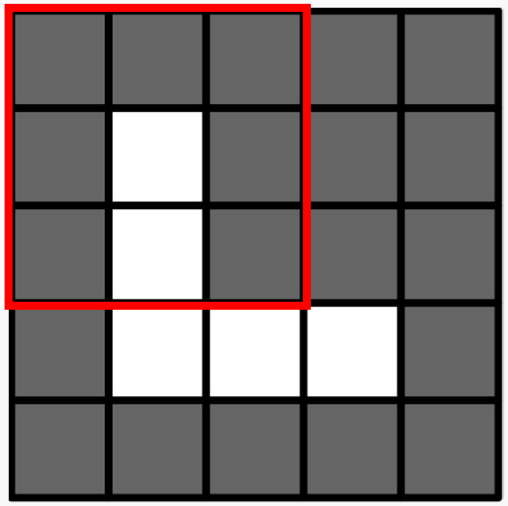
Morphological dilation

Basic principle

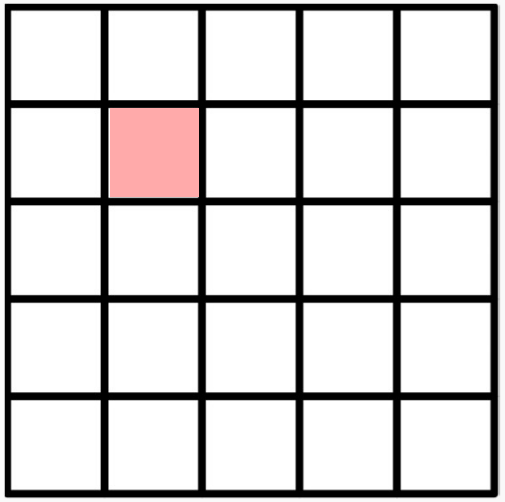
Structuring element



Input image



Output image

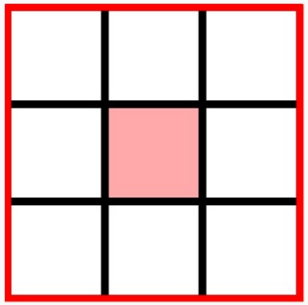


If **<u>any</u>** true pixel in the structuring element overlaps with a true pixel in the image, the output is true

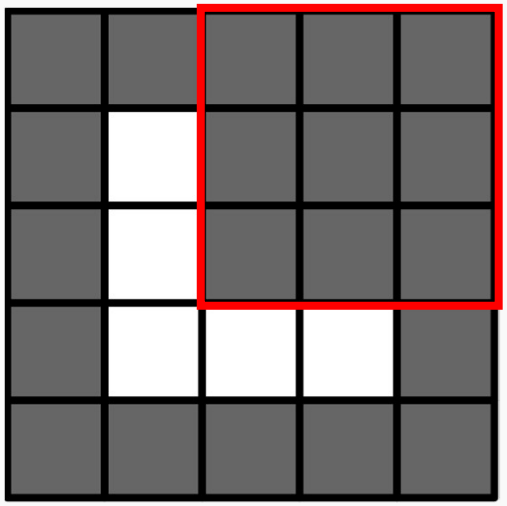
Morphological dilation

Basic principle

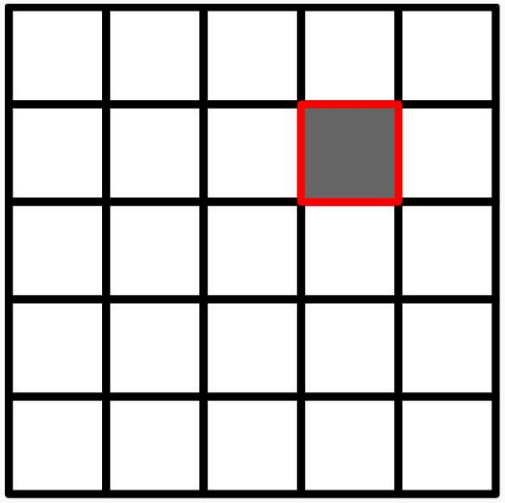
Structuring element



Input image



Output image

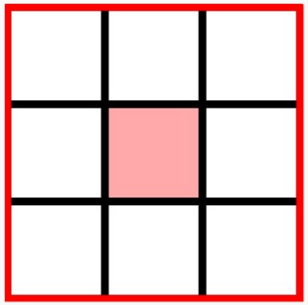


If **<u>any</u>** true pixel in the structuring element overlaps with a true pixel in the image, the output is true

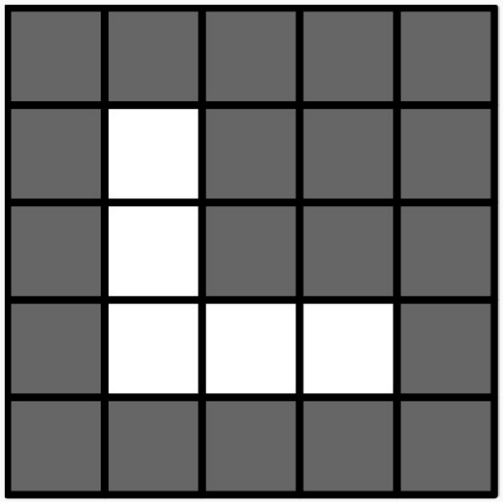
Morphological dilation

Basic principle

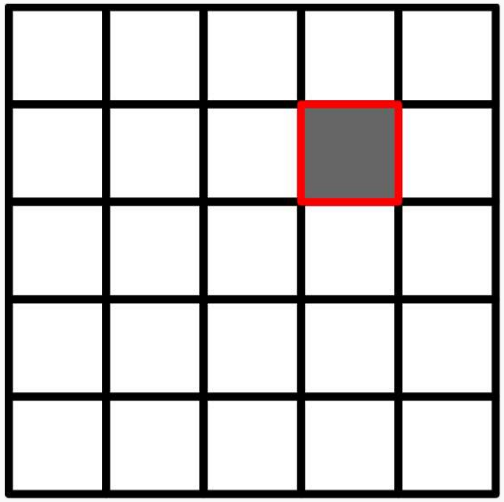
Structuring element



Input image



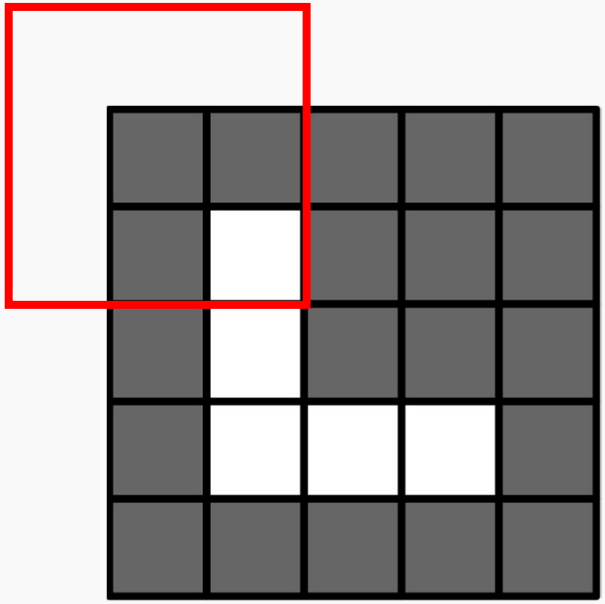
Output image



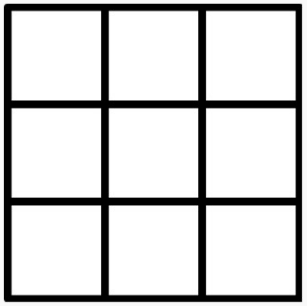
Repeat process for every pixel in the image

What about edge pixels?

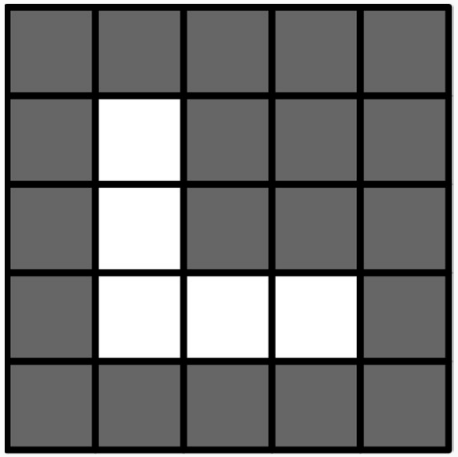
- Ignore the pixels that do not overlap with the image



What is the result of the morphological dilation?

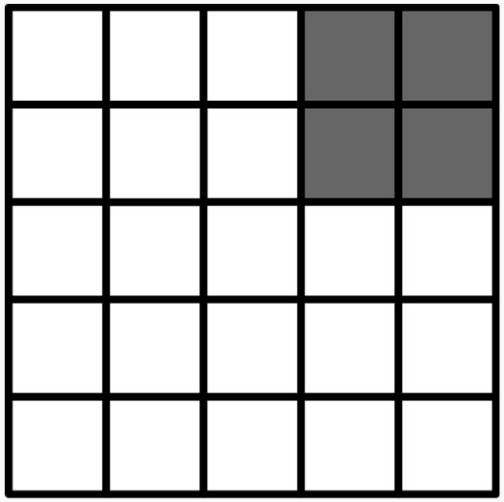


Structuring element

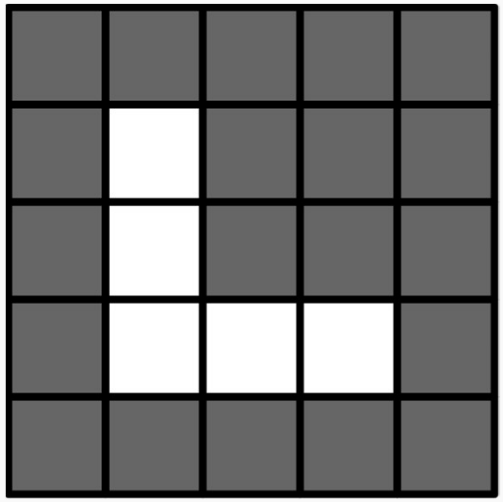


Input image

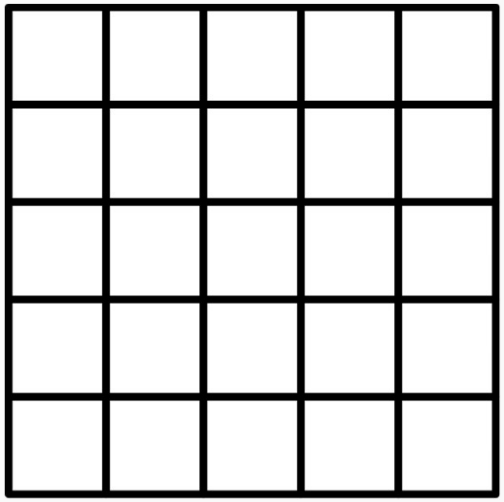
(A)



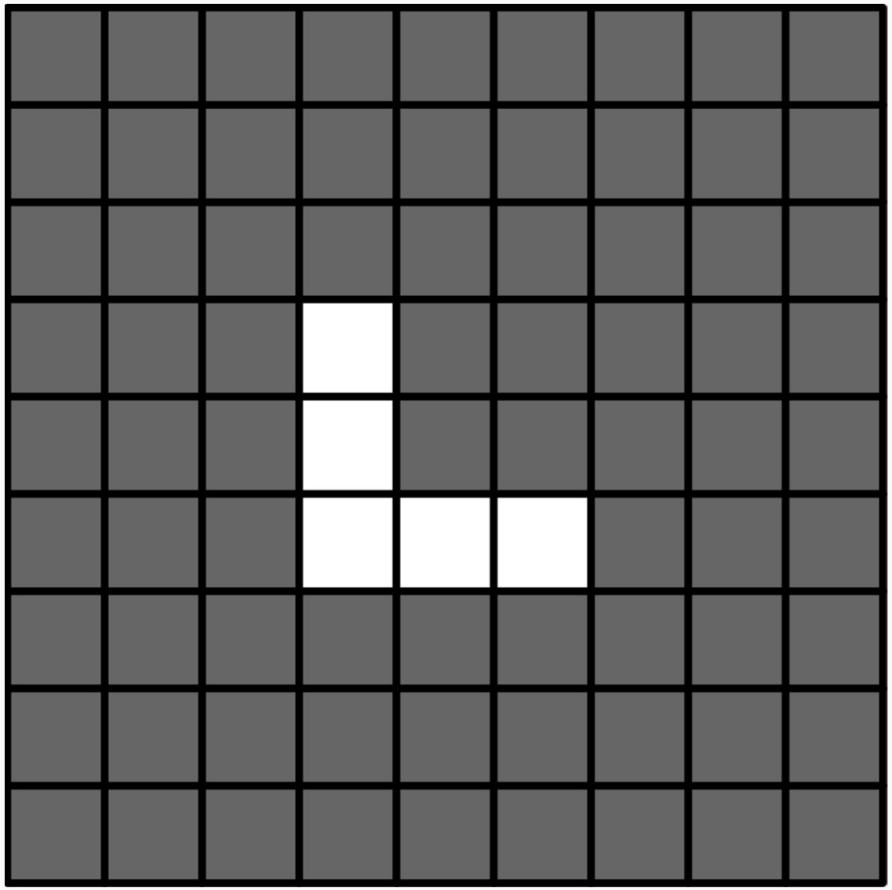
(B)



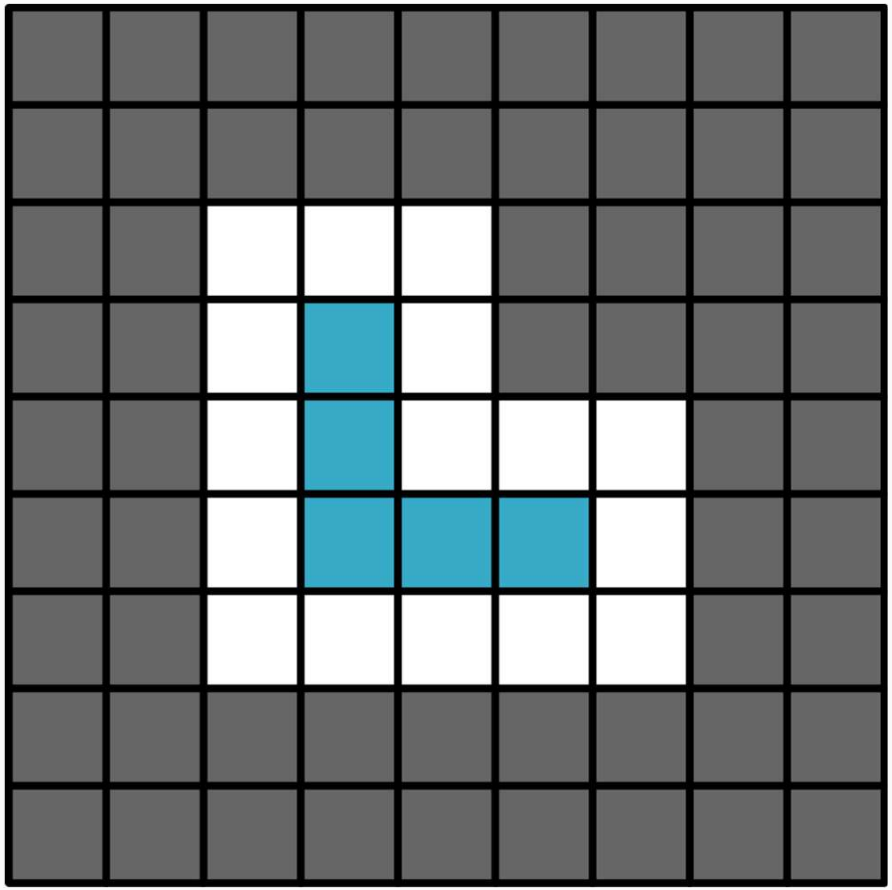
(C)



The object in the output image is larger

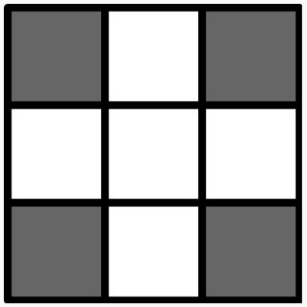


Original

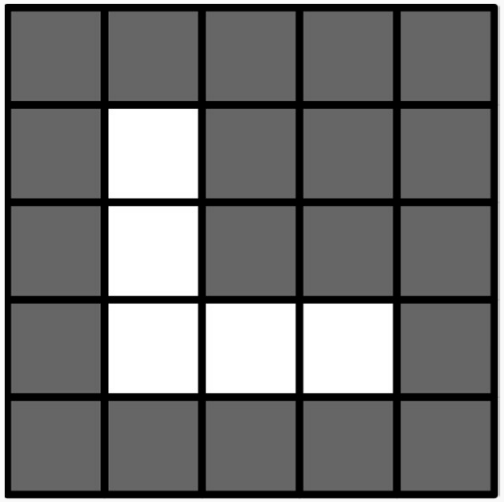


After dilation

What is the result of the morphological dilation?

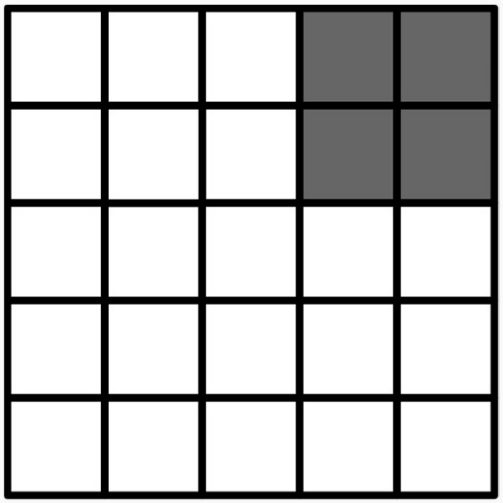


Structuring element

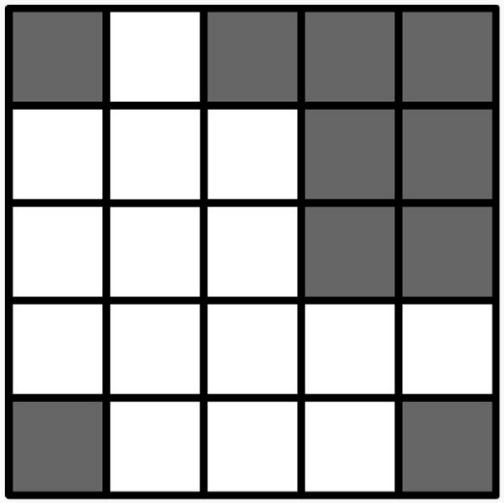


Input image

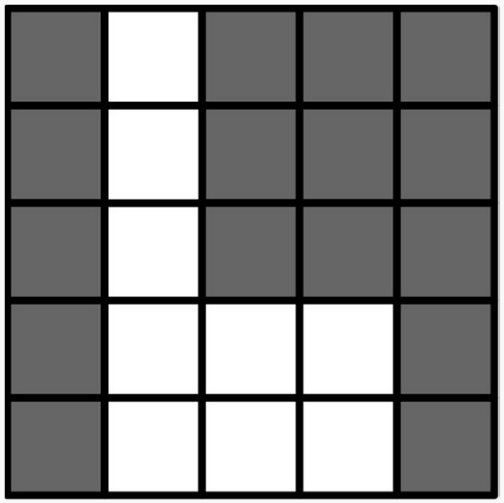
(A)



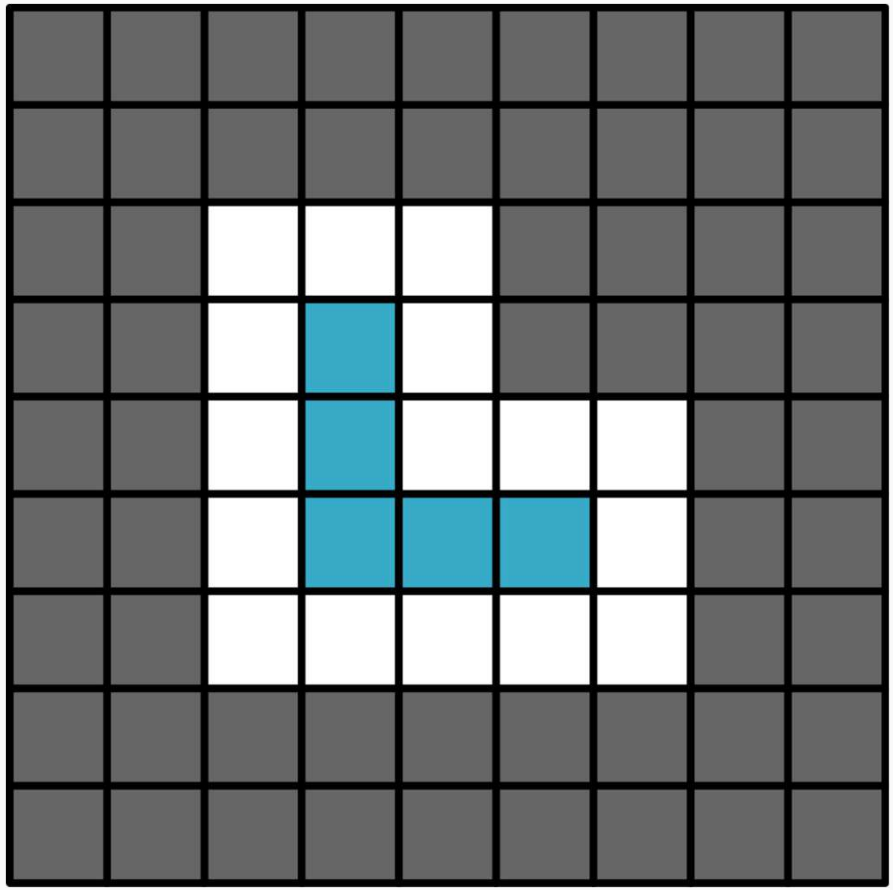
(B)



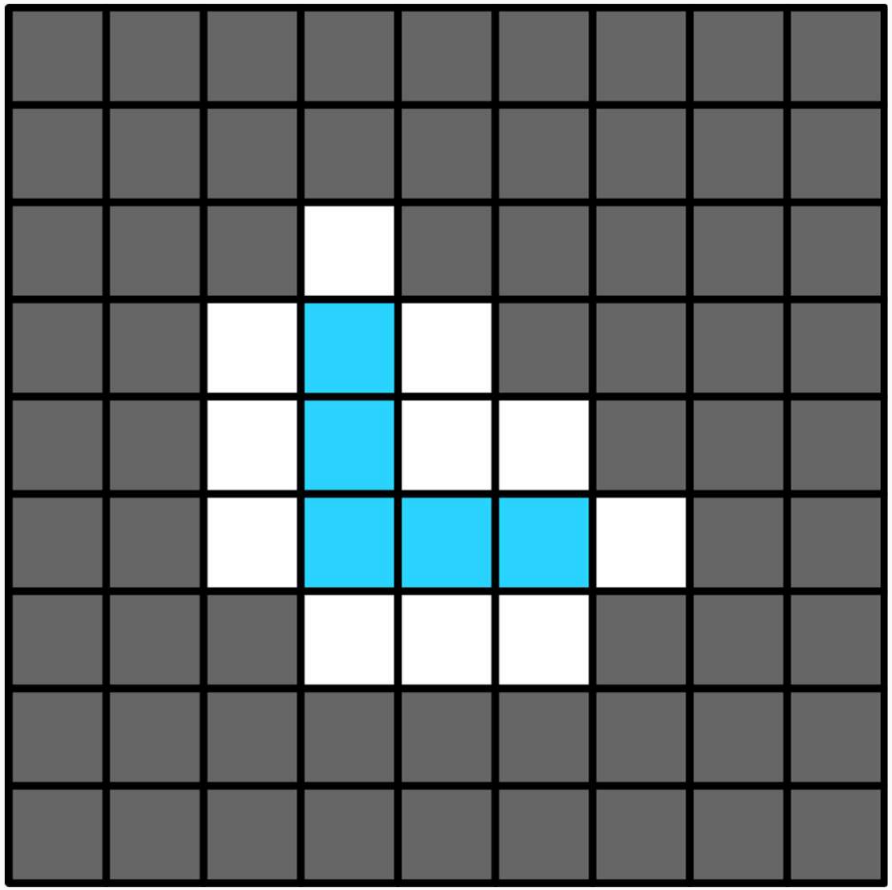
(C)



Final shape follows shape of structuring element



Square structuring element



Circular structuring element

MATLAB implementation

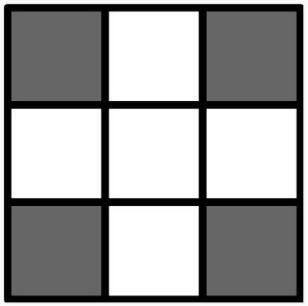
To generate the structuring element, you can either:

- Declare a matrix yourself
- Use the function `strel`

```
SE = strel('disk', Radius)
```

Look at the documentation to see how to get other shapes

Which command returns the structuring element shown?



Type in each command below

Then type `SE.Neighborhood` to get the matrix

a) `SE = strel('line', 3, 90)`

b) `SE = strel('disk', 3)`

c) `SE = strel('disk', 2.5)`

d) `SE = strel('disk', 1)`

MATLAB implementation

- Read in the image `'blobs.png'` as variable `I`

- Then run the dilation

```
SE = strel('disk', 1)
I_dilated = imdilate(I, SE);
```

- Display the dilated image

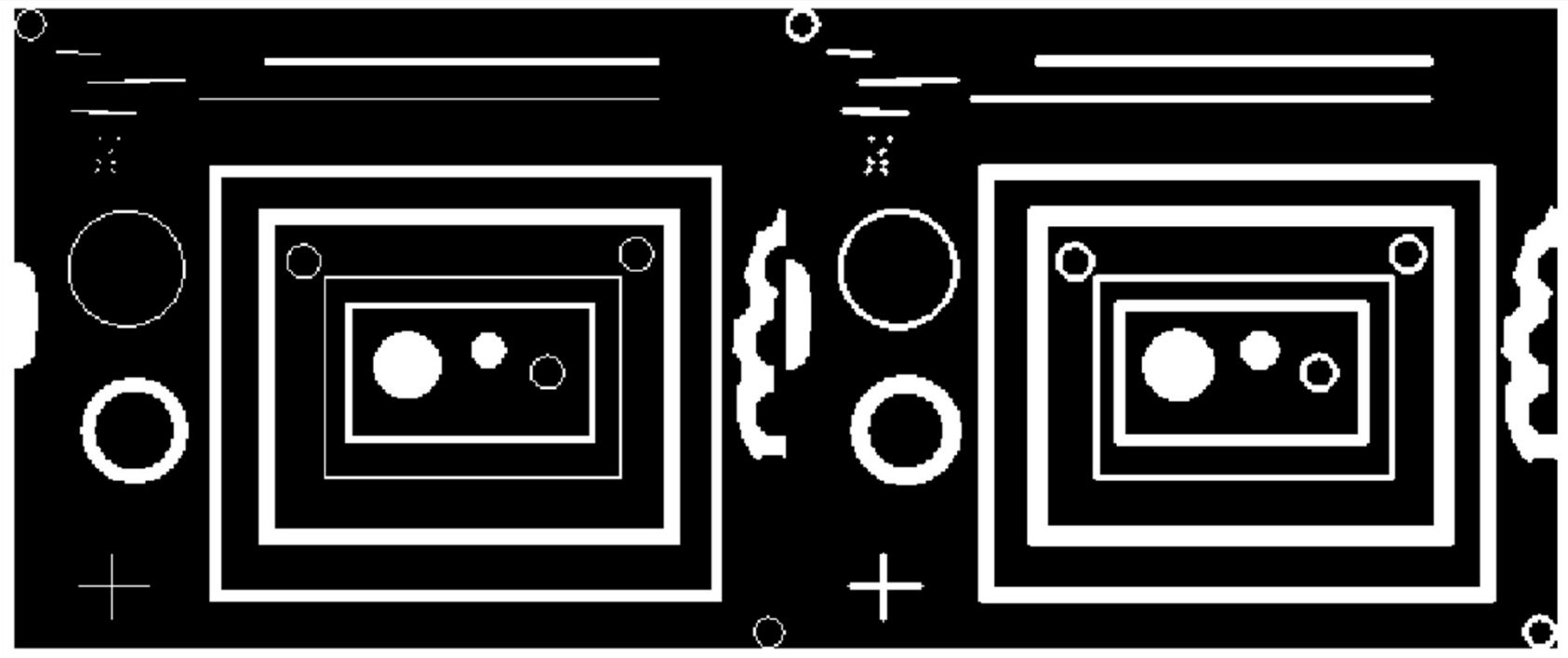
Example of dilation

```
%Read in the image 'blobs.png'
I = imread('blobs.png');

%Create a disk-shaped (1 px radius) structuring element
SE = strel('disk', 1);

%Run the dilation operation
I_dilated = imdilate(I, SE);

%Display the images side by side
imshowpair(I, I_dilated, 'montage')
```

The effect of morphological dilation

Original Image

After dilation

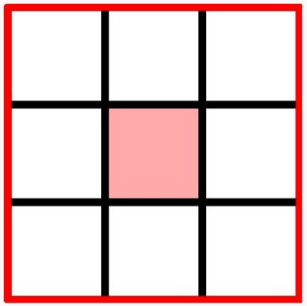


Dilates or expands the edges of objects with a shape that is similar to the structuring element (look at the corners)

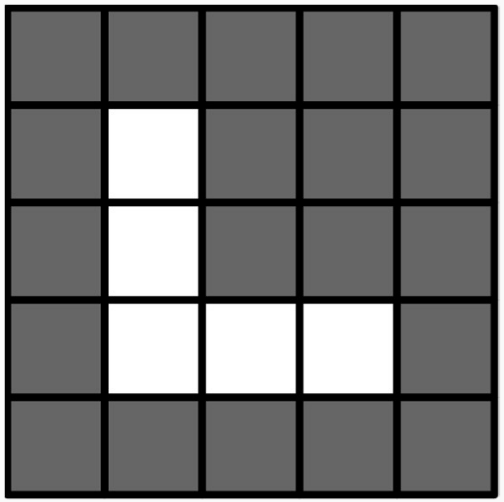
Morphological erosion

Basic principle

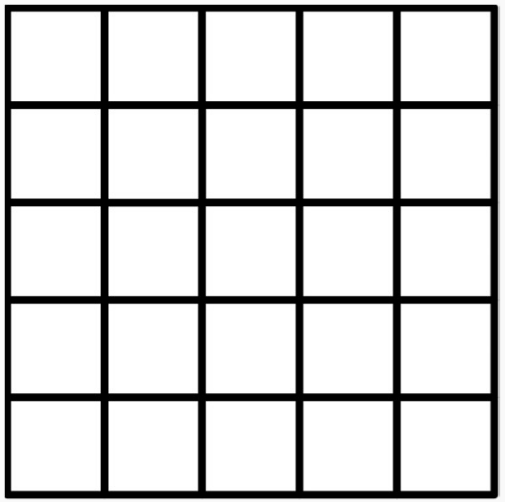
Structuring element



Input image



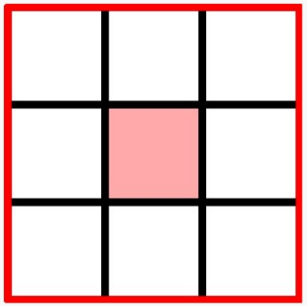
Output image



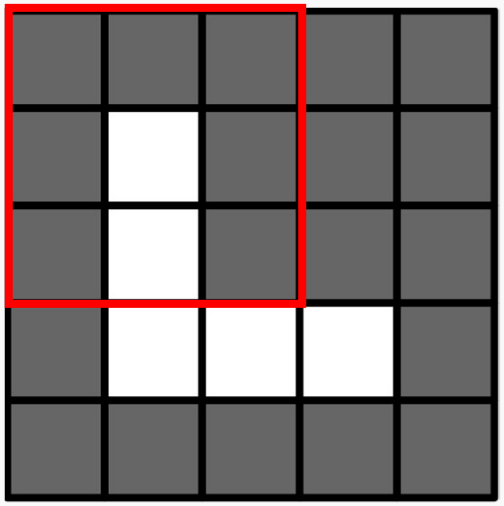
Morphological erosion

Basic principle

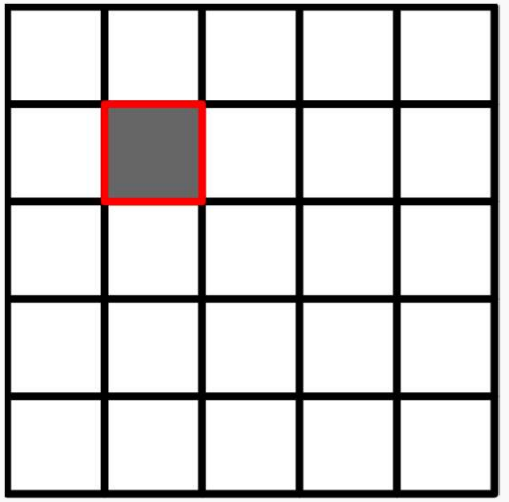
Structuring element



Input image

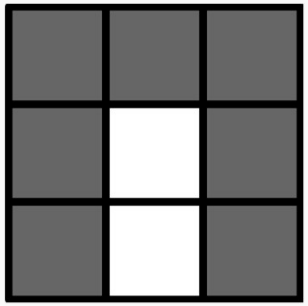


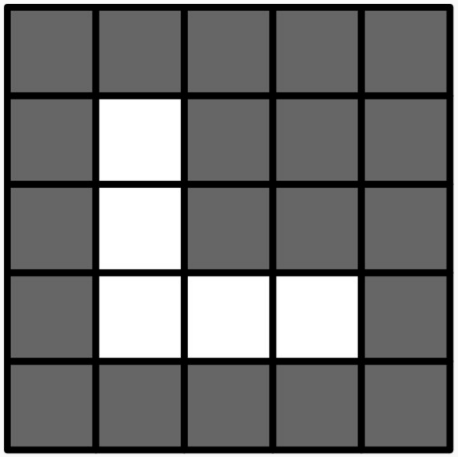
Output image



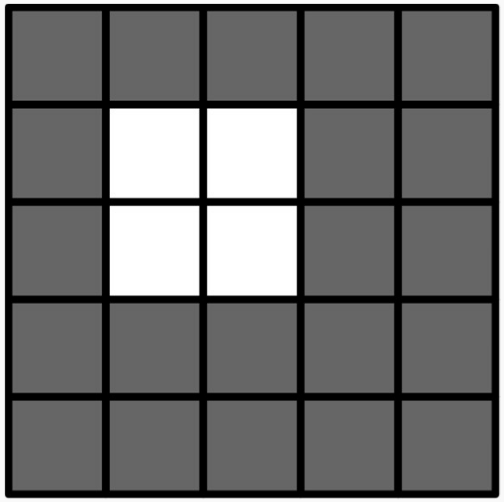
If **every** true pixel in the structuring element overlaps with a true pixel in the image, the output is true

What is the result of the morphological erosion?

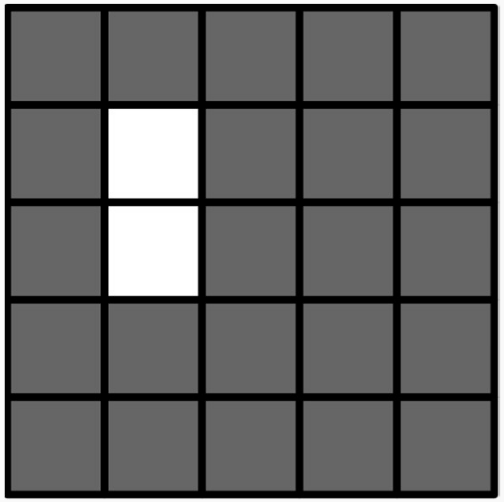




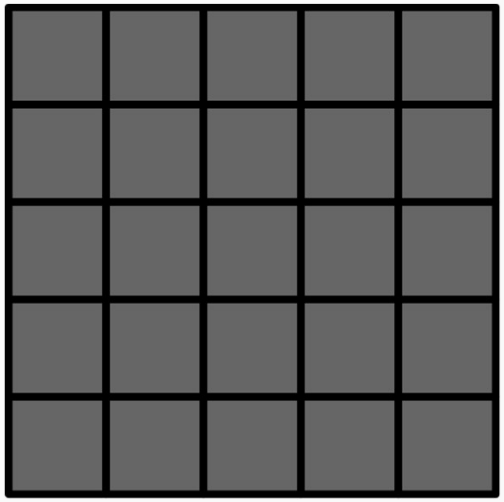
(A)



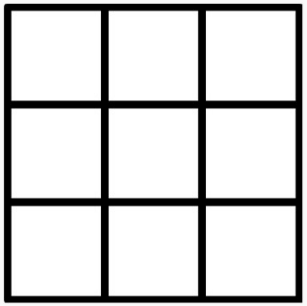
(B)

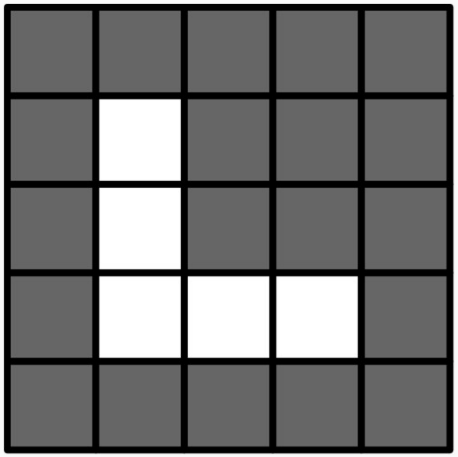


(C)

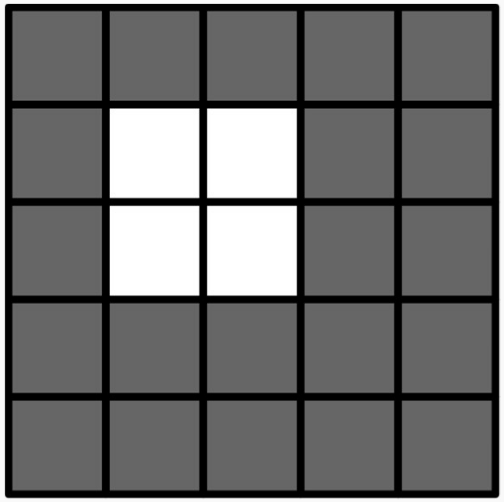


What is the result of the morphological erosion?

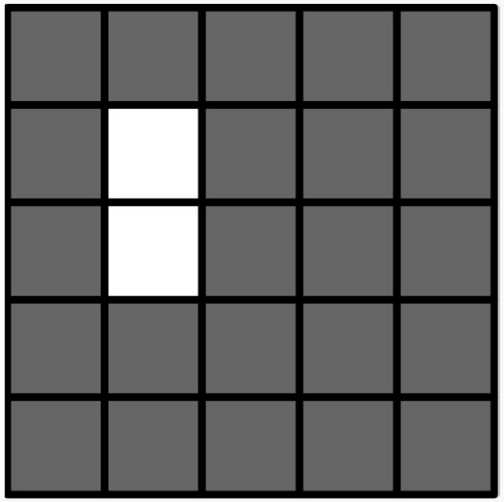




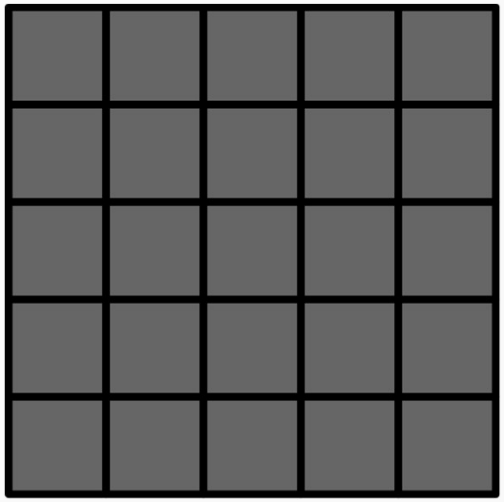
(A)



(B)



(C)



MATLAB implementation

- Erode the image `'blobs.png'` with a line structuring element (3 pixels in length, 0 degrees – horizontal line)

```
I_eroded = imerode(I, SE);
```

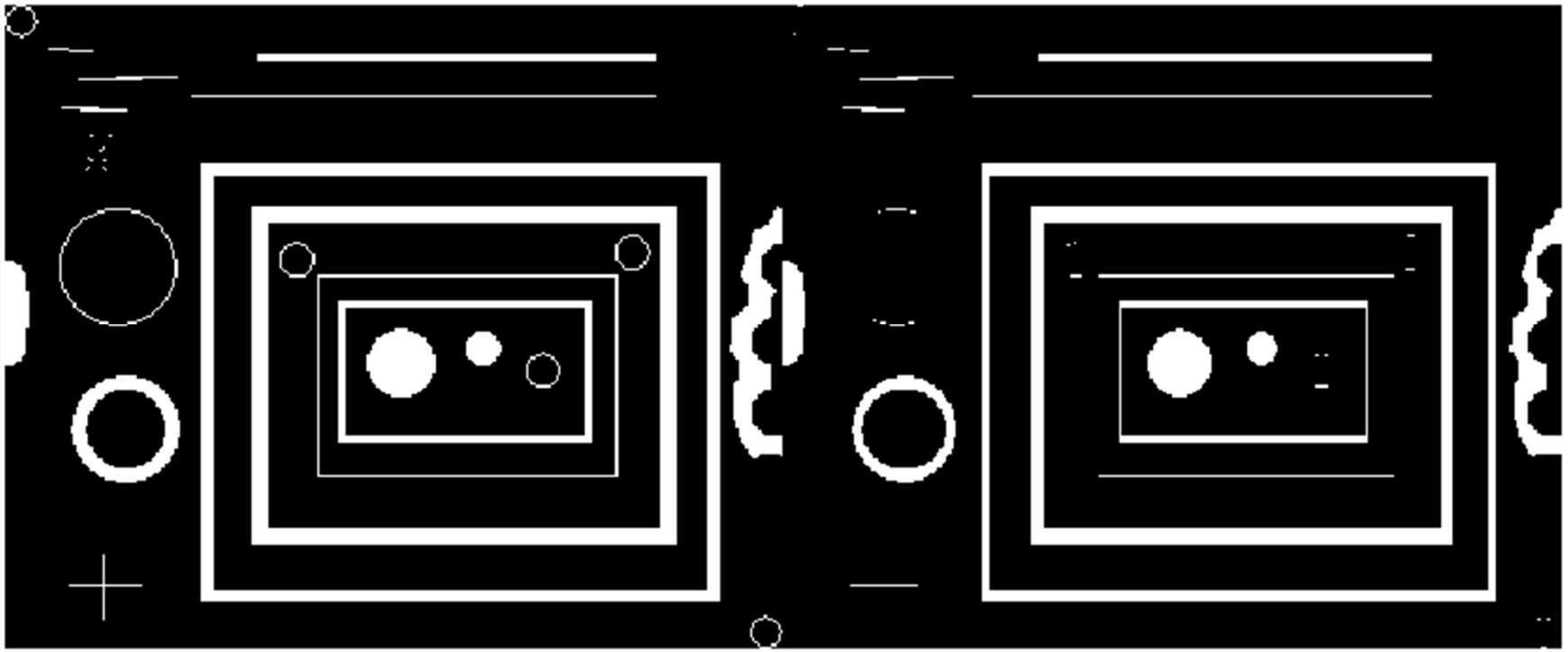
- What is the command to generate the line structuring element?

```
SE = strel('line', 3, 0);
```

The effect of morphological erosion

Original Image

After erosion



Erodes or shrinks the edges of objects with a similar shape to the structuring element (possibly removing them)

Compound operations

- Erosion and dilation are useful but change the size of the objects

- The compound operations opening and closing preserve the sizes better

Opening

- Erosion followed by a dilation using the SAME structuring element

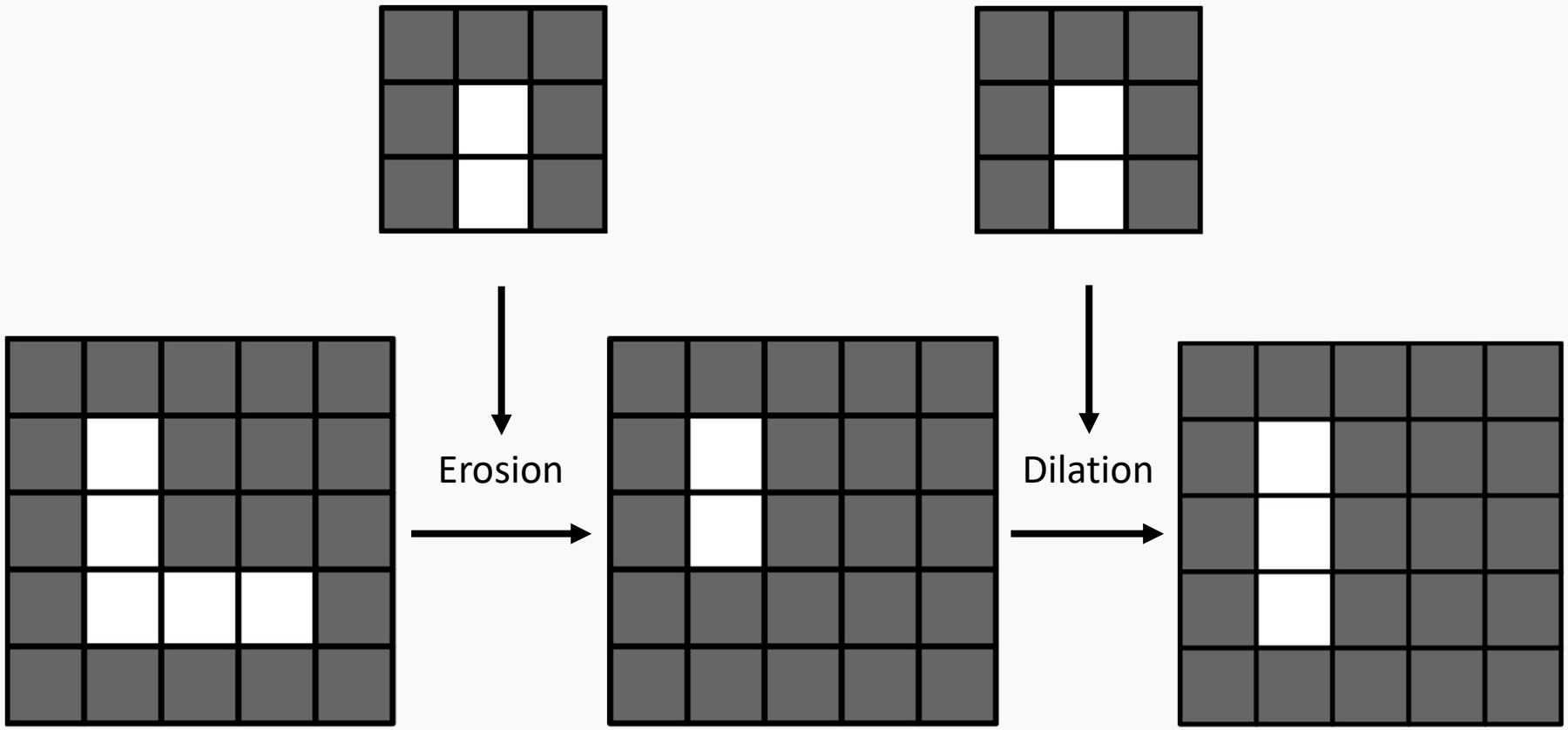
`imopen`

Closing

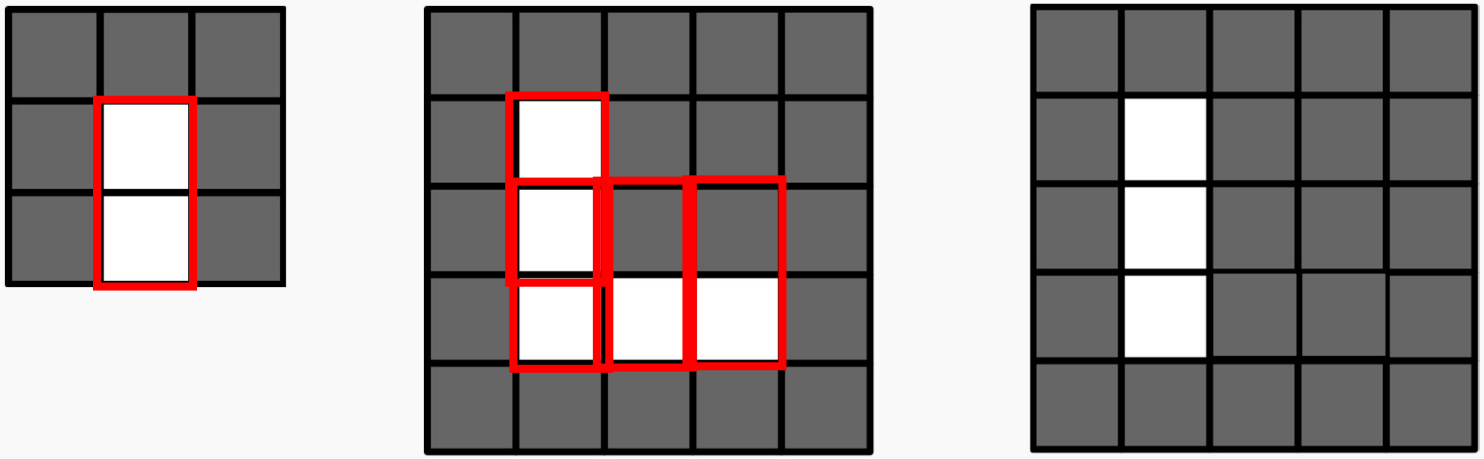
- Dilation followed by erosion using the SAME structuring element

`imclose`

How morphological opening works



Another way to visualize this



Slide the structuring element over all the foreground pixels

All pixels in the image which fits the structuring element will be kept

MATLAB implementation

- Read in the image `'blobs.png'`

- Open the image with a disk-shaped structuring element, 5 pixel radius

```
I_open = imopen(I, SE);
```

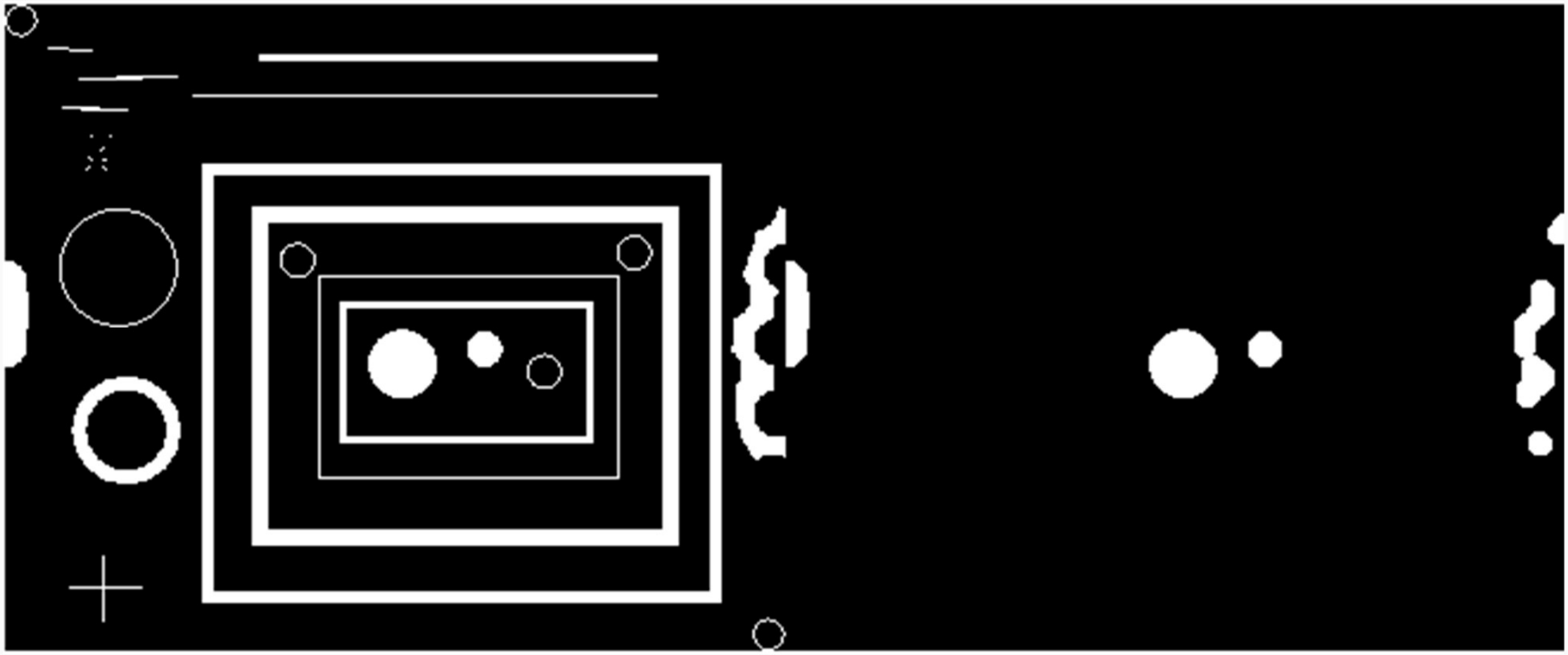
- Display the image

Example of morphological opening

```
%Read in the image 'blobs.png'
I = imread('blobs.png');

%Create a disk-shaped (5 px radius) structuring element
SE = strel('disk', 5);

%Run the opening operation
Iopen = imopen(I, SE);

%Display the images side-by-side
imshowpair(I, Iopen, 'montage')
```

Original Image

After opening



Morphological closing

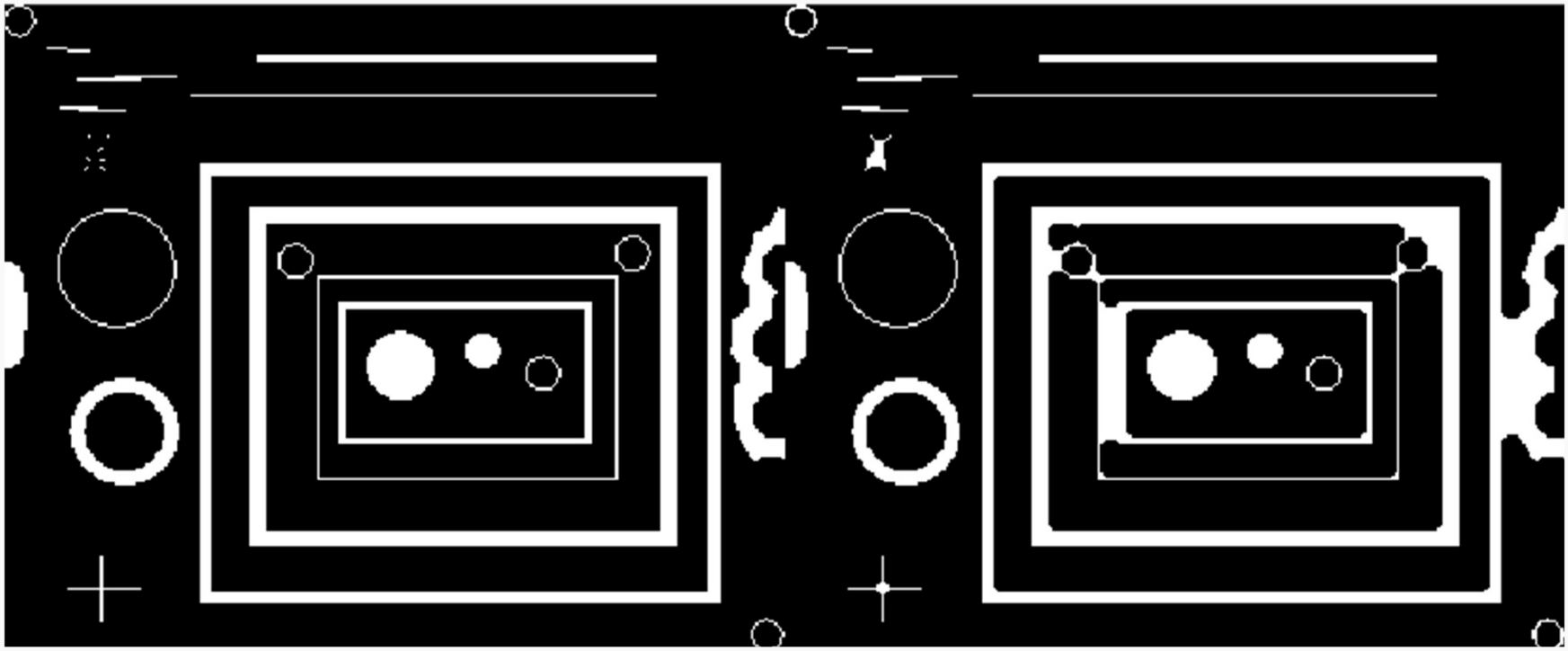
- Closing is dilation followed by an erosion

- Try closing `blobs.png` with a disk-shaped structuring element, 5 pixel radius

```
I_closed = imclose(I, SE);
```

Original Image

After closing



Example of morphological closing

```
%Read in the image 'blobs.png'
I = imread('blobs.png');

%Create a disk-shaped (5 px radius) structuring element
SE = strel('disk', 5);

%Run the closing operation
Iclose = imclose(I, SE);

%Display the images side-by-side
imshowpair(I, Iclose, 'montage')
```

Morphological opening

Opening because it tends to open gaps (remove pixels) in the image

Morphological closing

Closing tends to close gaps (add pixels) to the image

Closing remarks about the structuring element

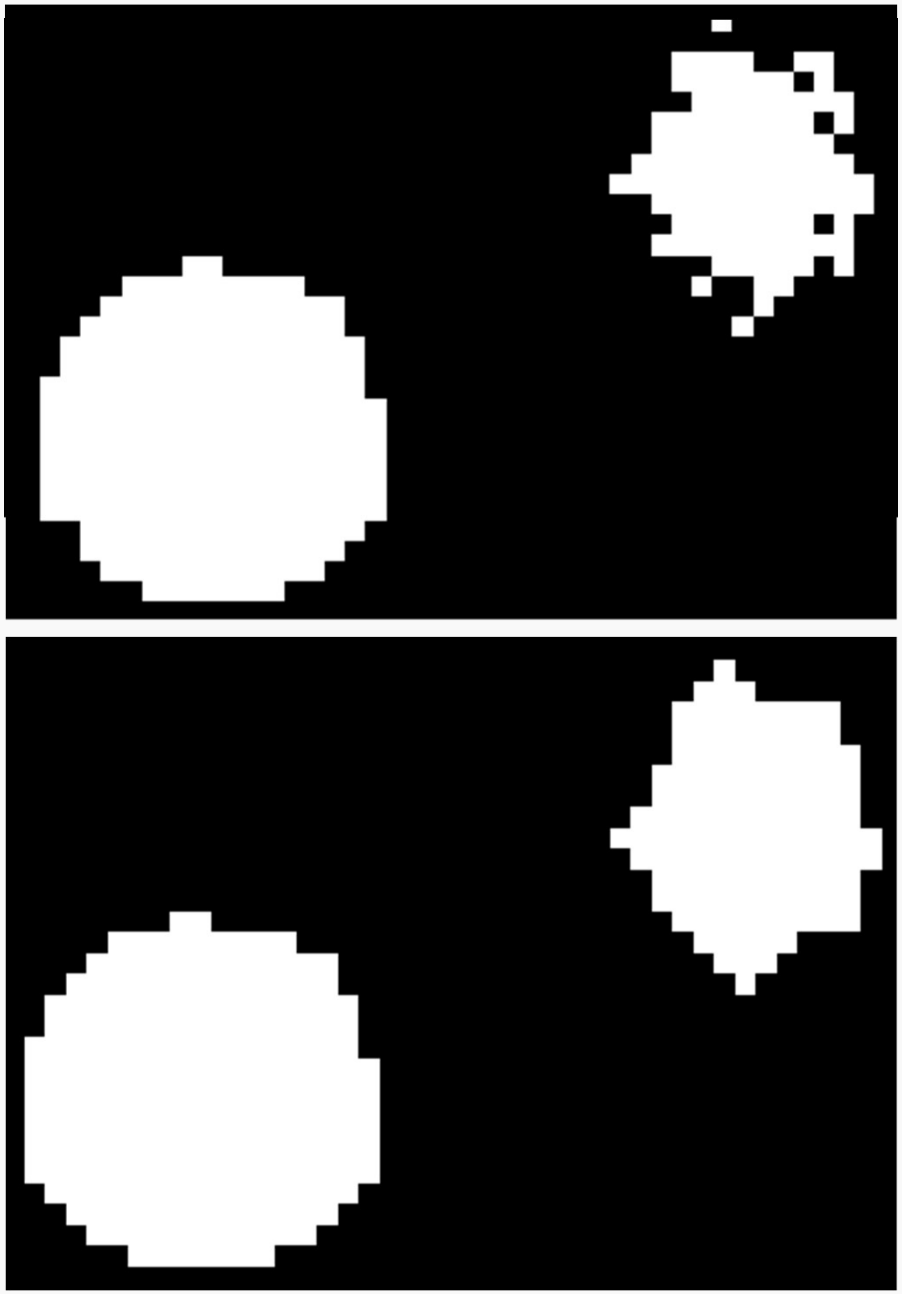
- It is important to choose a structuring element that matches the shape you are trying to preserve
- For circular objects, you should choose a [redacted] structuring element
- For lines (e.g. straight edges), you should choose a [redacted] structuring element
- For more complex cell morphology, sometimes a diamond shaped element works best

Remember this for homework in two weeks!

Closing remarks about the structuring element

- It is important to choose a structuring element that matches the shape you are trying to preserve
- For circular objects, you should choose a circular structuring element
- For lines (e.g. straight edges), you should choose a line structuring element
- For more complex cell morphology, sometimes a diamond shaped element works best

Remember this for homework in two weeks!



- Opening with a disk-shaped structuring element, 7 pixel radius
- Feel free to try this on your data from last week

Next week

No MATLAB class next Friday October 4

For the mid-term:

- Any material in slides and homework could potentially end up in the exams
- You should know basic MATLAB commands and simple statistics functions
- You should know conceptually how the algorithms we have used so far work
  - Think about when you might want to use them/when they might fail