nvidia

Visual Computing

2024/2025

Class 10

Brief on Image Segmentation and Mathematical Morphology

deti departamento de electrónica, telecomunicações e informática

universidade de aveiro

Agenda

Image Segmentation

Region Segmentation

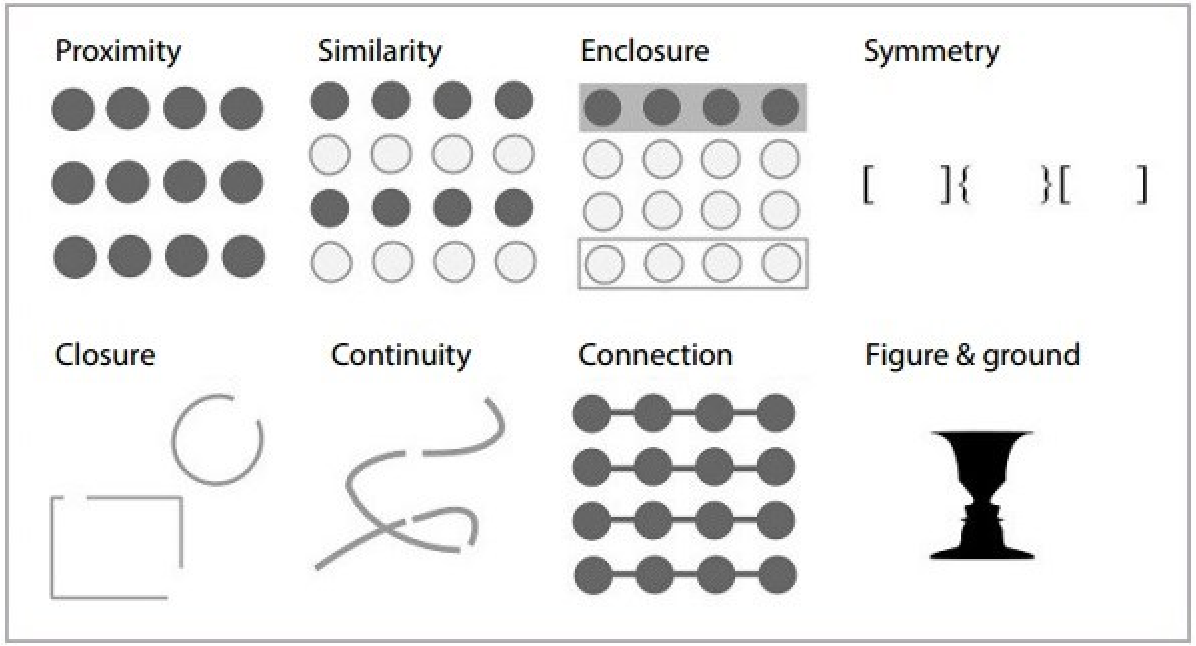
Mathematical Morphology

no Lenas have been harmed in producing these slides

What is Segmentation

How do we do it?

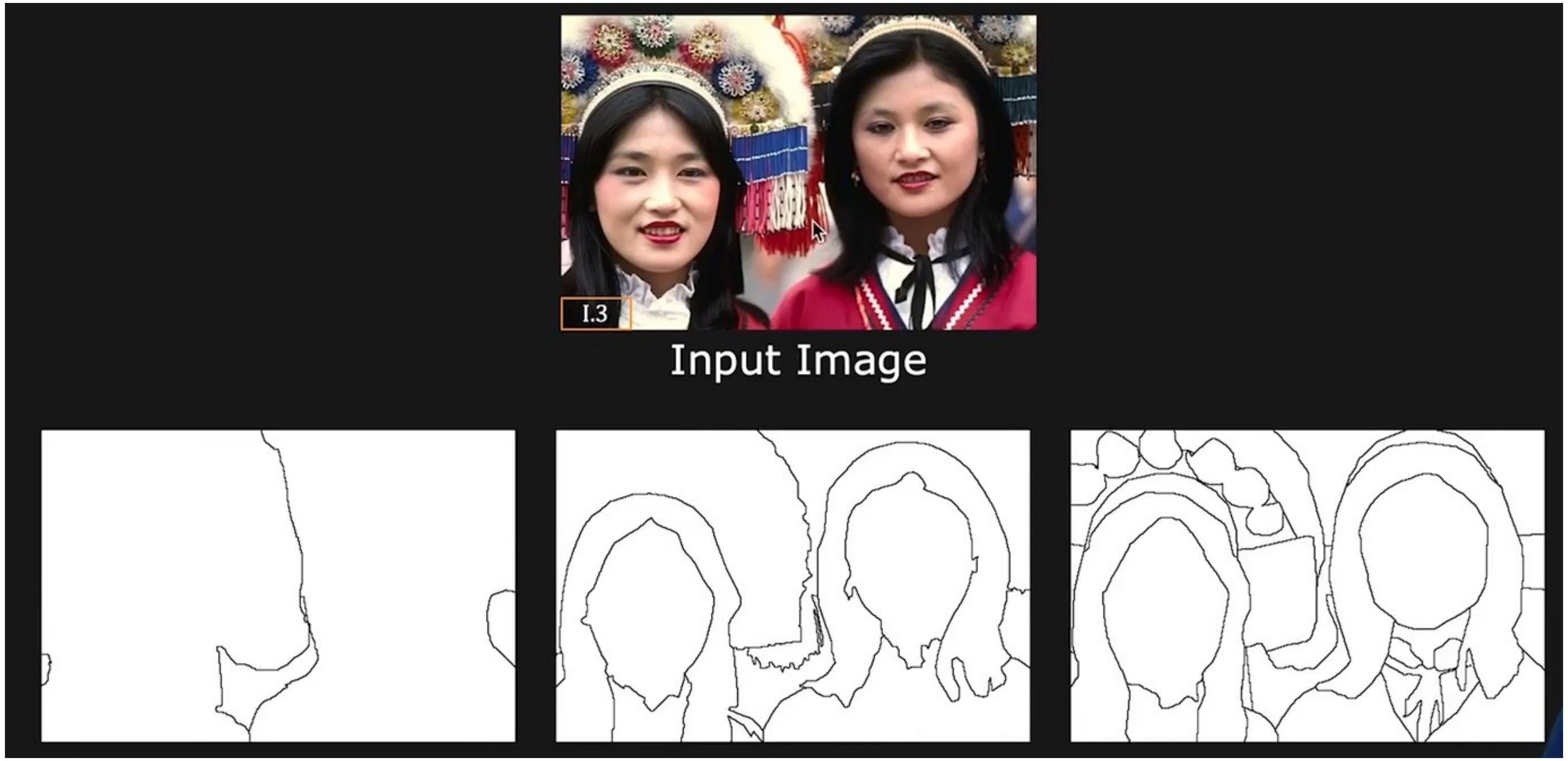
Remember the Gestalt Principles and the class on Visual Perception



One more tick in the list, Anita...

What is Segmentation
a subjective task

Very hard to translate into algorithms



What is the right segmentation ?

Segmentation

Two overall approaches:

Top-down Segmentation:

Pixels grouped because they come from the same object

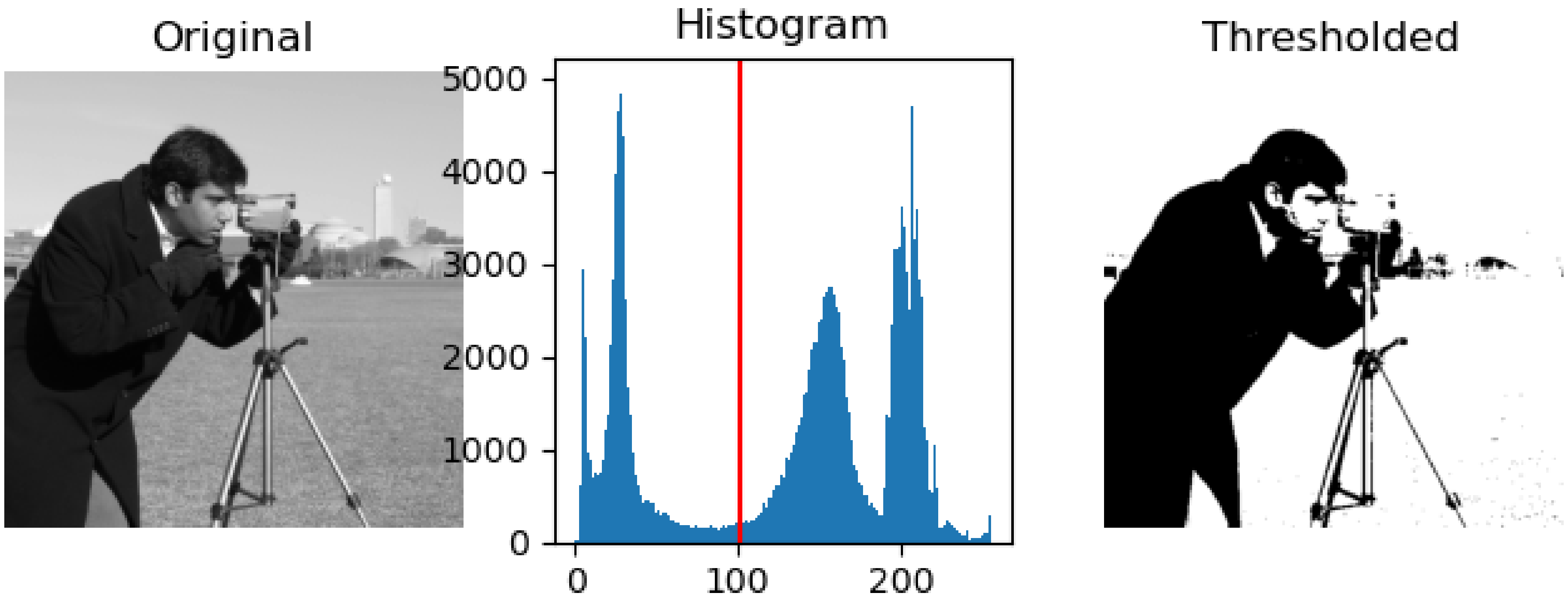
Bottom-up Segmentation:

Group pixels that are similar (luminance, colour, position, texture, depth, ...)

Thresholding

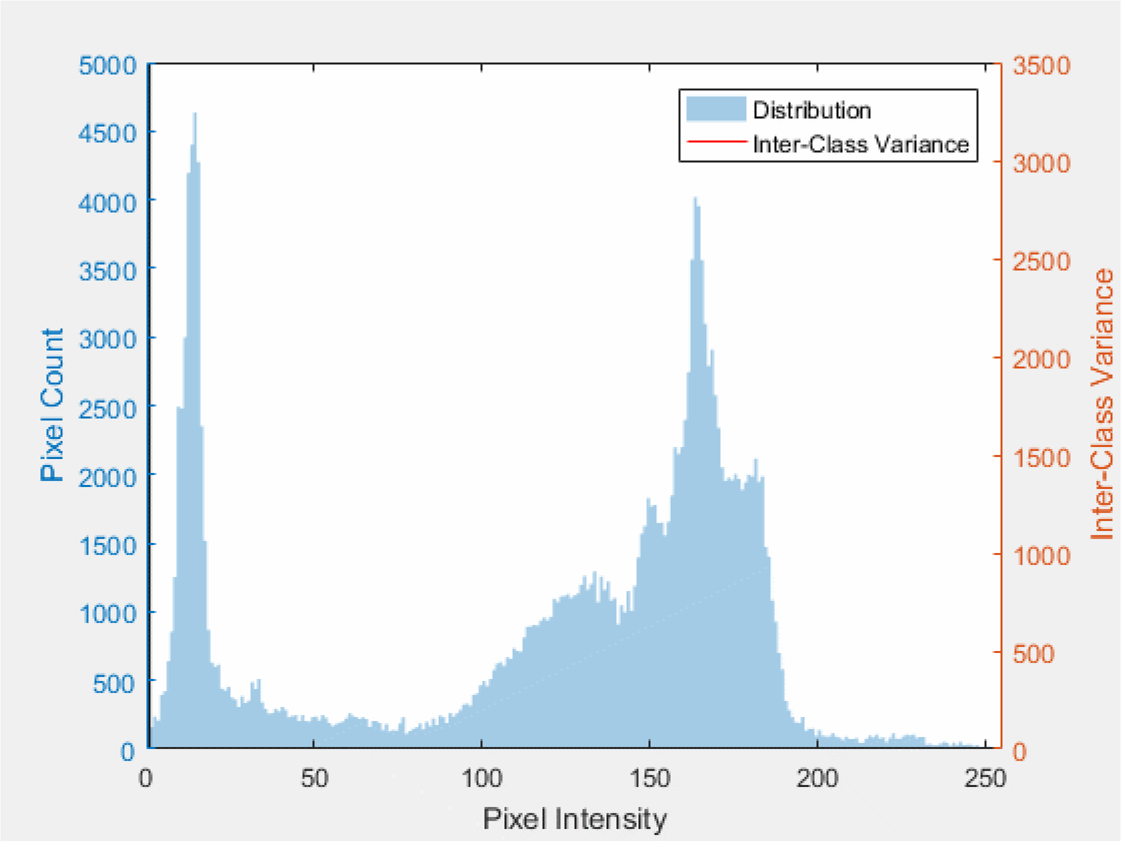
Threshold

Divide histogram in two by defining a threshold value



Threshold
Otsu's method

Determine threshold level that maximizes inter-class variance



Region Growing

Flood Fill

Establish a seed

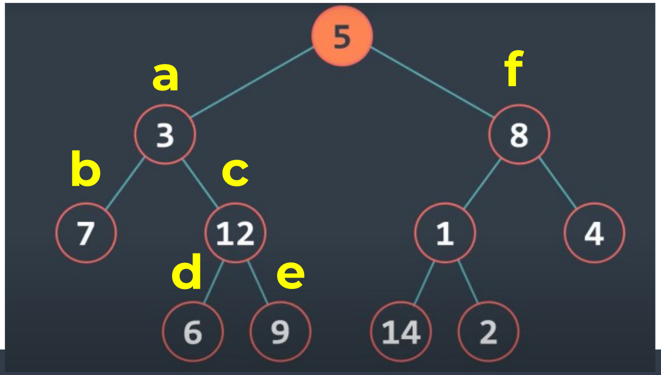
Propagate region based on a criterion
- pixel has same color as seed,
- pixel colour is within interval of seed color

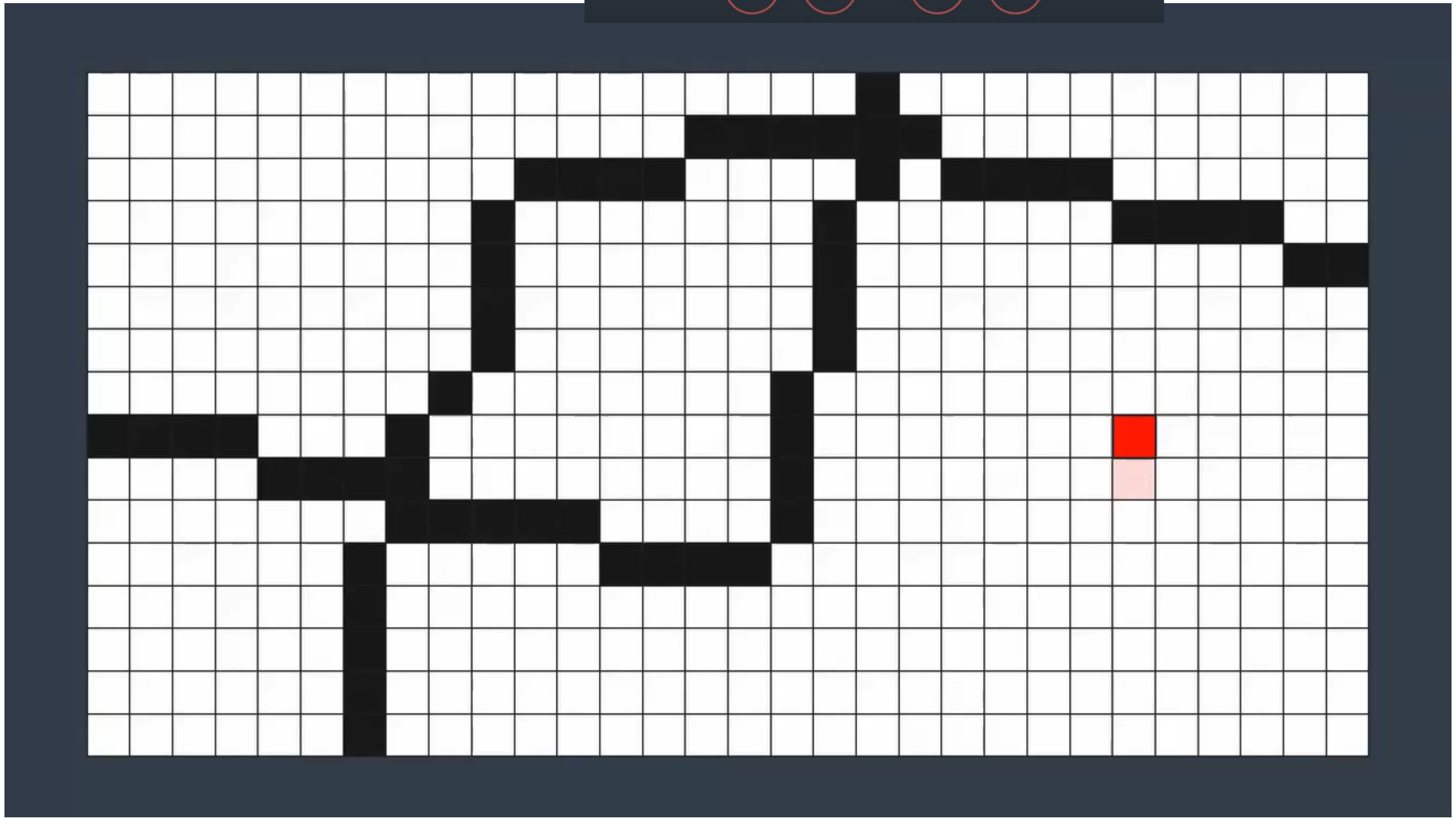
Termination criteria

How to perform the propagation?

Flood Fill

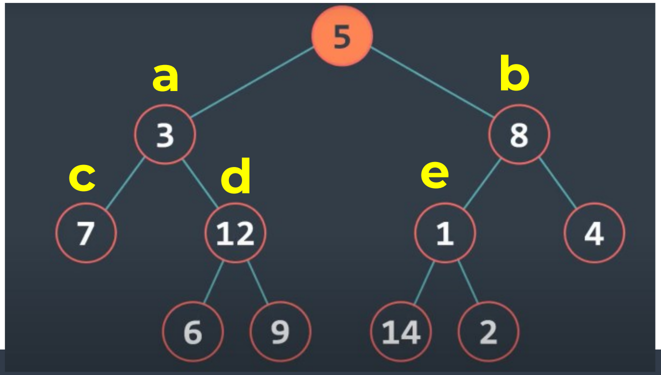
Depth first search

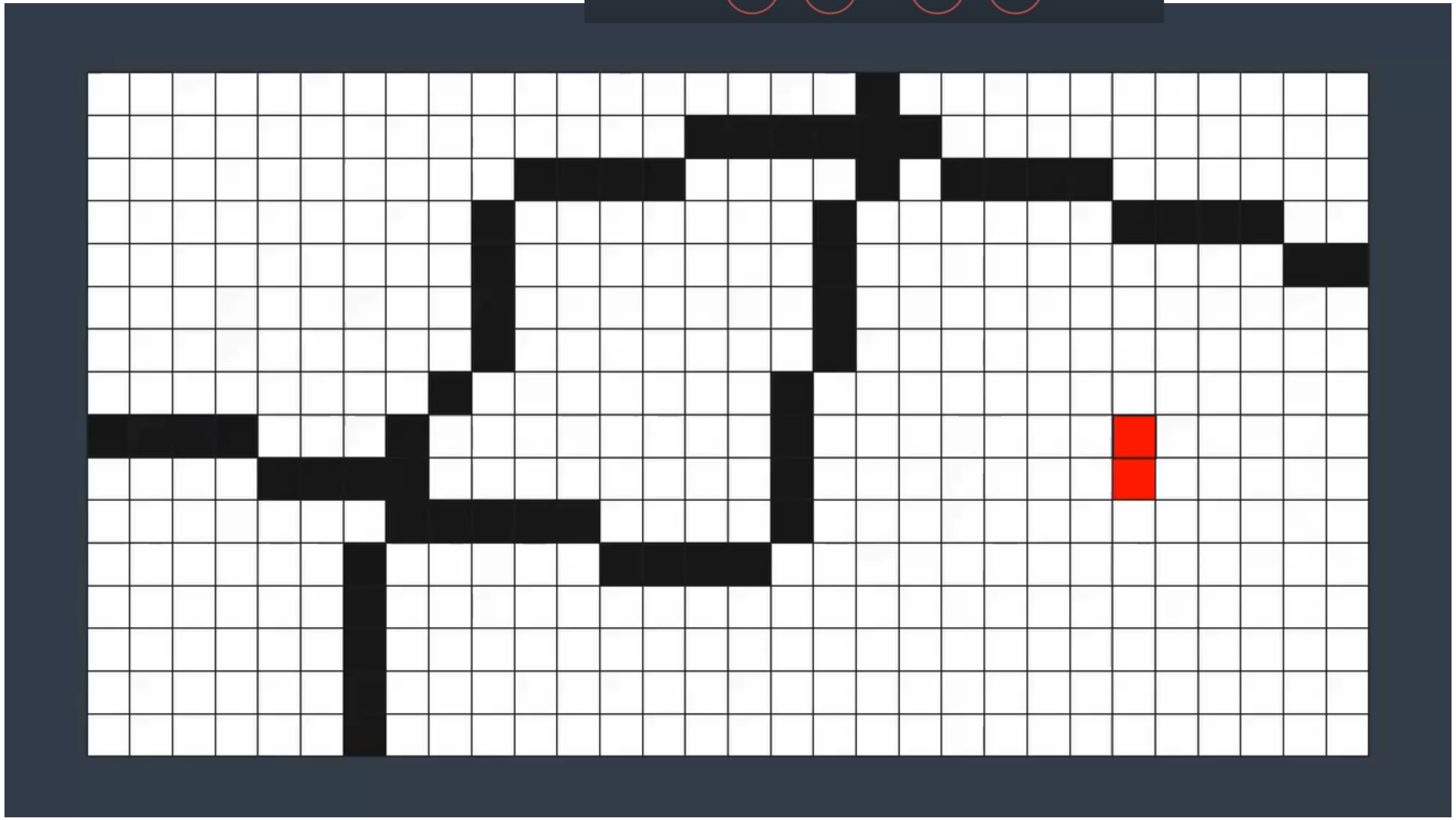




Flood Fill

Breath first search





k-Means

k-means

Looking for **k** segments in an image

- Take image and map it to feature space
- In feature space, find k clusters
- Find the clusters by finding the mean of their elements

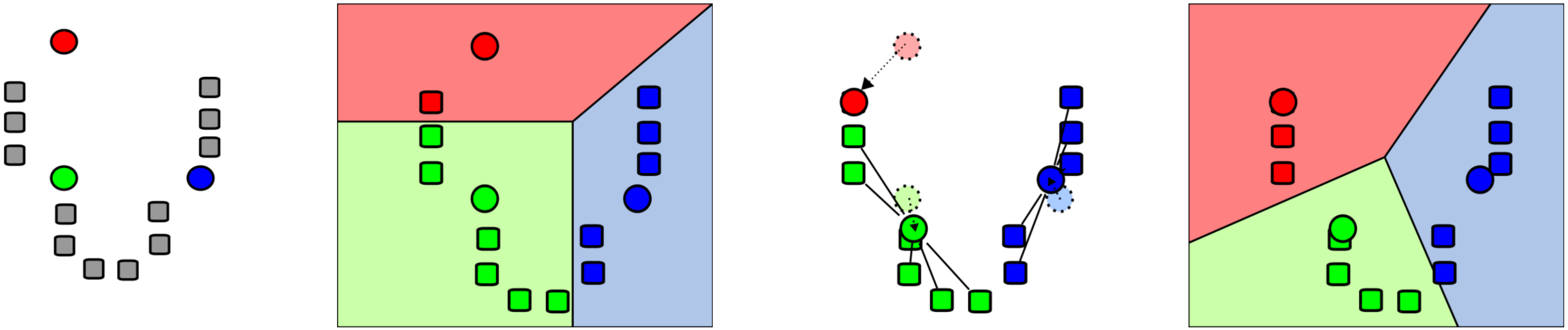
k-means

steps

1. Choose the **number of clusters** K
2. Select **K points, at random**: the centroids (may not belong to data set)
3. Assign **each point to the closest centroid** -> yields k clusters
4. **Compute new centroid** for each cluster
5. **Reassign each point** to the new closest centroid. If any point changed, go to step 4
6. If not, k-means done!

k-means

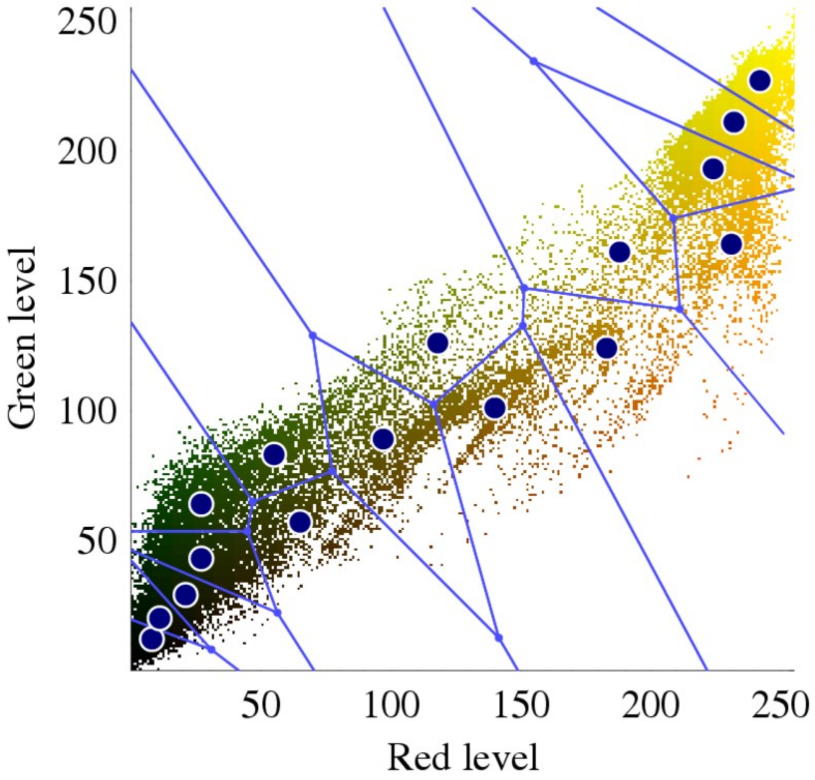
steps



k-means in action

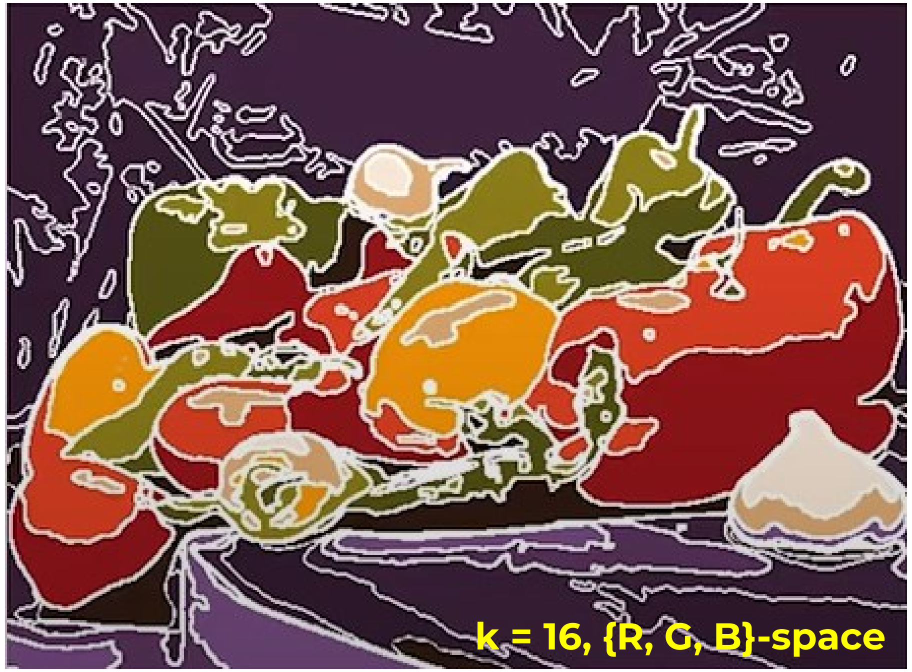
https://miro.medium.com/max/700/1*ZmktlQtiZSp6p03op3EvyA.gif

k-means
feature space

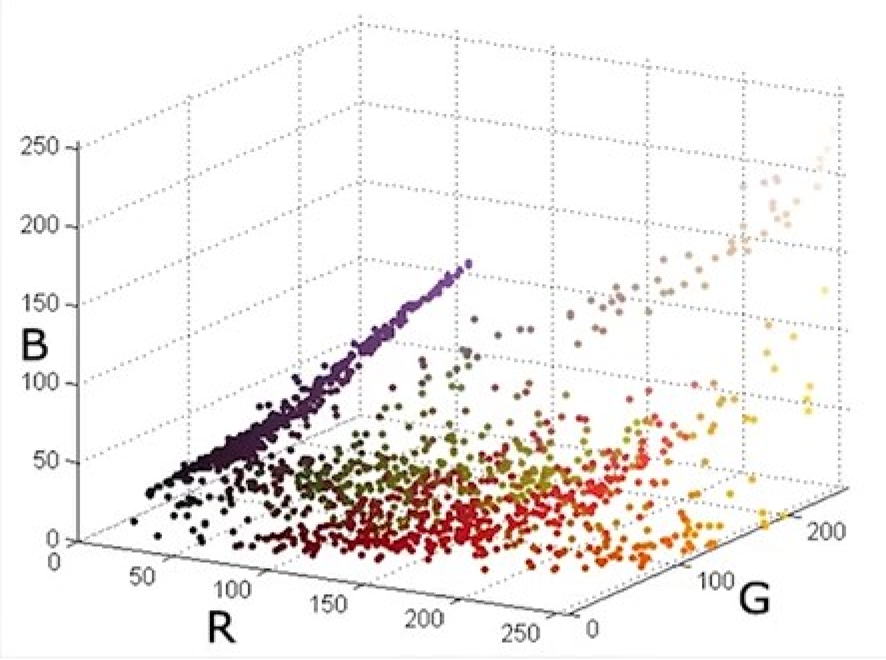


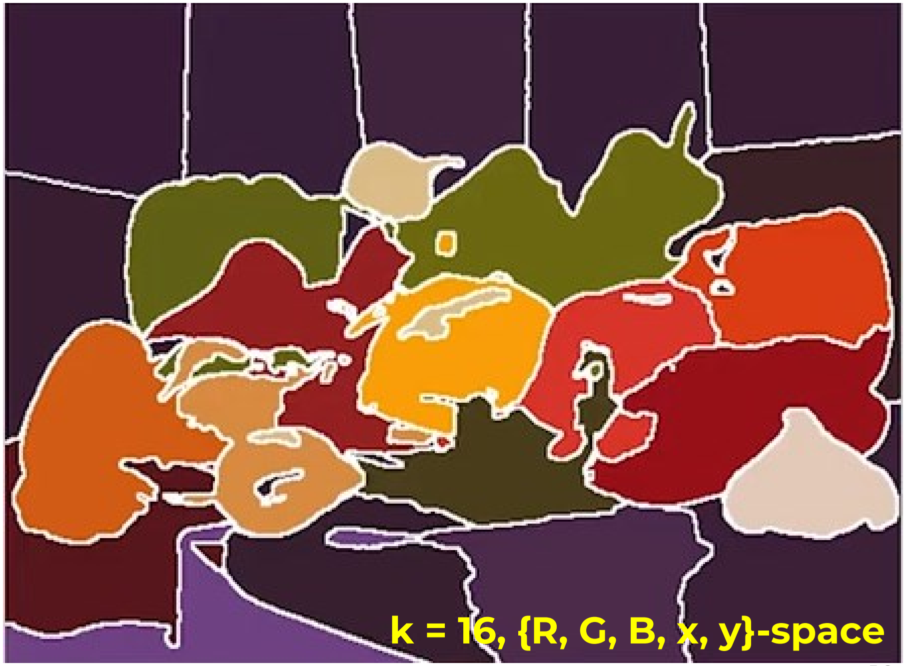
k-means

feature space



proper choice of the feature space can improve outcomes





https://www.youtube.com/watch?v=22mpExWh1LY

k-means


Final
k=16


first
last B
pixelation
first B
Final
Gaussian blur
k=5

k-means
image segmentation

Simple to understand and implement

Needs picking the number of clusters (how do we do this?)

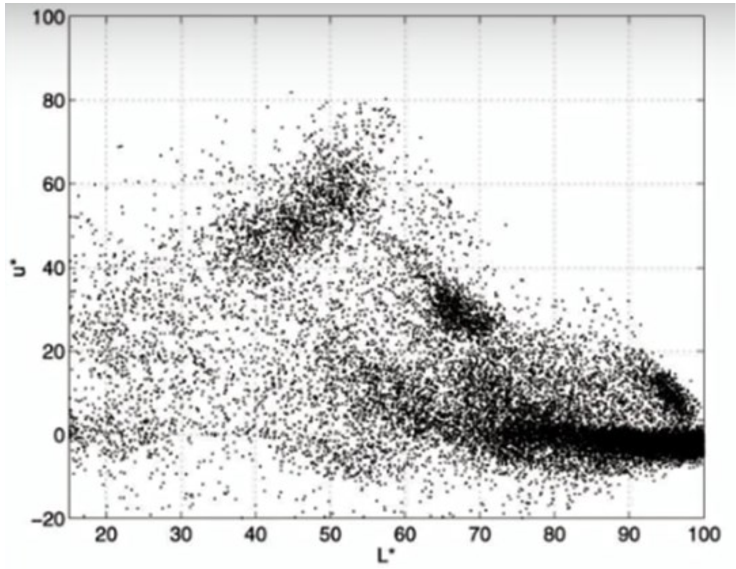
Sensitive to initial points and outliers

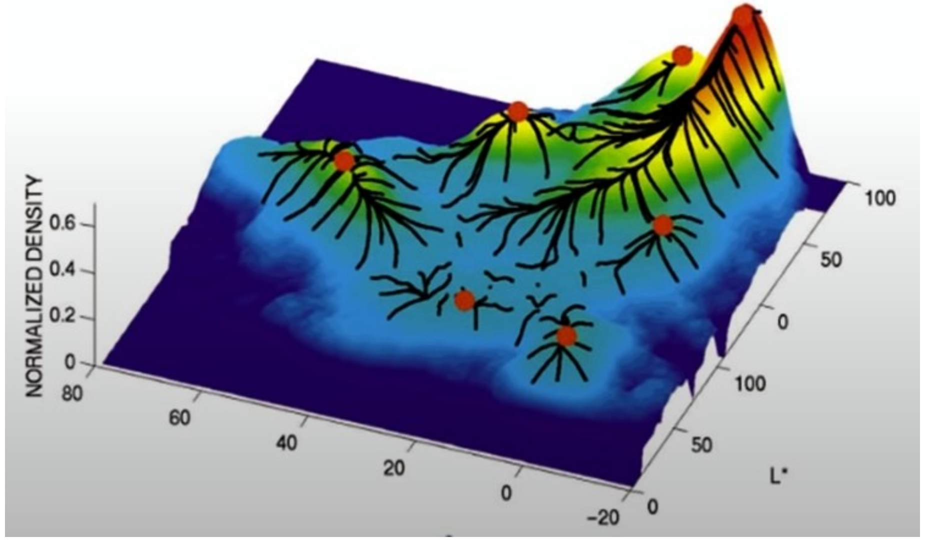
Mean-Shift

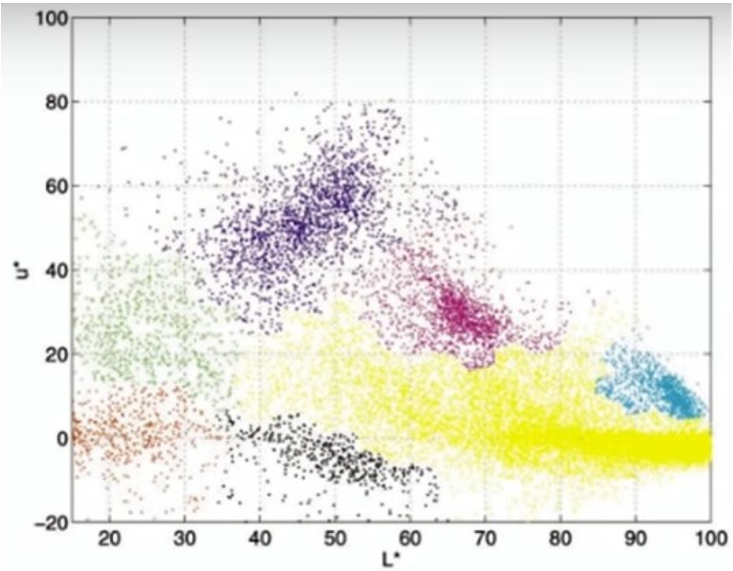
Solves problem of having to choose number of clusters

Solves initialization problem

Uses peaks of normalized density as modes (i.e., the centroids of clusters)

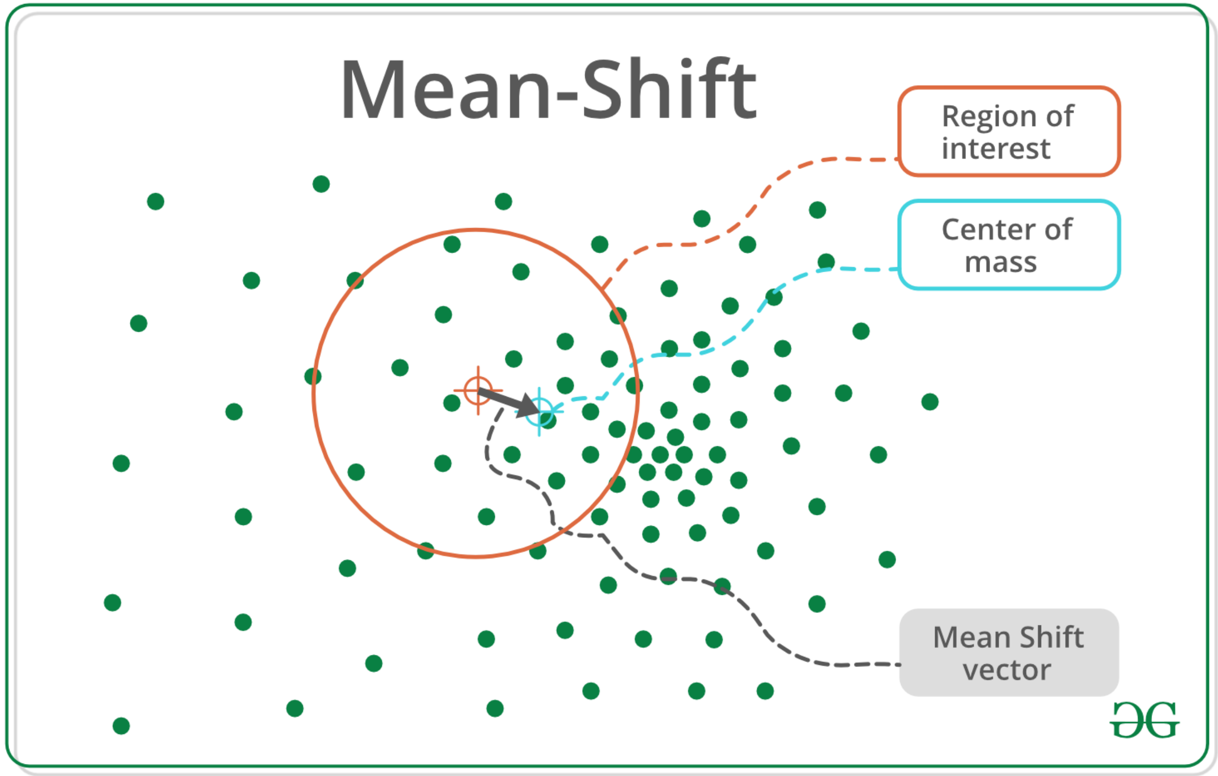






mean-shift
determining modes

1. Choose data point
2. Compute mean for window centred on that point
3. Shift to computed mean
4. Repeat until no change



Mathematical Morphology

Mathematical Morphology

Mathematical morphology operations treat images as sets of points

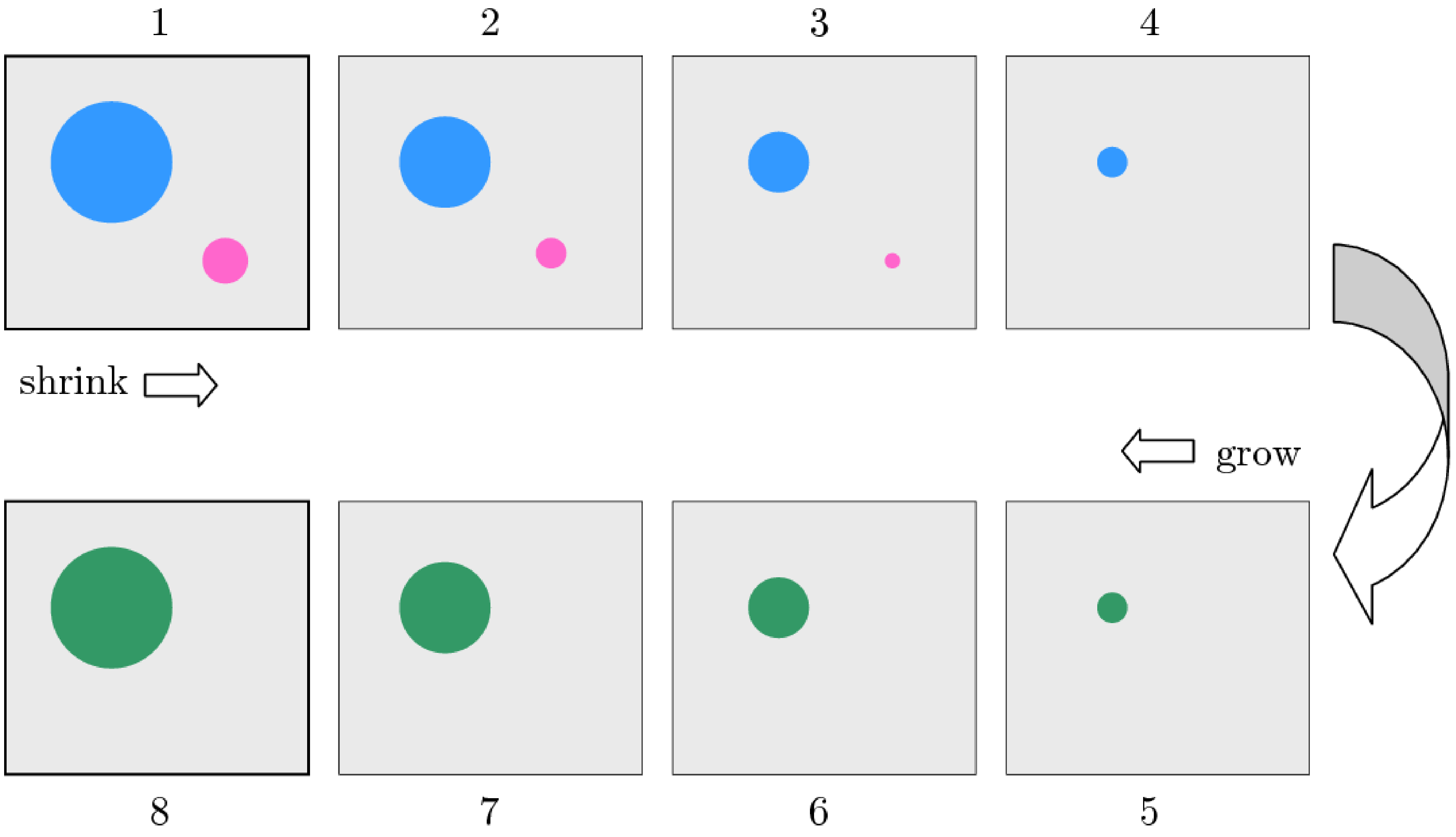
They modify in a controlled way the structure / morphology of an image

They can be easily applied to binary images (but also grayscale or colour too)

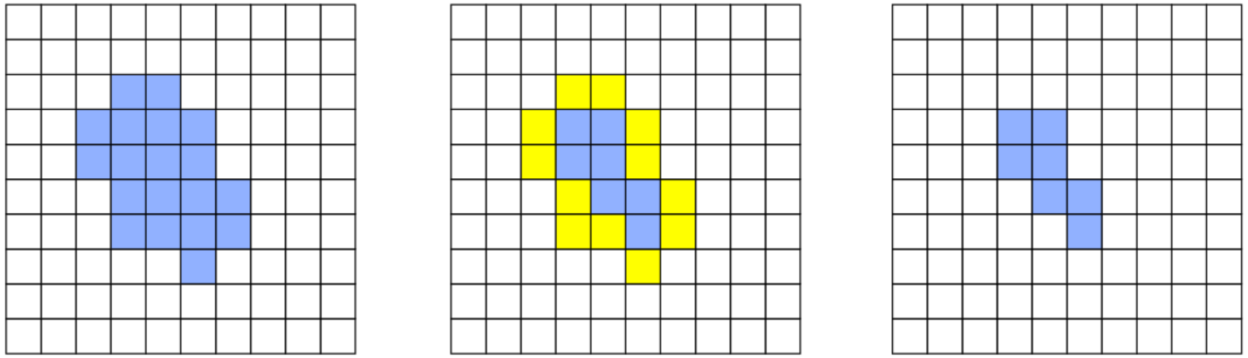
Encompass a set of methods used in image analysis for:

- Filtering
- Segmentation

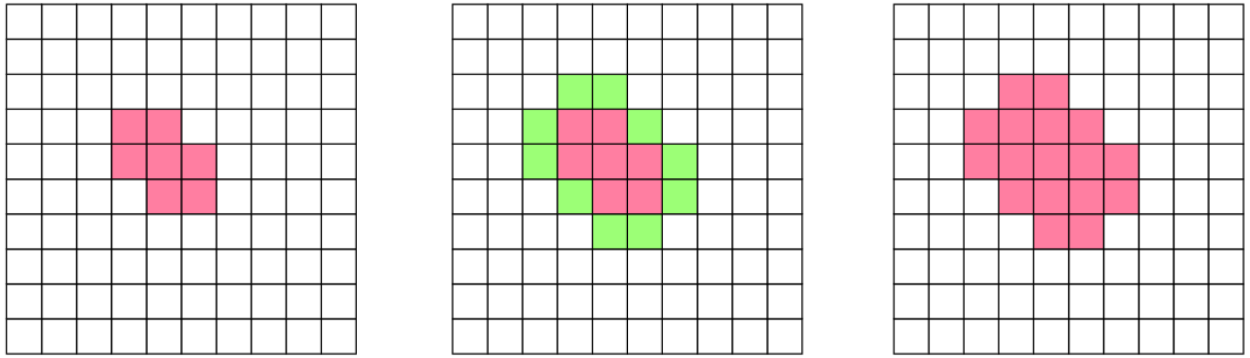
Fundamental Ideas



Fundamental Ideas



(a) (b) (c)



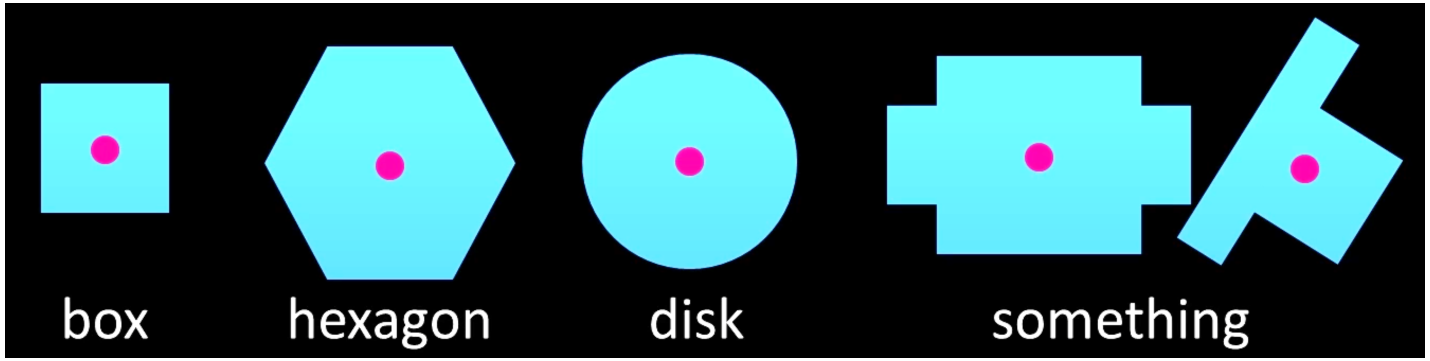
(a) (b) (c)

Structuring Element
base concept in Math. Morph.

Similar to the concept of kernel in filtering

A shape mask used for morphological operations

Have a defined origin

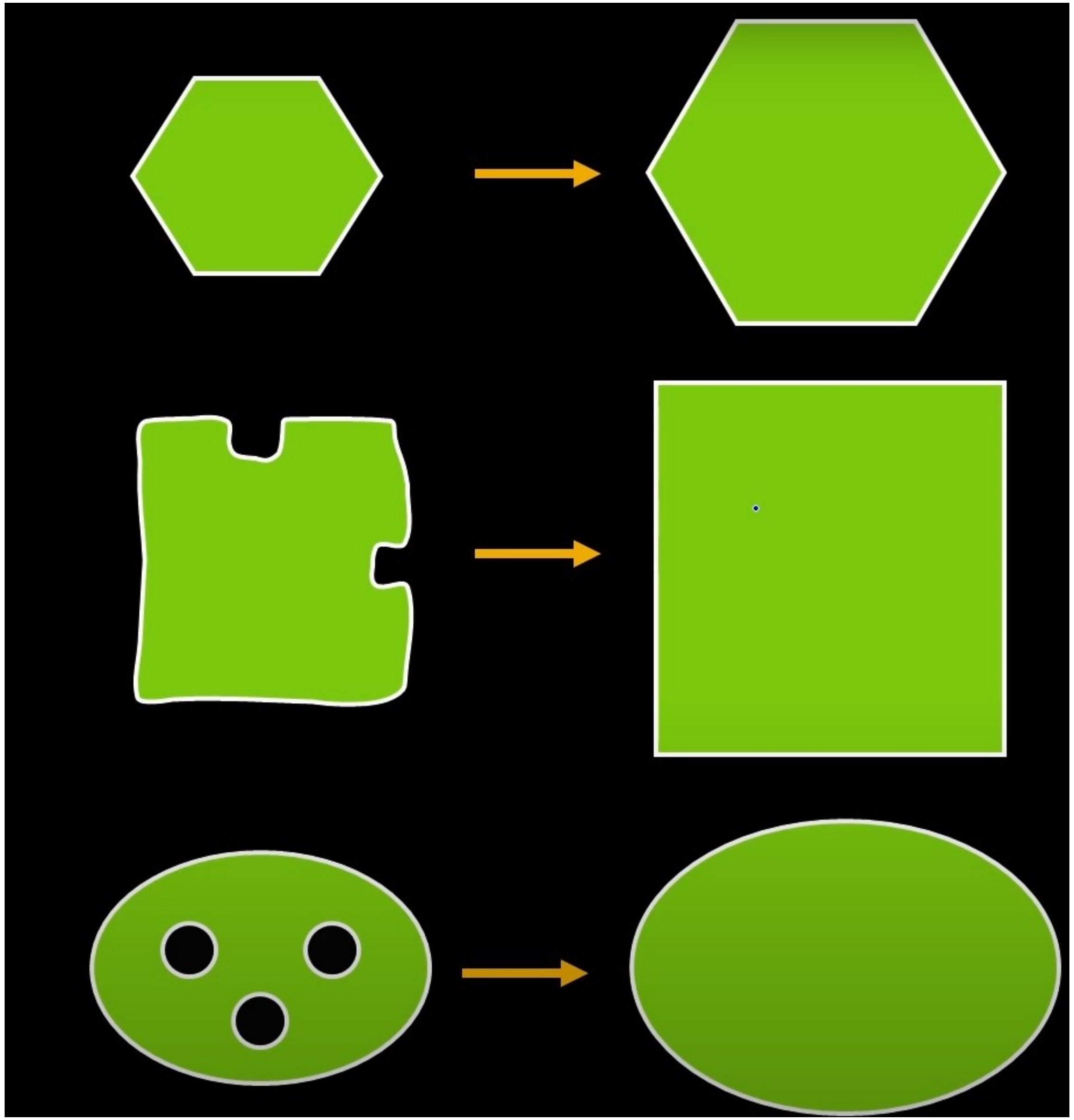


Dilation

Used for:

Growing features

Filling holes and gaps



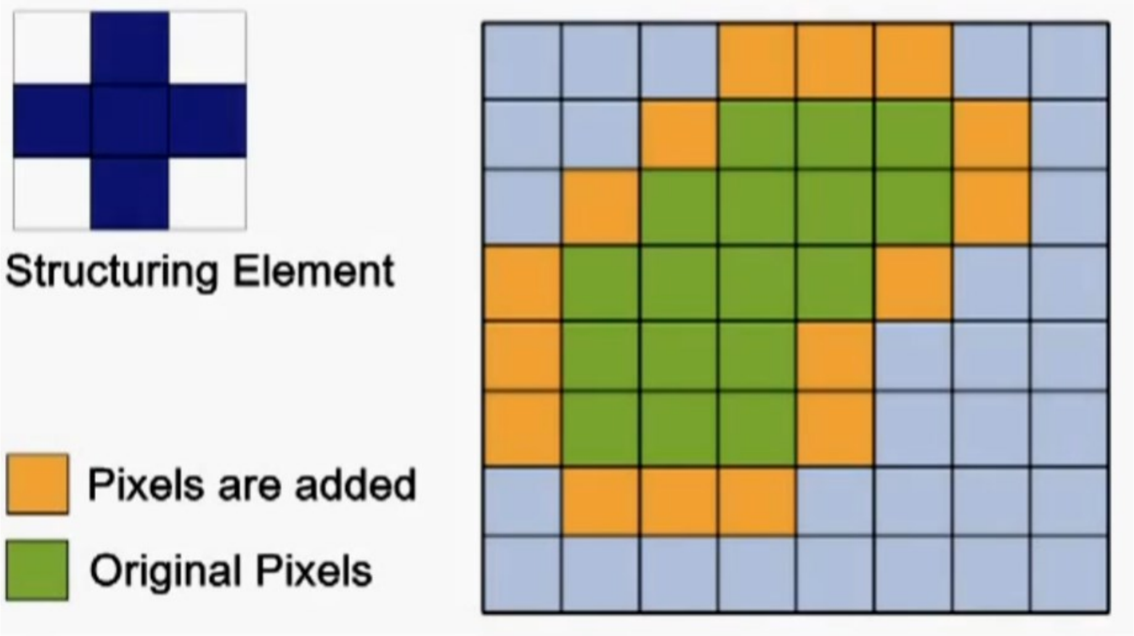
Dilation

Replicate the SE at each original image foreground pixel

In general, it yields an **expanded** version of the foreground

Small holes and intrusions are filled

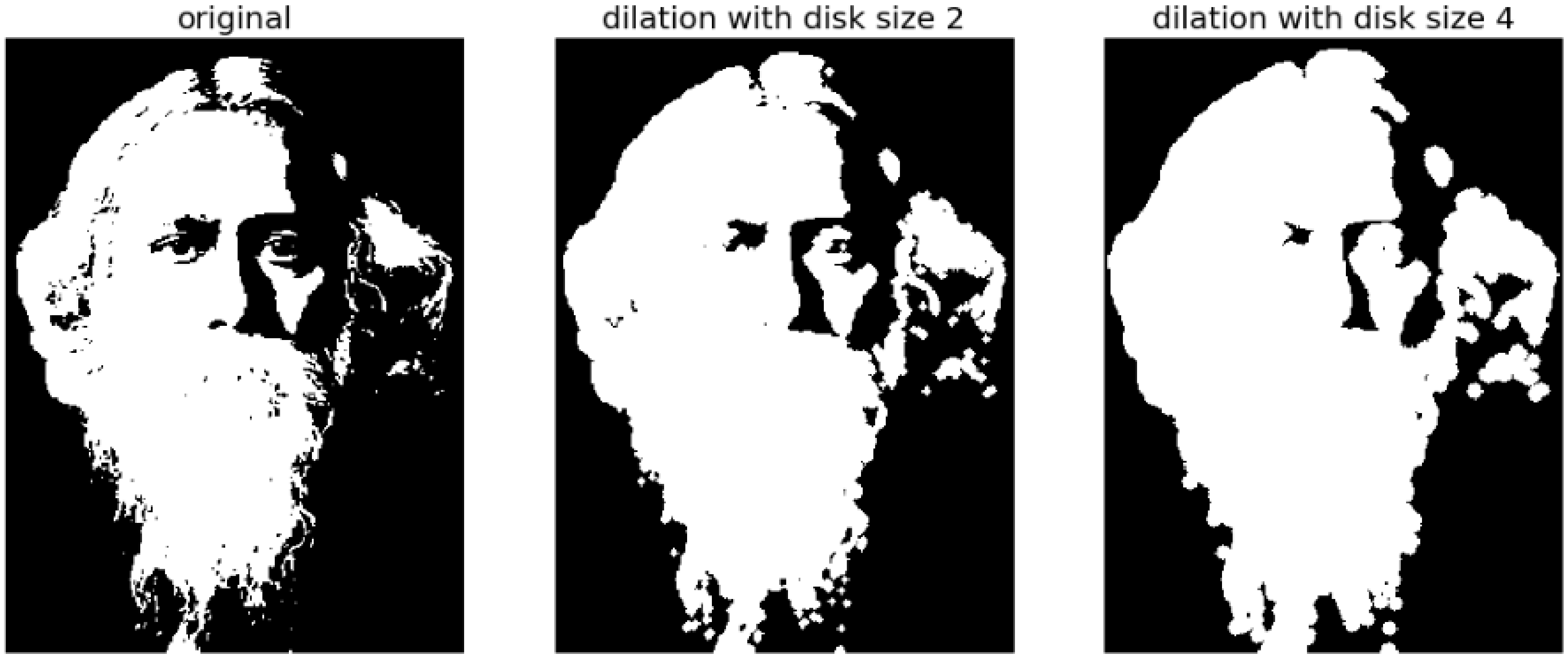
Place the origin of the SE at each foreground (1) pixel of image ***I*** and **copy all SE 1 pixels to the corresponding pixels** in the result image



https://www.youtube.com/watch?v=xO3ED27rMHs&ab_channel=SmarTE-learning

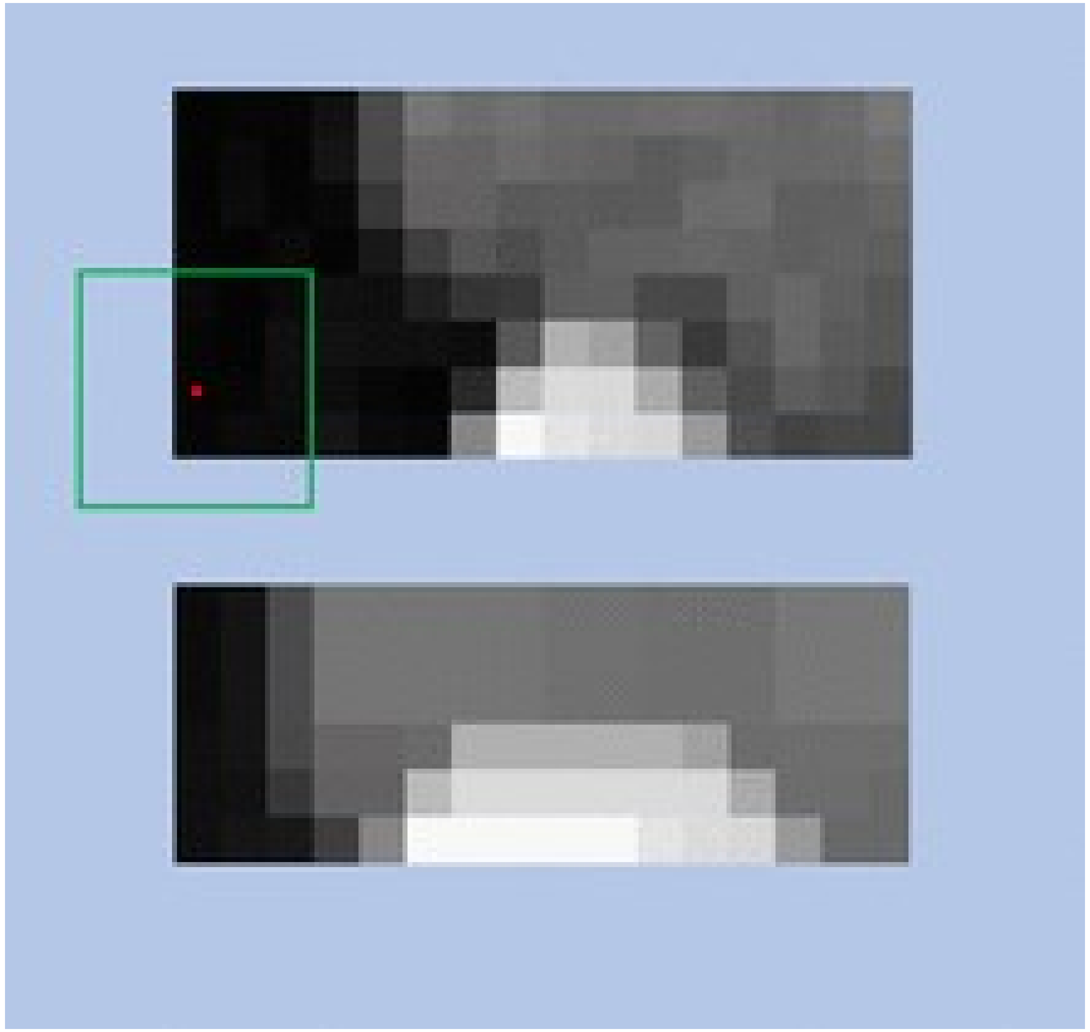
Slide SE over image and set center to maximum found pixel

Dilation


original
dilation with disk size 2
dilation with disk size 4

Greyscale Dilation

Corresponds to selecting the maximum intensity inside neighborhood (structuring element)

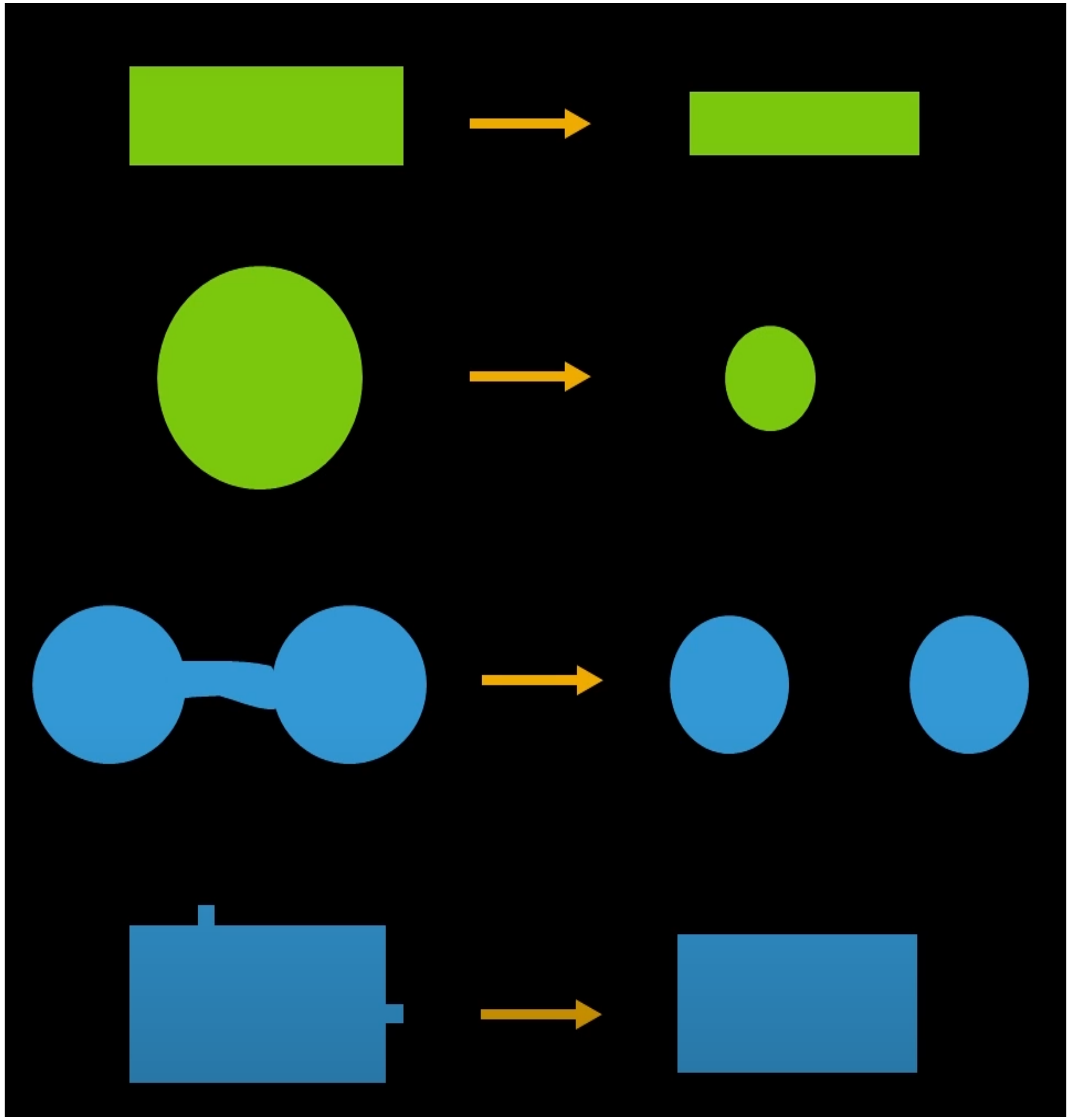


Erosion

Used for:

Shrinking features

Removing bridges, branches, protrusions



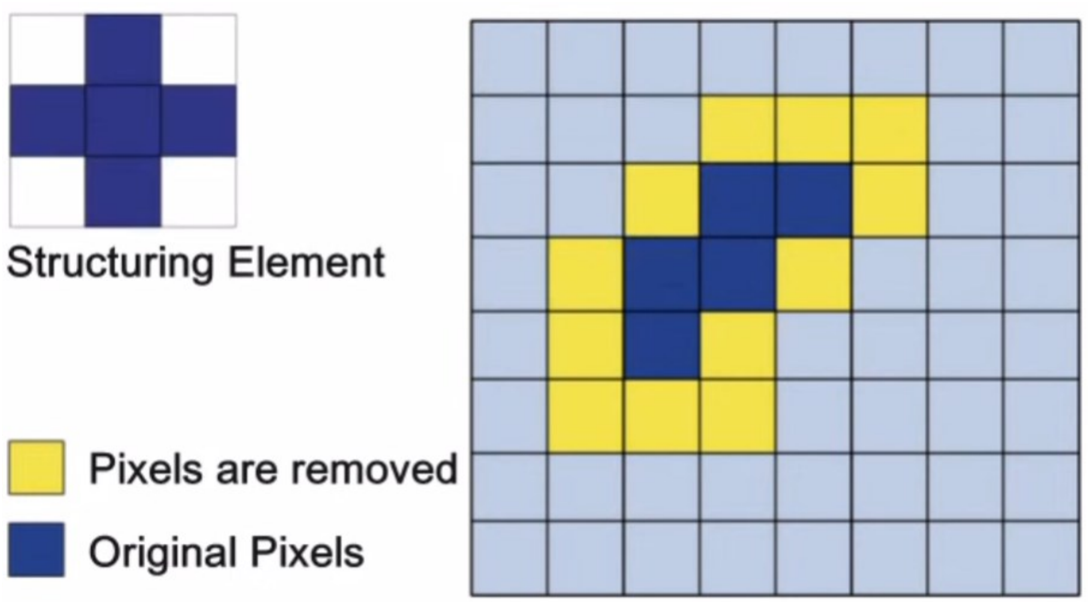
Erosion

Keep as 1 each pixel for which SE is replicated

In general, the eroded object is **shrunk**

Holes are enlarged and small extrusions are removed

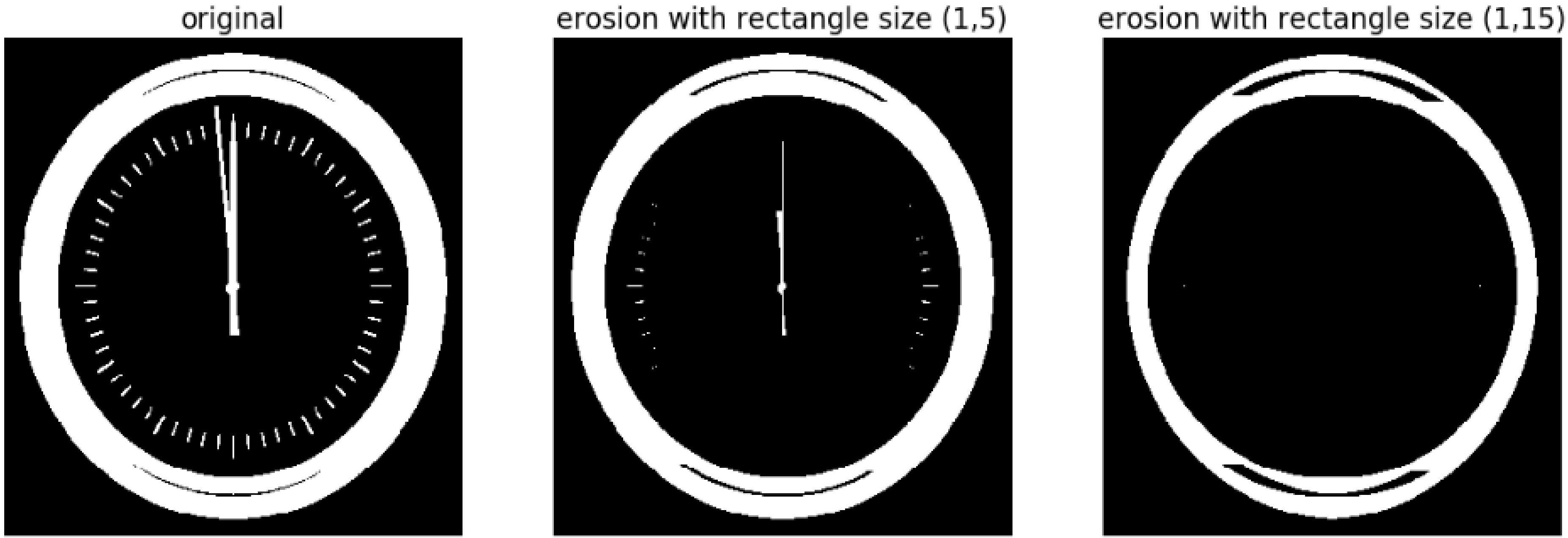
Place origin of SE at each foreground (1) pixel of image ***I*** and set to 1 the corresponding pixel in the result image, **whenever the SE pattern exists in the original image**



https://www.youtube.com/watch?v=fmyE7DialYQ&list=PLHLtQZu3roXhE4JrGja1soerwkZlFjERH&index=1&ab_channel=SmarTE-learning

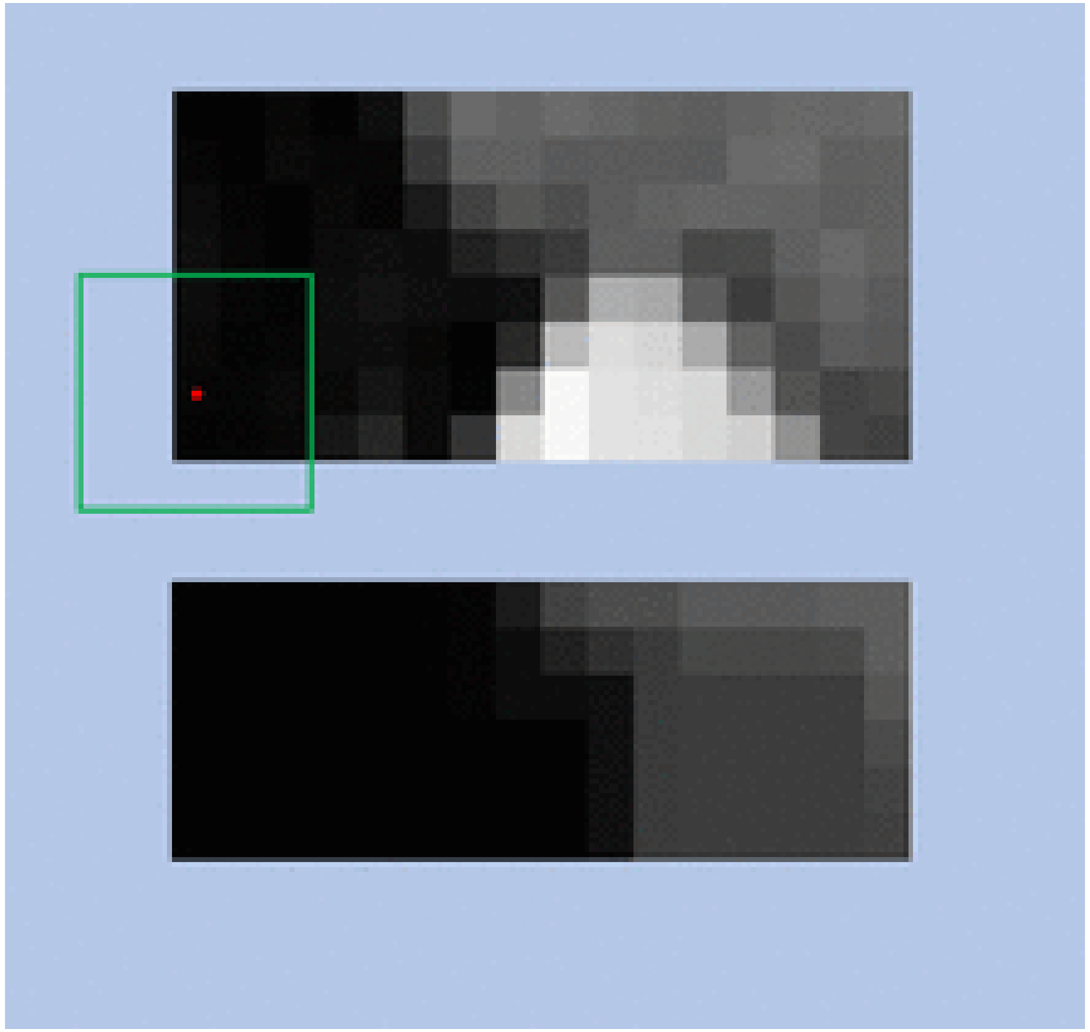
Slide SE over image and set center to minimum found pixel

Erosion


original
erosion with rectangle size (1,5)
erosion with rectangle size (1,15)

Greyscale Erosion

For greyscale, erosion corresponds to selecting the minimum intensity inside neighborhood (structuring element)

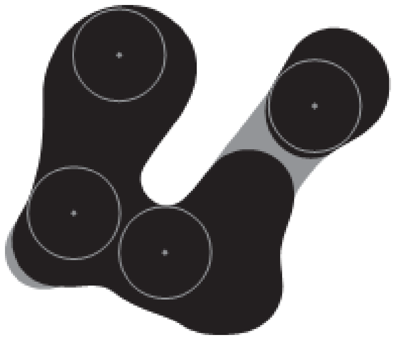


Opening and Closing

https://www.shutterstock.com/image-photo/dark-door-light-behind-it-600nw-2258237653.jpg

Opening

Erosion followed by dilation



Idempotent

Union of all SEs that fit inside the object

Opening with a circular SE tends to:

- smooth contours
- break narrow bridges
- remove small extrusions

The SE is applied to the whole object, but no 1 pixel of the SE can appear outside the object

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

Struturing element

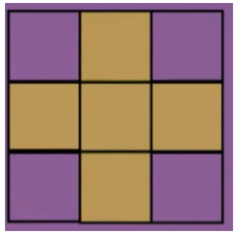
0	1	1	0	0
0	1	1	0	0
0	1	0	0	0
0	1	1	1	0
0	0	1	1	0

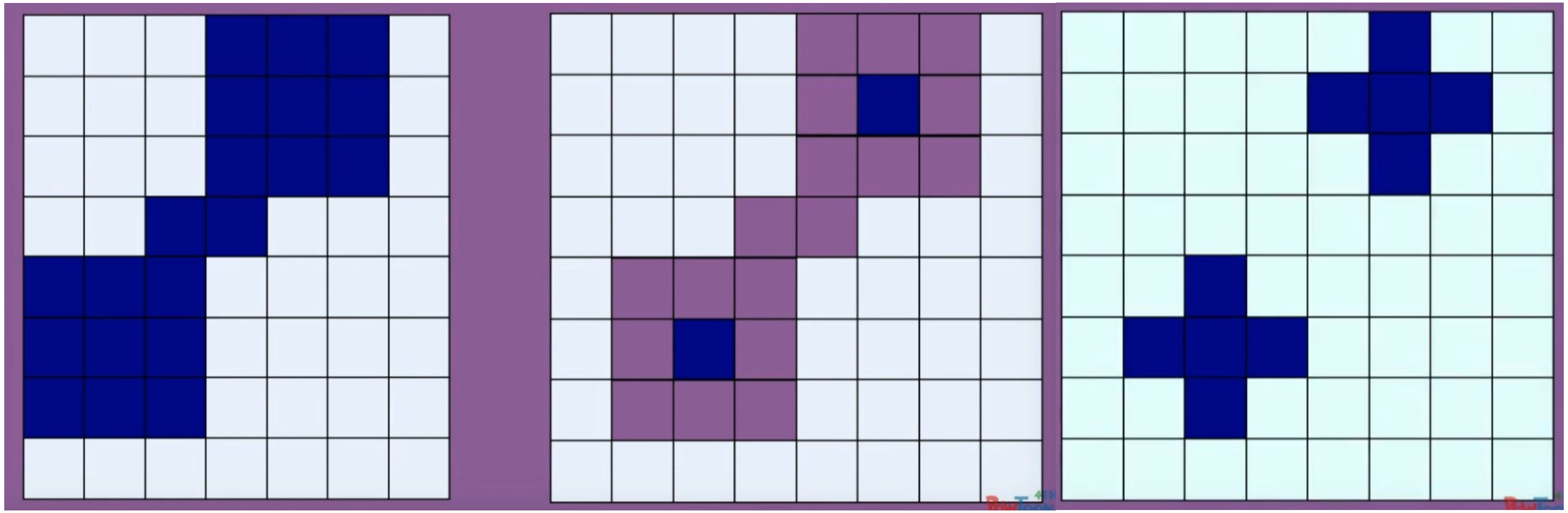
0	1	1	0	0
0	1	1	0	0
0	0	0	0	0
0	1	1	1	0
0	0	1	1	0

$I \circ X$

sss_VC_V2

Opening

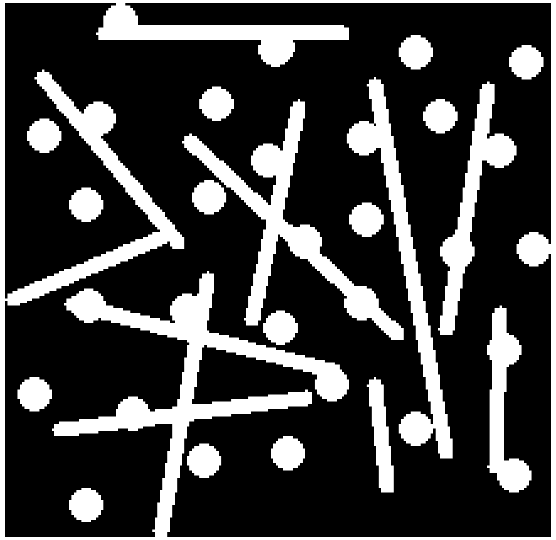




original erosion dilation

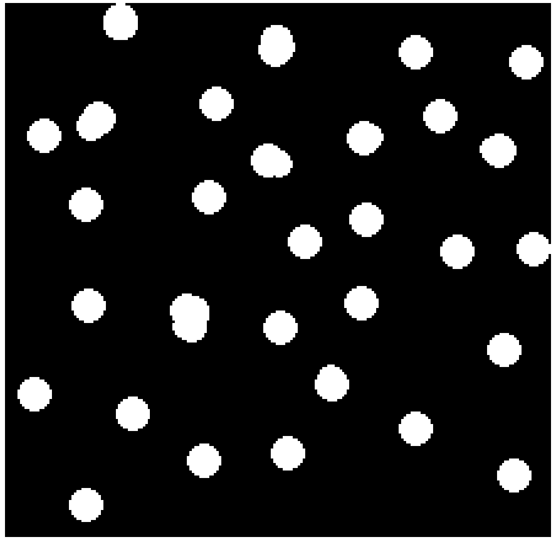
Opening

Remove lines…



opening with
disk-shaped structuring element

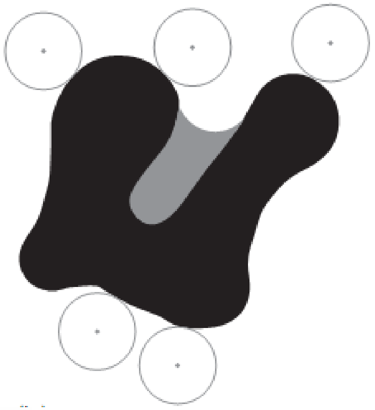
diameter larger than line width,
smaller than circles'



https://homepages.inf.ed.ac.uk/rbf/HIPR2/open.htm

Closing

Dilation followed by erosion



Dual of *opening*

Idempotent

The SE is slided along the border and regions where it does not fit are filled

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

Original image

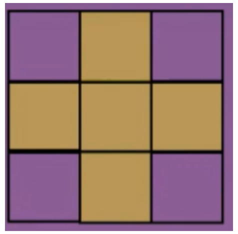
1	1

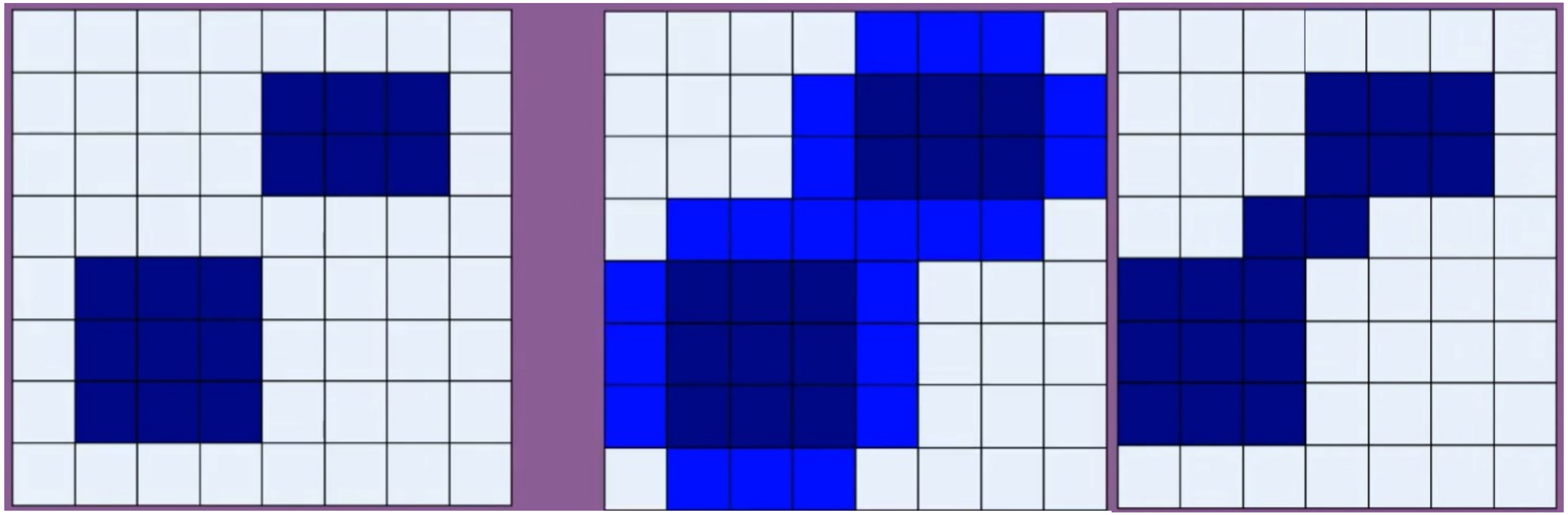
Structuring element

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

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

Closing

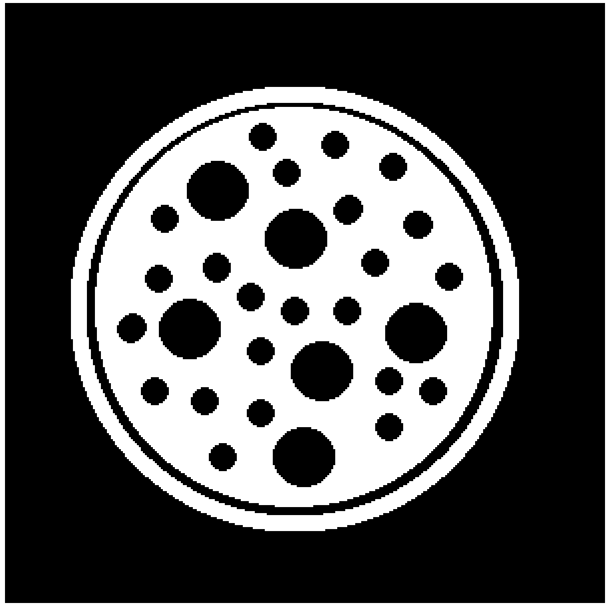




original dilation erosion

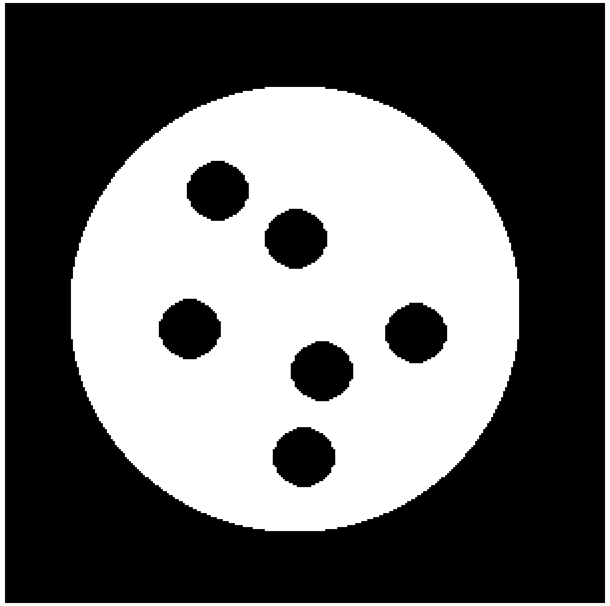
Closing

Remove small holes, keep large holes

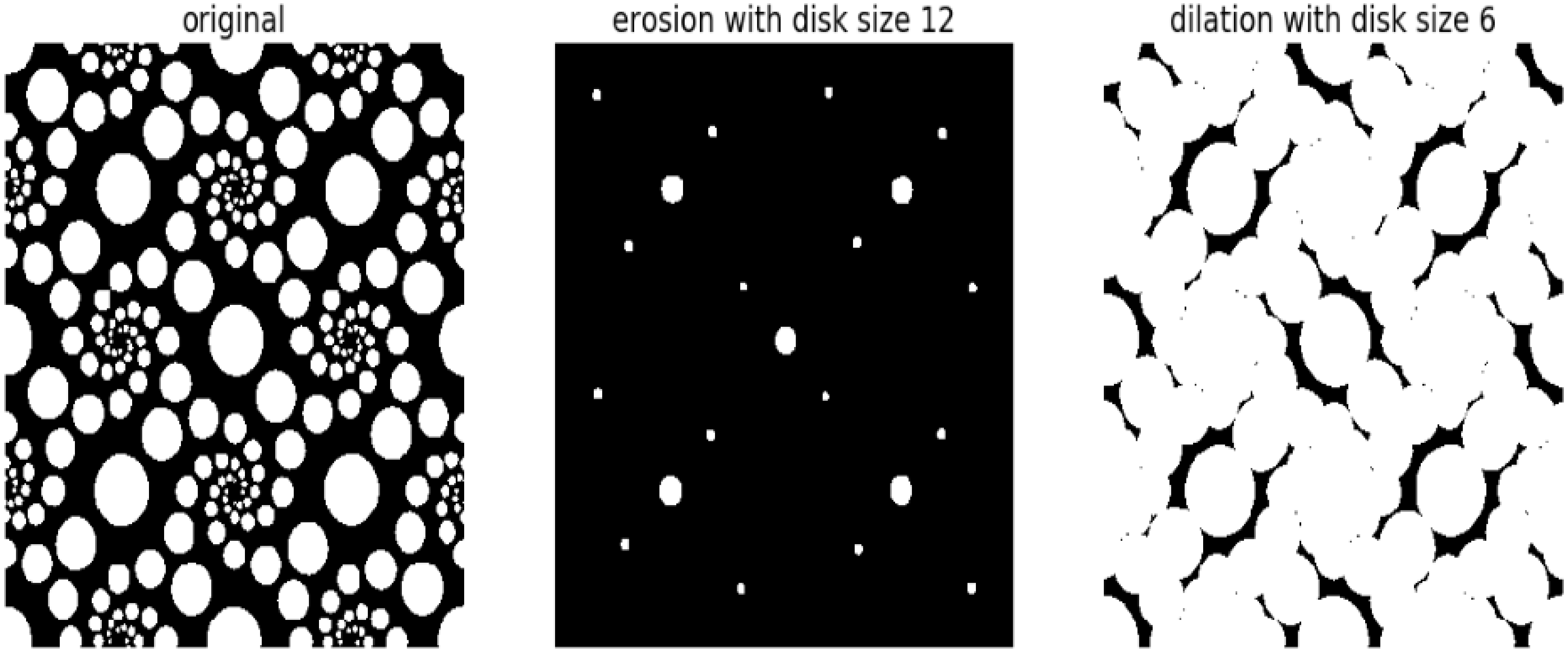


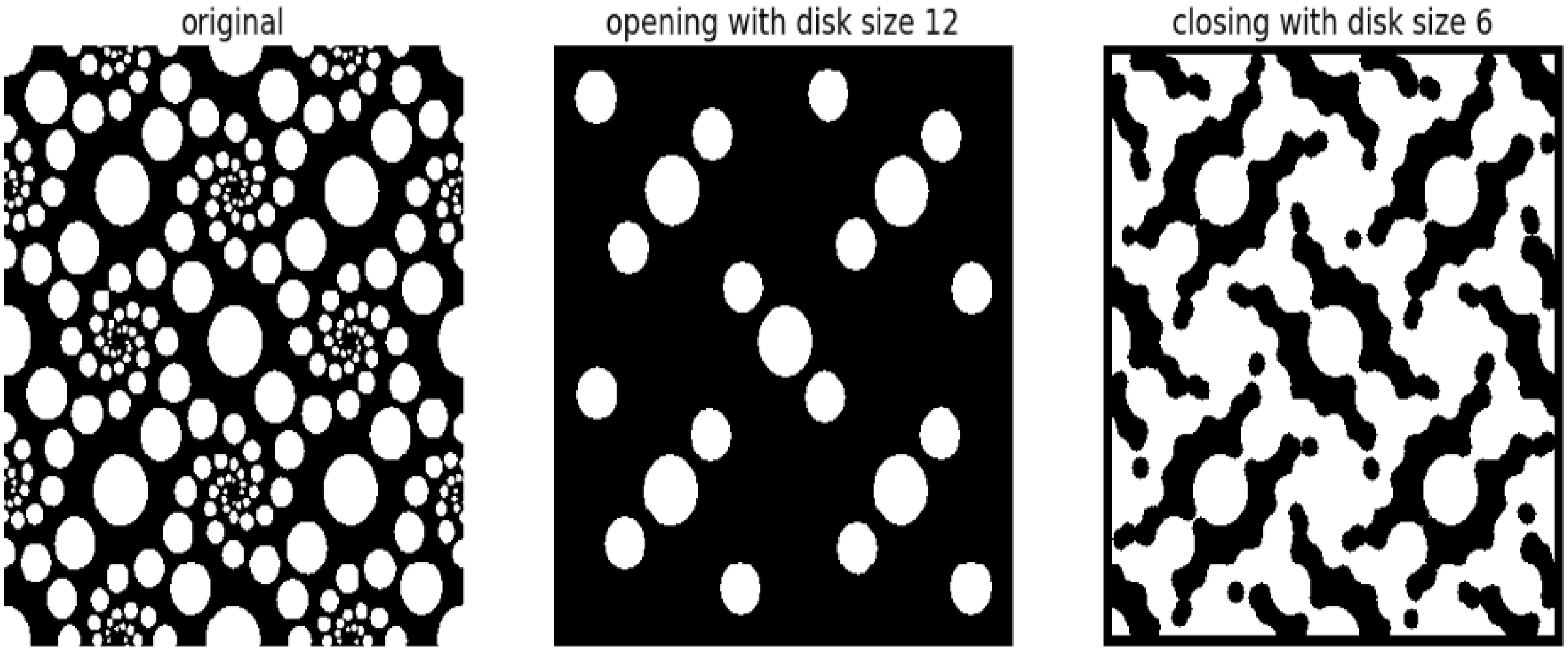
closing with
disk-shaped structuring element

bigger that small holes,
smaller than big holes

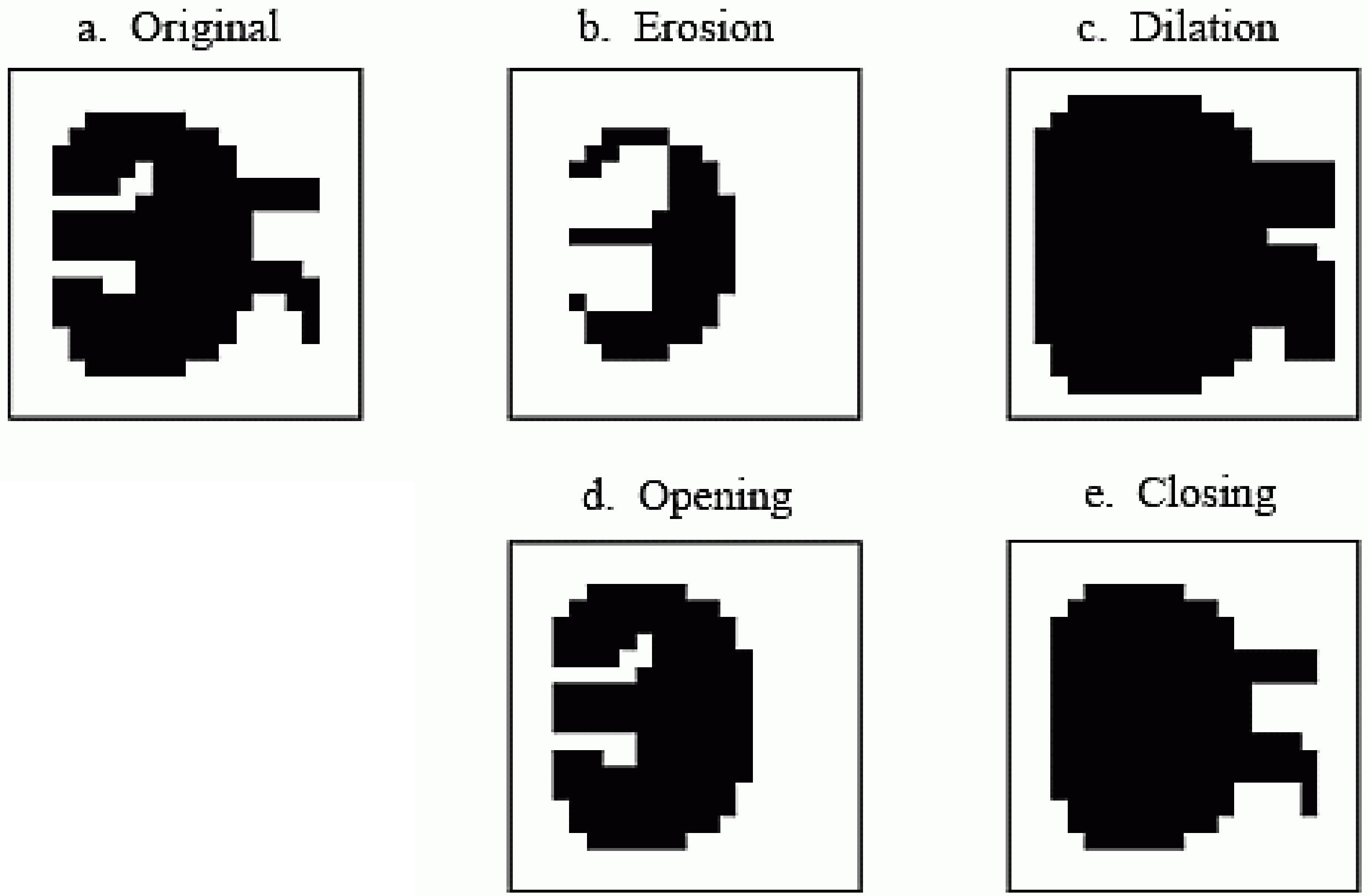


https://homepages.inf.ed.ac.uk/rbf/HIPR2/close.htm


original
erosion with disk size 12
dilation with disk size 6


original
opening with disk size 12
closing with disk size 6

All together now



https://www.dspguide.com/graphics/F_25_10.gif

Bibliography

- W. Burger, M. J. Burge, Principles of Digital Image Processing, Vol.1, Springer, 2009

For more complex image processing methods, out of the scope of this introductory course, such as filtering in frequency space, the interested reader is forwarded to:

- W. Burger, M. J. Burge, Principles of Digital Image Processing, Vol.2, chapter 8, Springer, 2009