Computational Vision

Lecture 3.1: Image Segmentation

Hamid Dehghani

Office: 241

Topics

- Digital image representations
- Image properties
- Basic image segmentation: thresholding
  - Image histogram
  - Smoothing
  - Mathematical morphology
- Advanced segmentation methods

Digital images

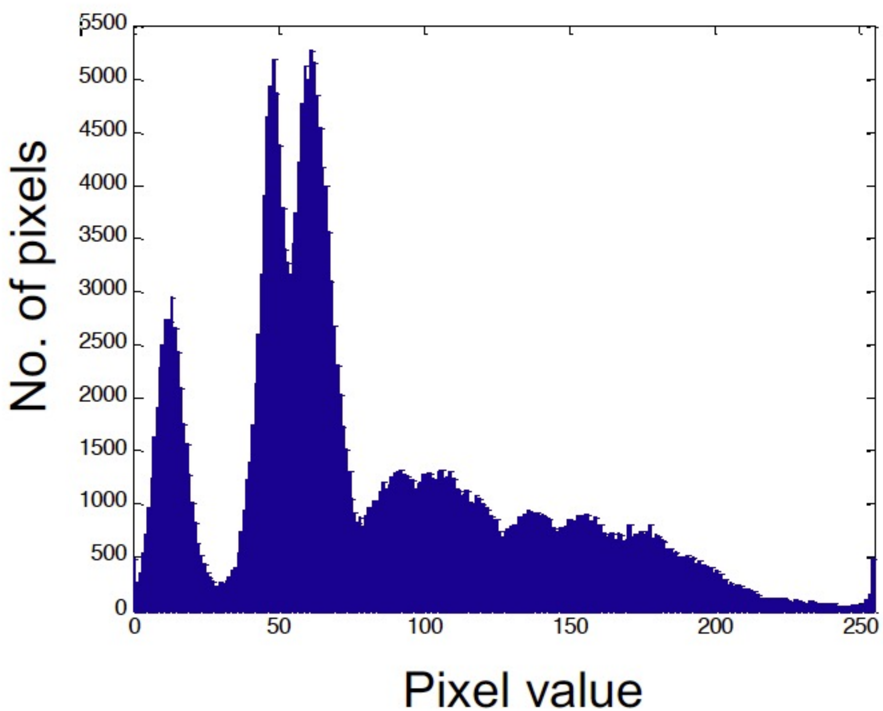
- Image representations
  - 2dimensional arrays of pixels
    - (x,y)
  - multi-dimensional arrays
    - (x,y,z)
    - (x,y,t)
    - (x,y,z,t)
    - $(x,y,z,b_1,b_2, \ldots , b_N)$

Characterising images

- Spatial resolution
  - Pixel size
  - Pixels / inch
- Intensity resolution
  - Bits per pixel
- Time resolution
  - Frames per second
- Spectral resolution
  - Number of bands + bandwidth

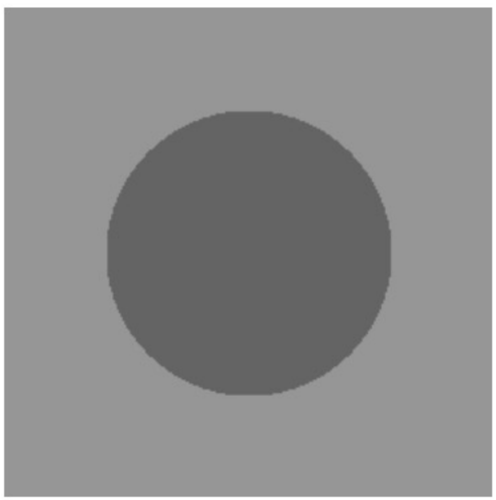
Characterising images as signals

- Image statistics
  - Mean, standard deviation
  - Histogram: frequency distribution graph

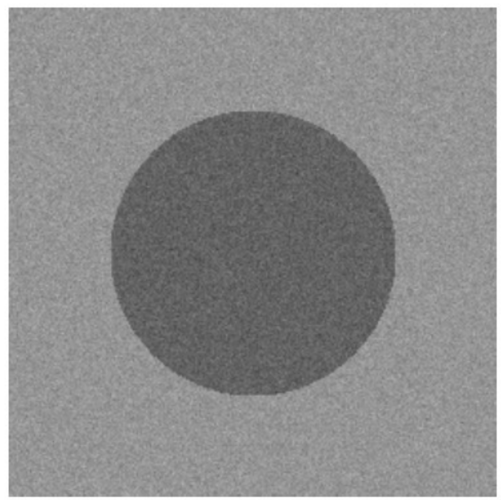


Characterising images as signals

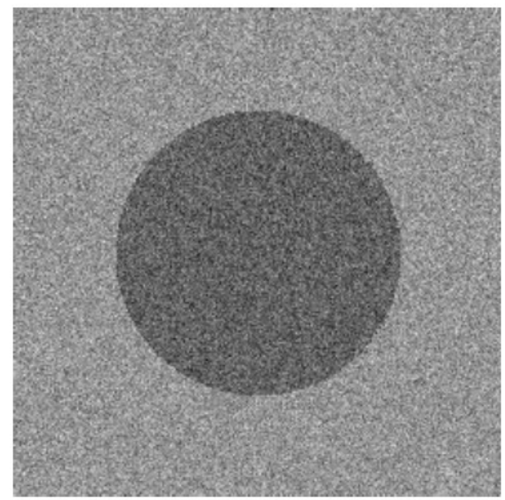
- Image noise
  - Signal-to-noise ratio (SNR)



Noise free

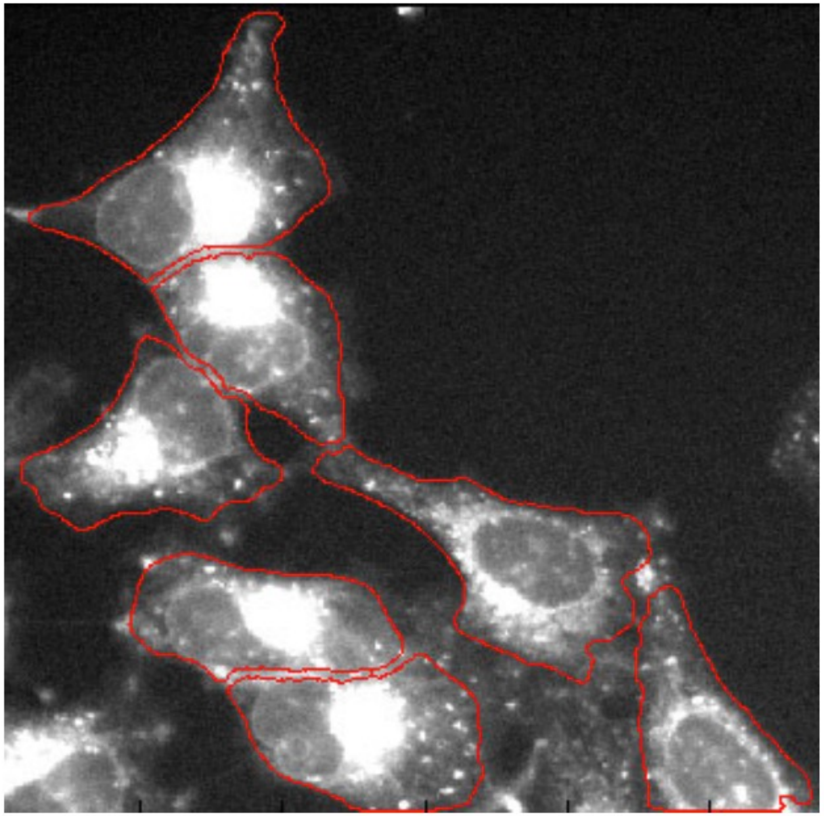


Low noise



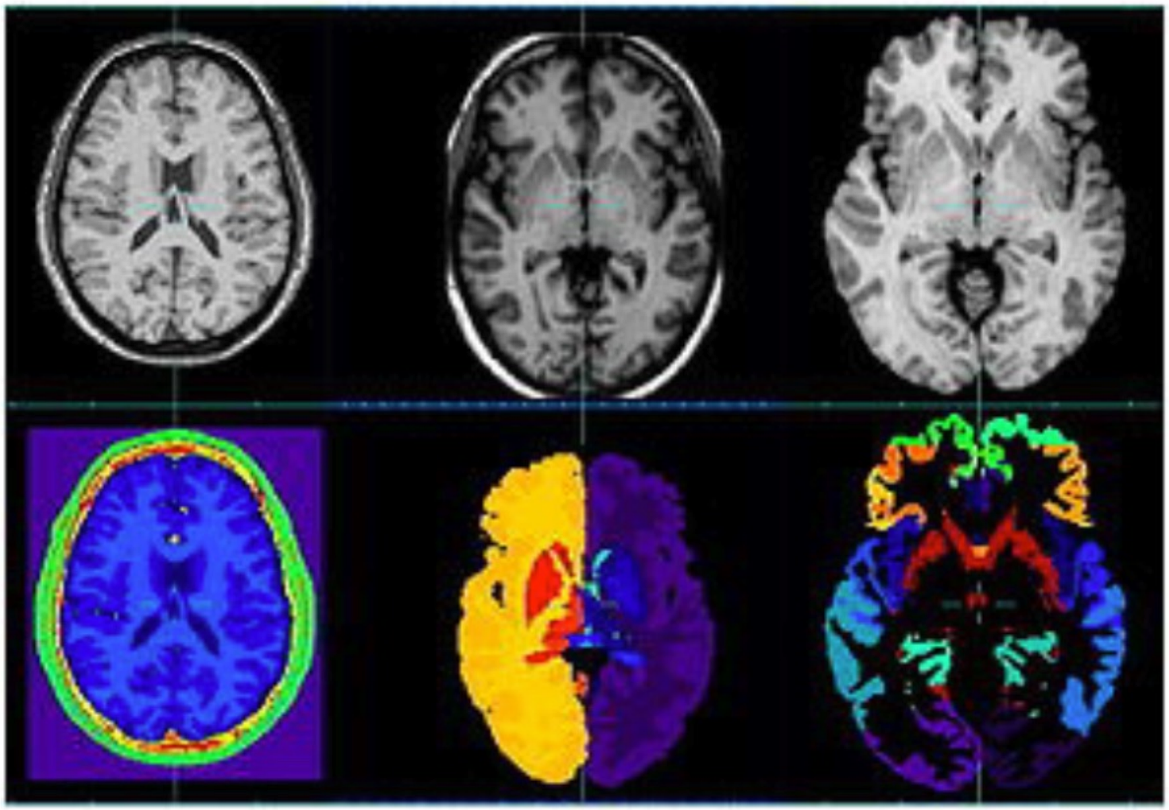
High noise

Characterising images as objects



Individual cells

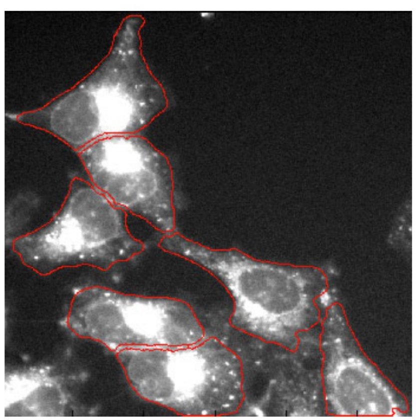
Characterising images as objects



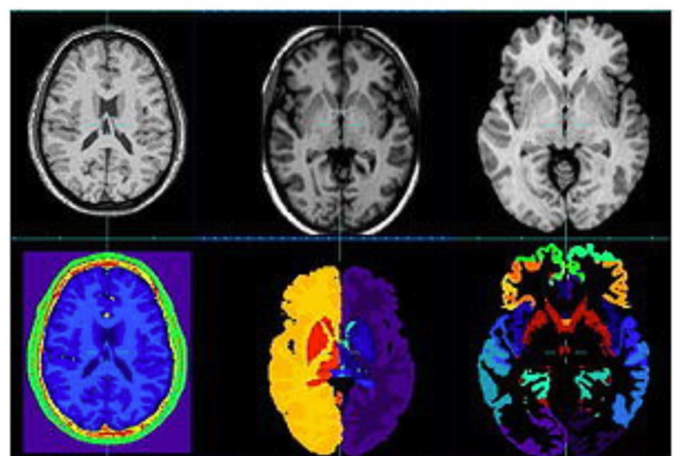
Parts of anatomy

Characterising images as objects

- This requires that image is partitioned into meaningful regions.
- The process of partitioning is known as segmentation



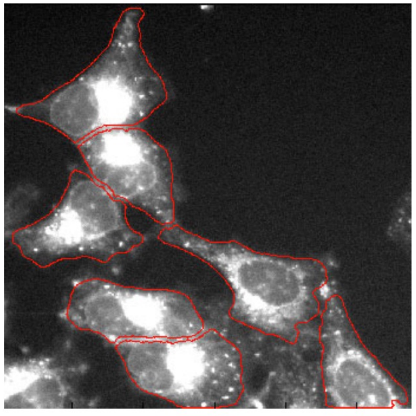
Individual cells



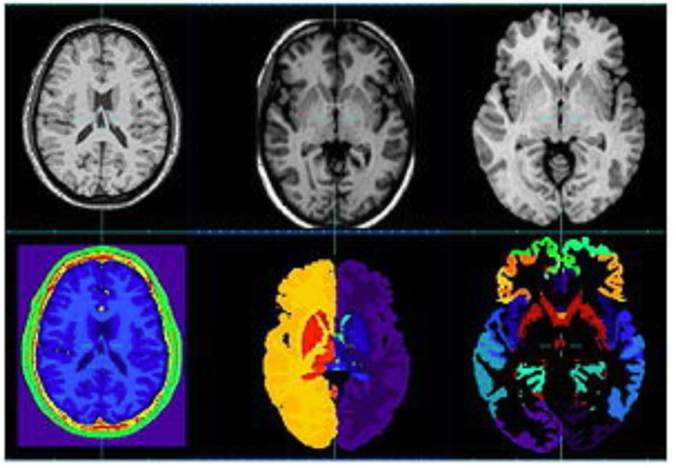
Parts of anatomy

Image Segmentation

- Partitioning an image into meaningful regions with respect to a particular application
- Simple segmentation is based on measurements taken from the image and might be based on brightness (grey-level), colour, texture, motion, etc.



Individual cells



Parts of anatomy

Image segmentation techniques

Regions	**Boundaries**
Pixel-by-pixel (global statistics) *Thresholding*	Image gradient (energy driven) *Active contours*
Groups of pixels (similarity) *Clustering* *Region growing* *Relaxation*	Model based (statistics of shape) *Active shape models*

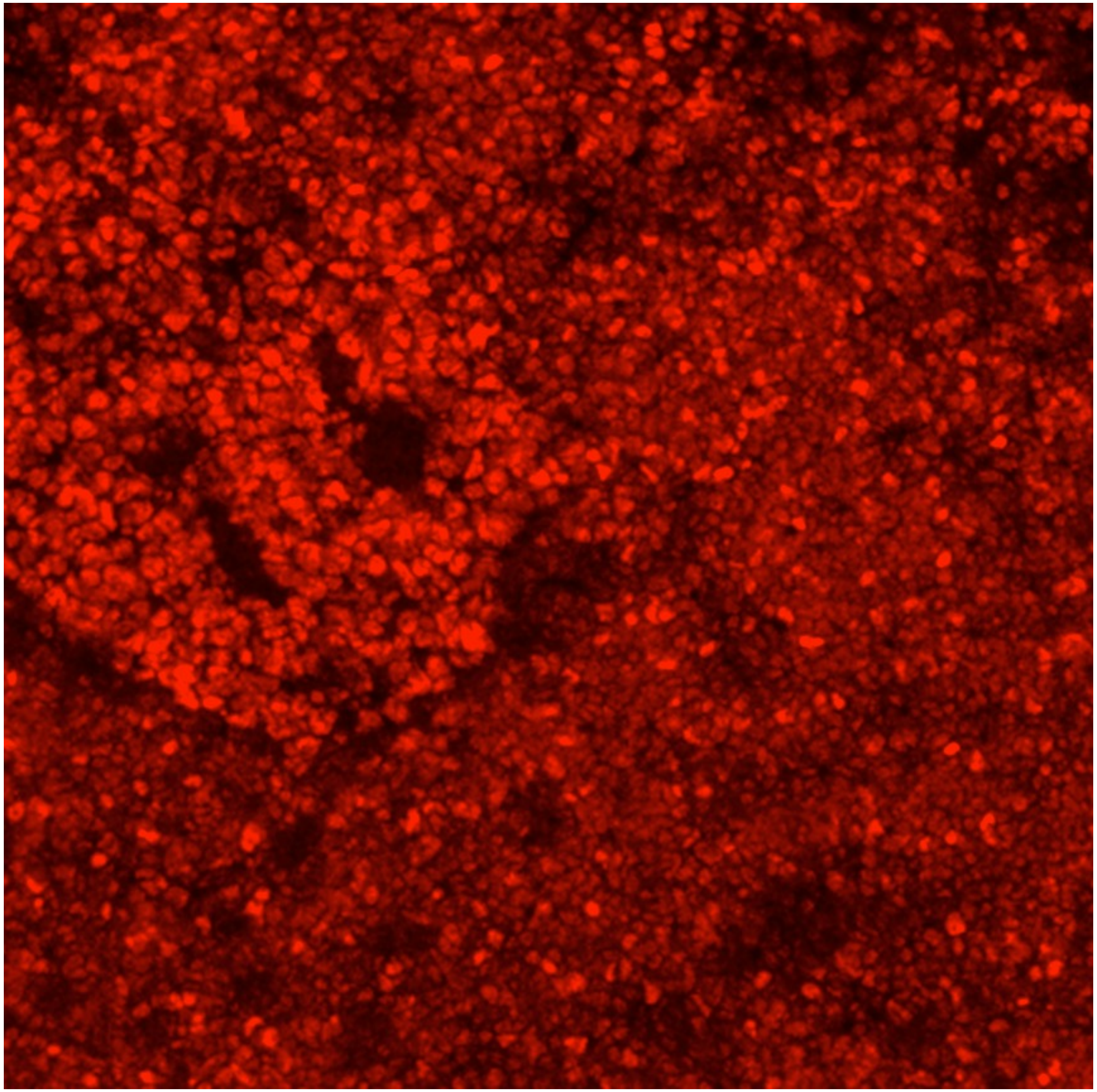
Image Segmentation

- Image Segmentation can be classified as:
  - Non-automated
    - Identifying regions by hand!
  - Semi-automated
    - Thresholding
    - Region Growing
    - Active Contour, etc …
- Automated
  - Model based
    - Area of intensive research

Non-automated

- Given an image, select and define a region of interest by hand.
  - Rough estimate

Hand Segmentation?



Thresholding

Classifying pixels as belonging to the “objects” or “background” depending on their value. T is called the “threshold value”.

if the value of pixel p <=T

then pixel p is an object pixel

else

pixel p is a background pixel

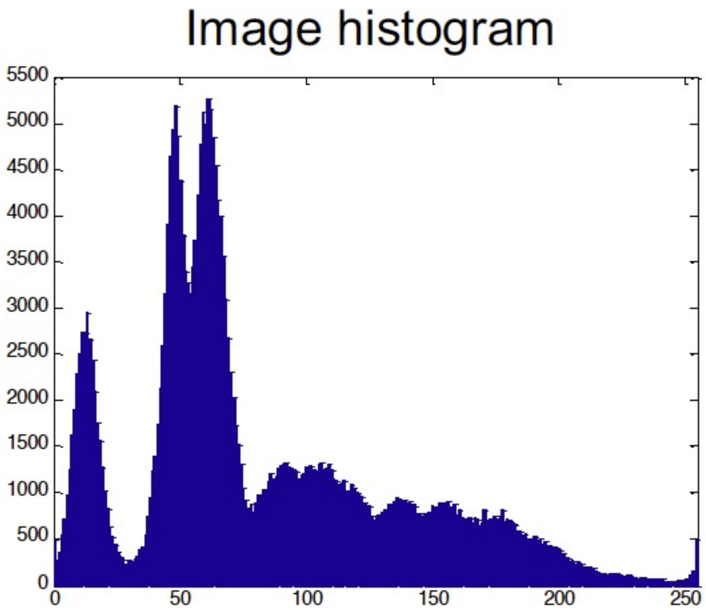
```
if I(x,y)<=T
   TI(x,y)=1
else
   TI(x,y)=0
```

```
TI = I<=T
```

But how do we select the threshold value???

Thresholding

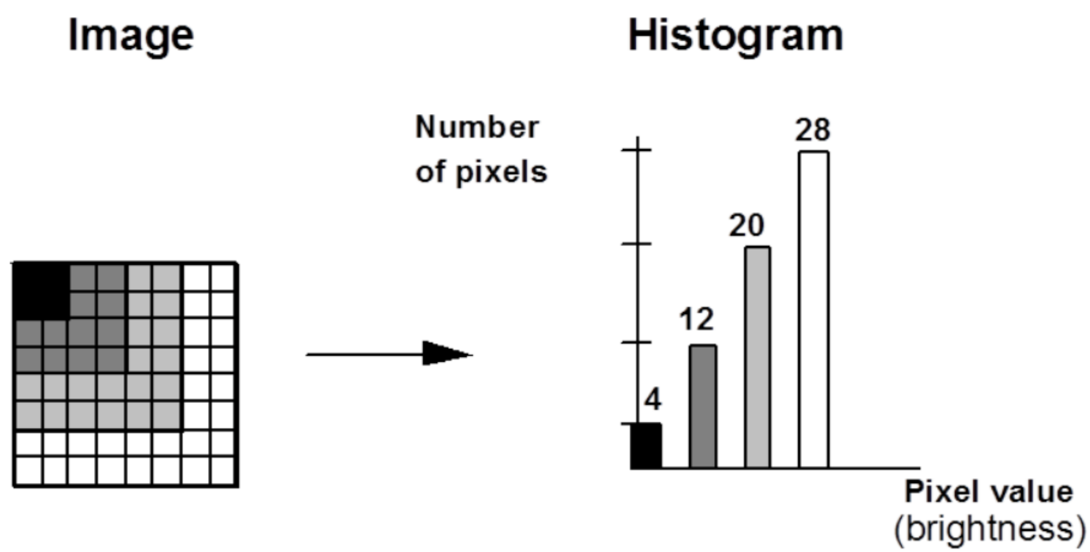
- Histogram-based segmentation
  - Given an image, select a suitable threshold value



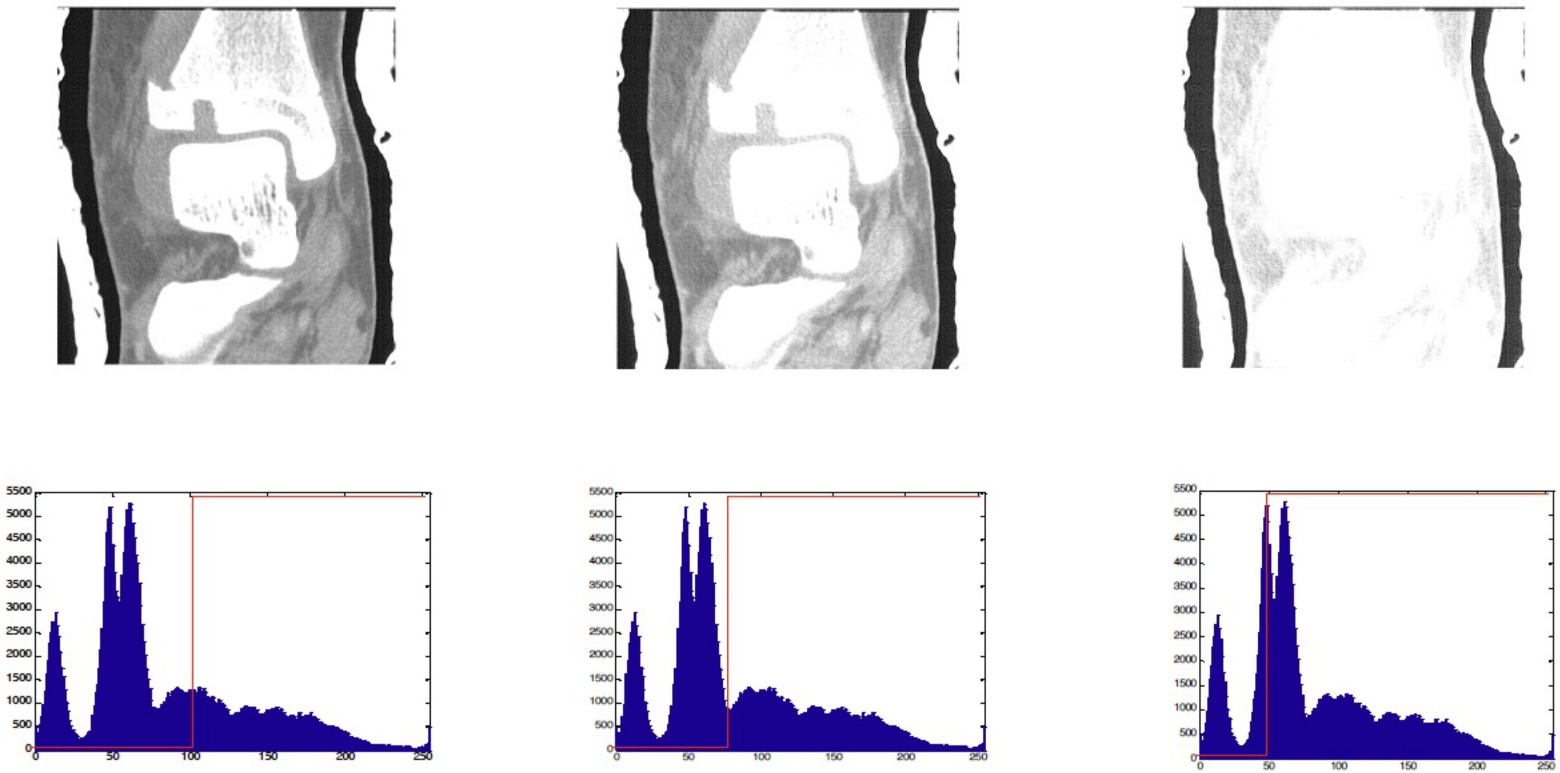
Histogram

A frequency distribution graph

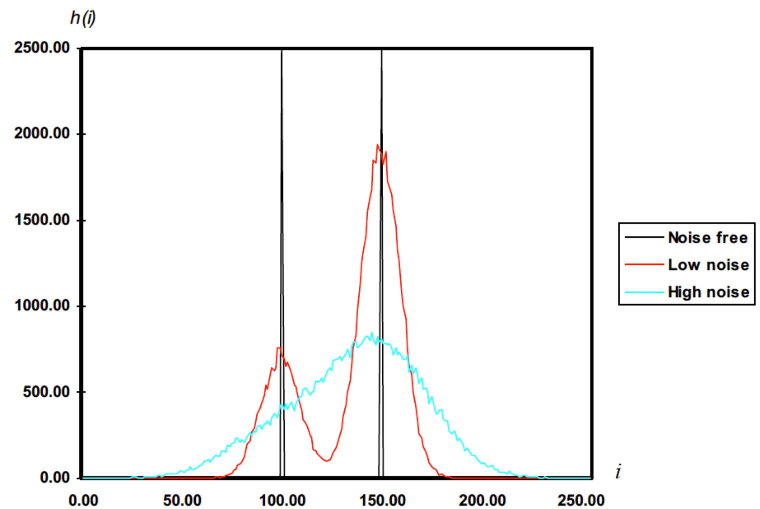
Shows the number of pixels in the image having a particular value or a range of values.

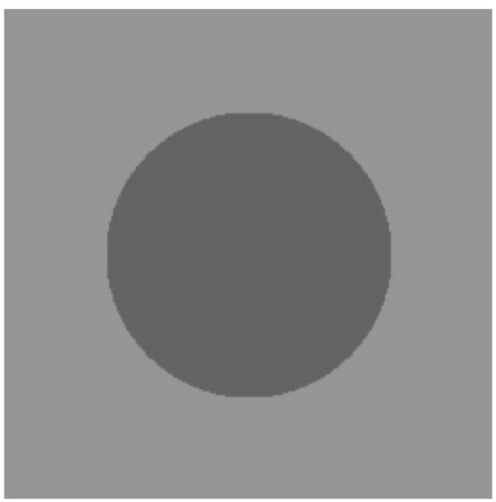


Thresholding

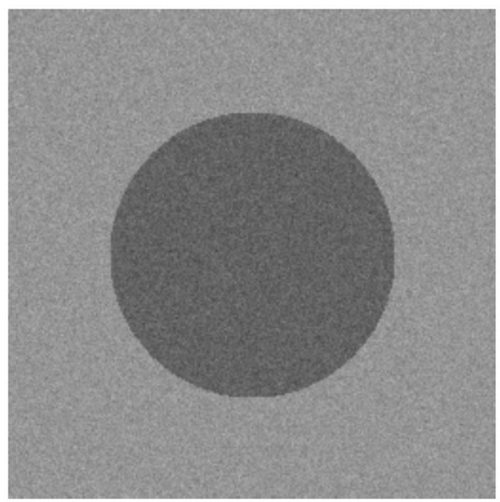


Thresholding challenges

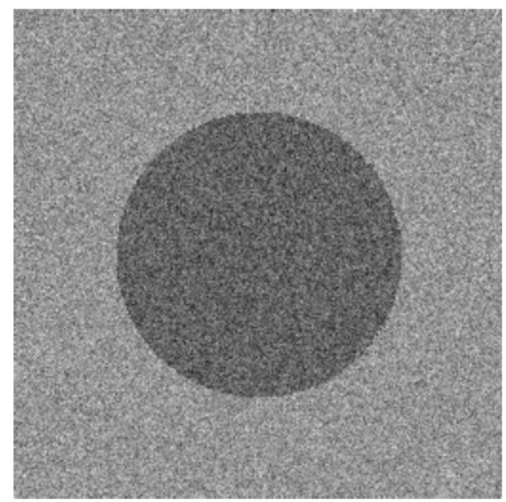




Noise free

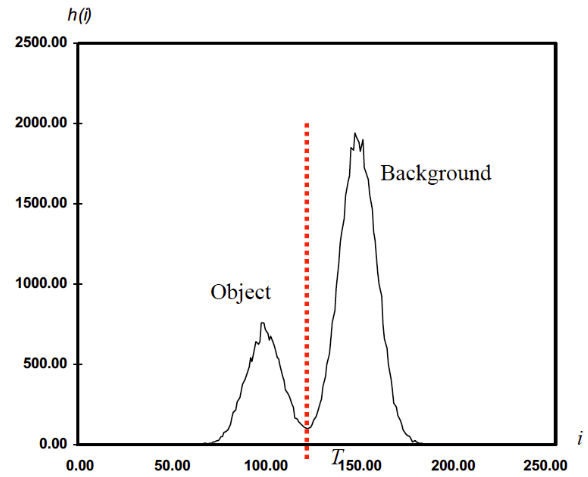


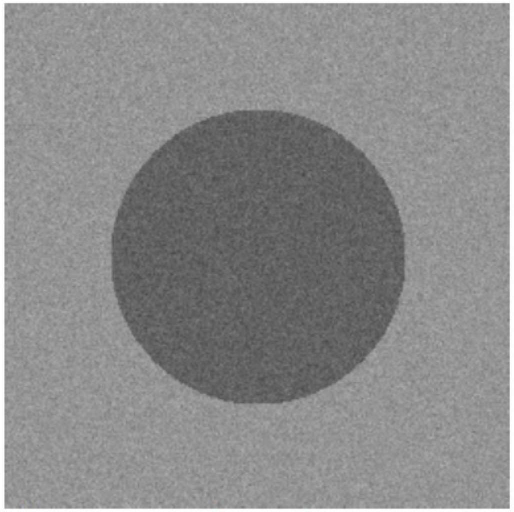
Low noise



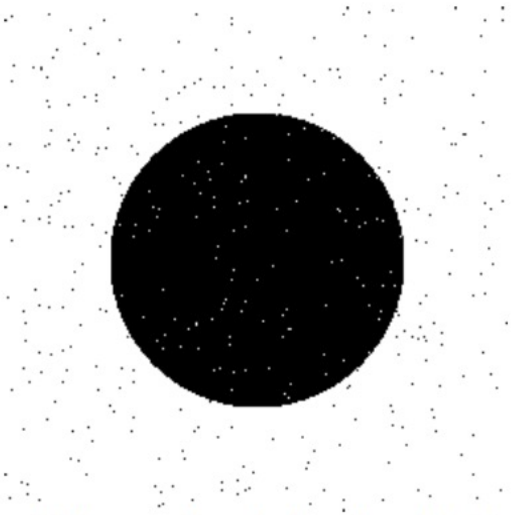
High noise

Thresholding challenges



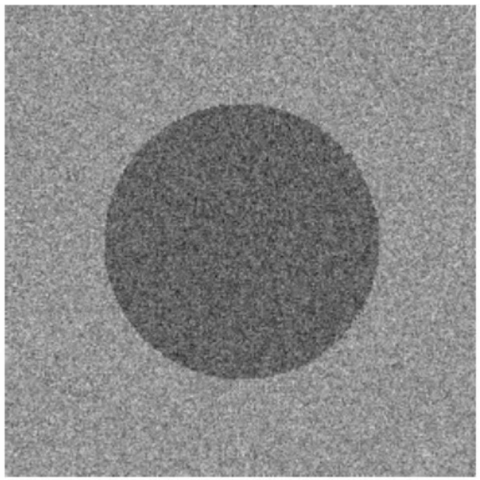


Low noise image

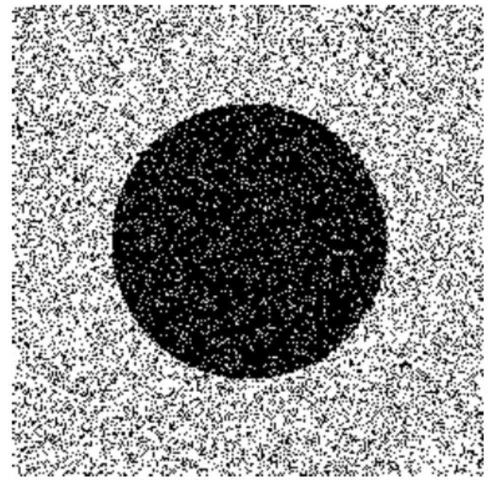


Thresholded at *T=124*

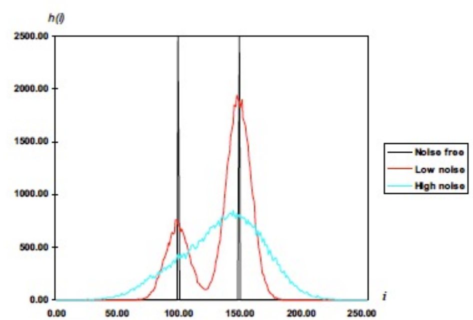
Thresholding challenges



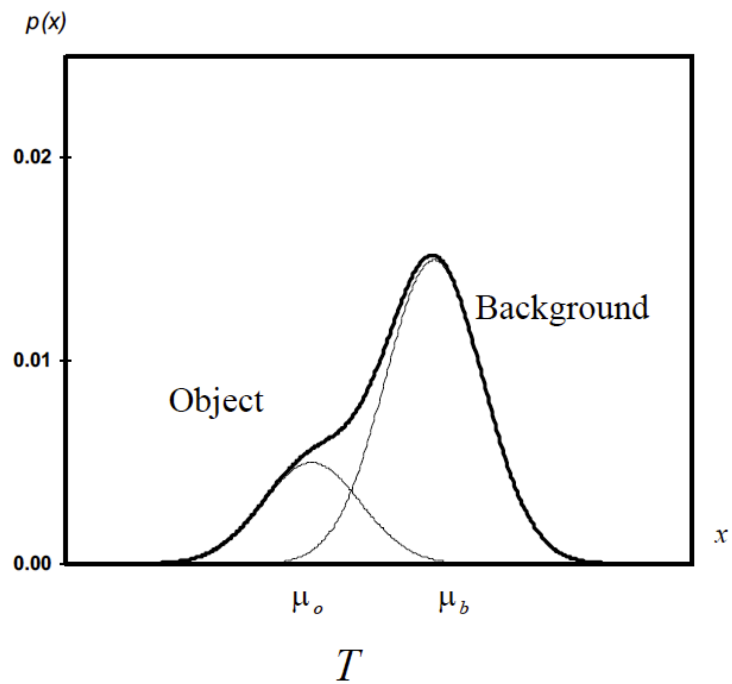
High noise image



Thresholded at $T=124$



Thresholding challenges



Often impossible to select a satisfactory threshold based only on pixel values

Thresholding challenges

- How do we determine the threshold ?
- Many approaches possible
  - Interactive threshold
  - Adaptive threshold
  - Variance minimisation method (Otsu threshold selection algorithm)
    - In the simplest form, the algorithm returns a single intensity threshold that separate pixels into two classes, foreground and background.
    - This threshold is determined by minimizing intra-class intensity variance, or equivalently, by maximizing inter-class variance.

Otsu's Threshold

Algorithm

1. Compute histogram and probabilities of each intensity level
2. Set up initial $\omega_i(0)$ and $\mu_i(0)$
3. Step through all possible thresholds $t = 1, \ldots$ maximum intensity
   1. Update ω_i and μ_i
   2. Compute $\sigma_b^2(t)$
4. Desired threshold corresponds to the maximum $\sigma_b^2(t)$

Event Code:

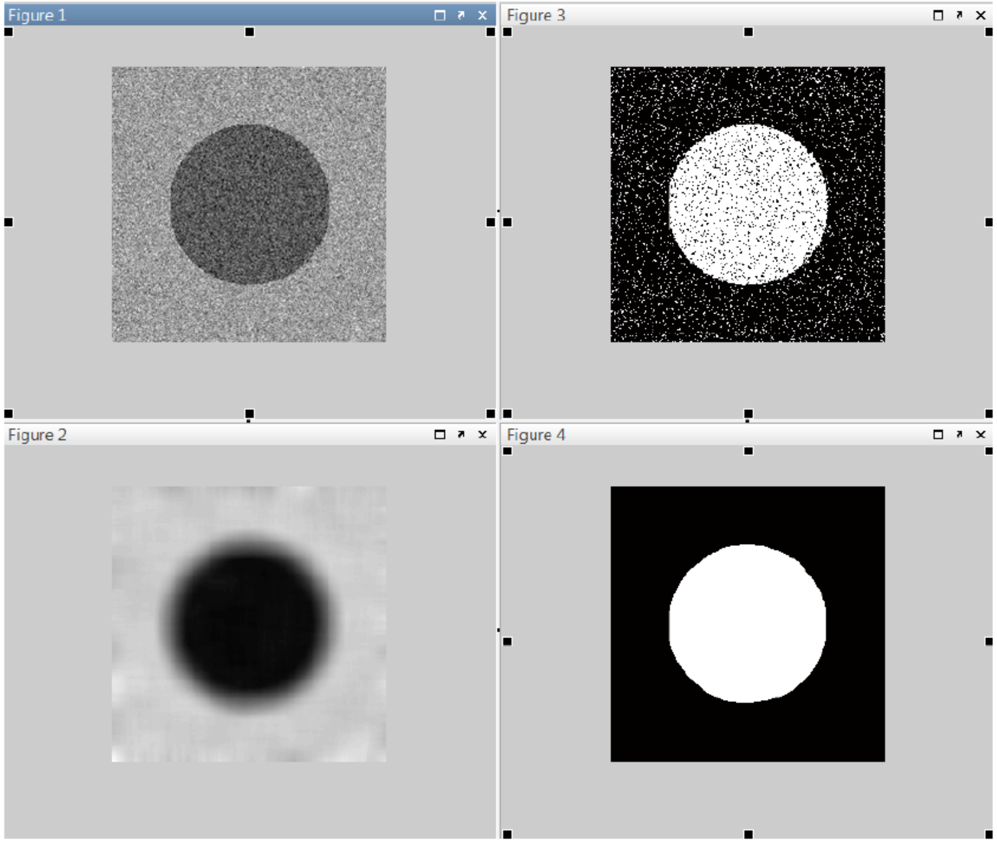
Thresholding - Problems

- Manual methods:
  - Time consuming
  - Operator error
  - Subjective
- Different regions / image areas may need different levels of threshold
- Noise

Smoothing & Thresholding

Original

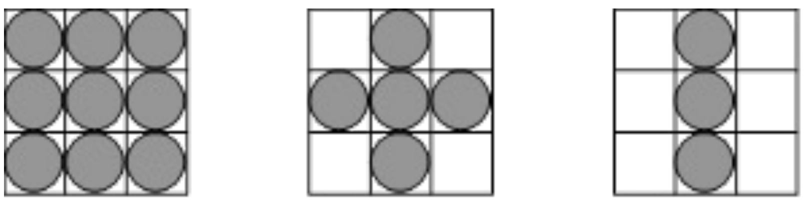
Smoothed



Thresholded at *T=124*

Mathematical morphology

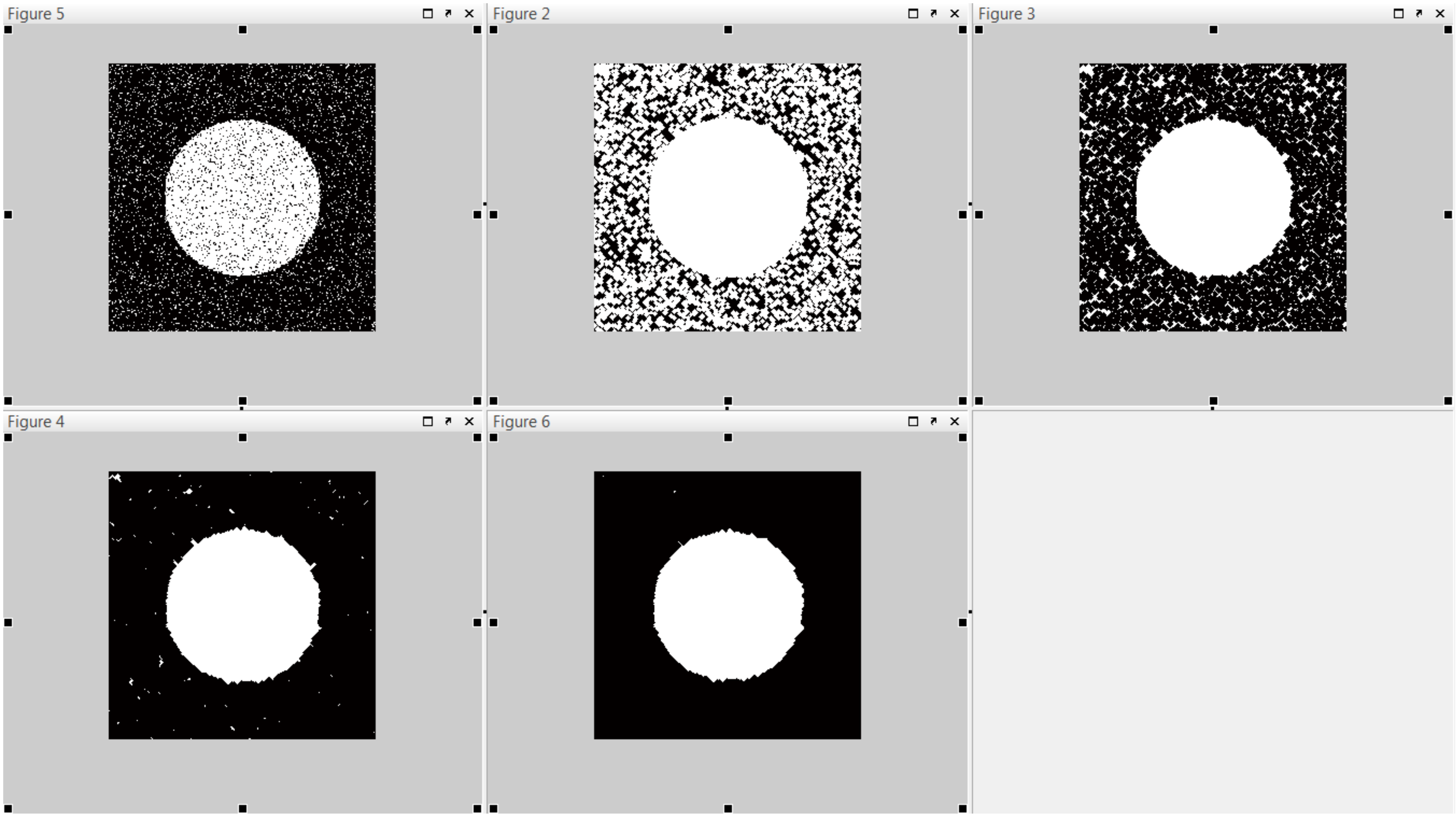
- Morphology is concerned with study of form and shape.
- Operations of mathematical morphology are defined in terms of interactions of two sets of points. One set (usually a large one) corresponds to an image; the other (usually much smaller) is called a structuring element.
- A structuring element can be thought of as a “brush” with which an image is “overpainted” in a number of specific ways, depending on the morphological operation.
- Examples of typical structuring elements (grey dots indicate “active” members of the structuring element set):



Mathematical morphology

- Two principal operations of mathematical morphology are dilation and erosion.
- Dilation (expansion)
  - adding a “layer” of pixels to the periphery of objects
  - the object will grow larger, close objects will be merged, holes will be closed
- Erosion (shrinking)
  - removing a “layer” of pixels all round an object
  - the object will get thinner, if it is already thin it will break into several sections

Mathematical morphology



Advanced segmentation methods

- Active contours (snakes)
- Watershed
- Level-set methods
- Active shape model segmentation

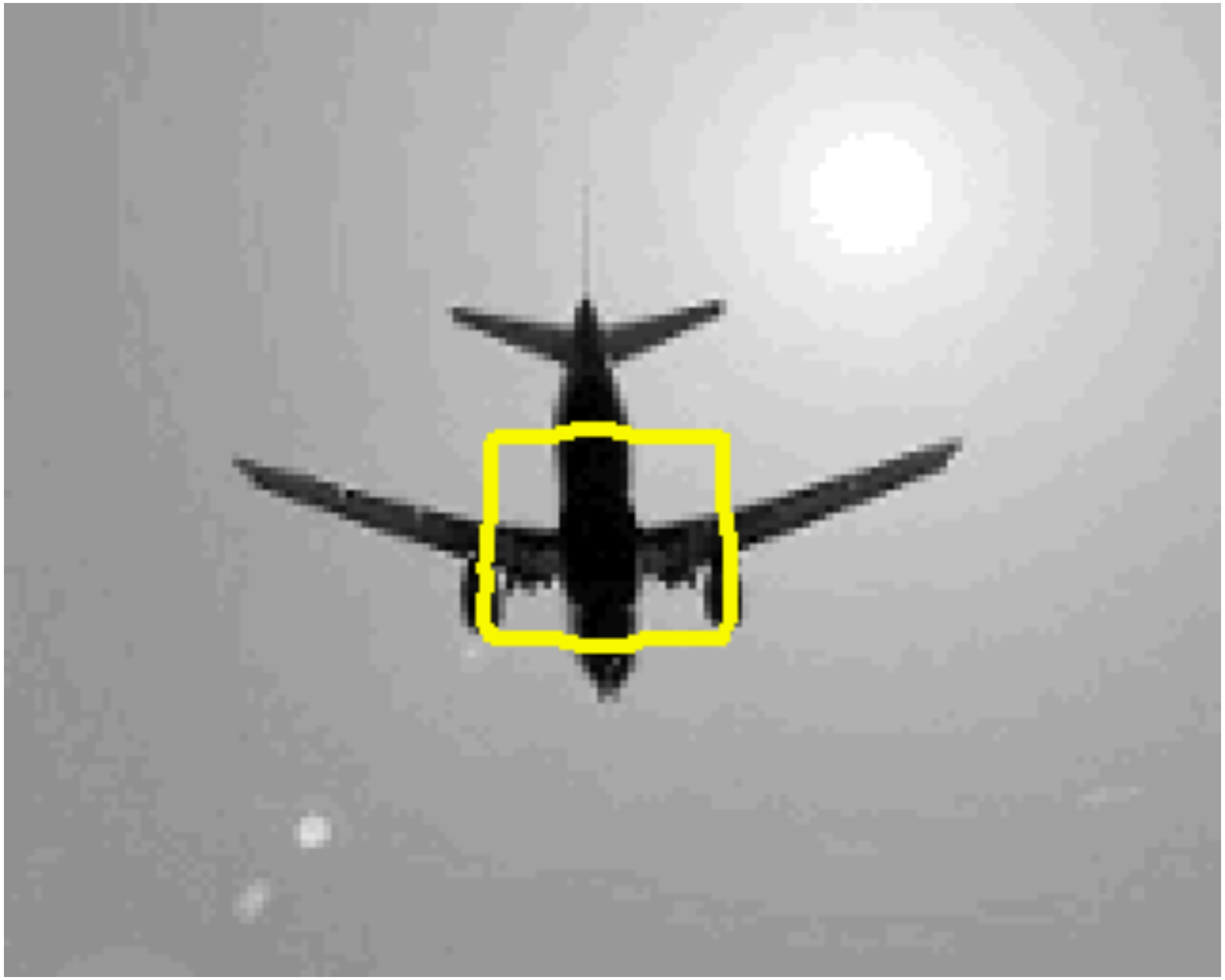
Active (snake) contours

$$E[(C)(p)] = \alpha \int_0^1 E_{int}(C(p))dp \; + \; \beta \int_0^1 E_{img}(C(p))dp \; + \; \gamma \int_0^1 E_{con}(C(p))dp$$

- The internal term stands for regularity/smoothness along the curve and has two components (resisting to stretching and bending)
  - sensitivity to the amount of stretch in the snake and the amount of curvature in the snake
- The image term guides the active contour towards the desired image properties (strong gradients)
  - Energy in the image is some function of the features of the image, for example edges
- The external term can be used to account for user defined constraints, or prior knowledge on the structure to be recovered
  - allows for user interaction to guide the snakes, not only in initial placement but also in their energy terms.
- The lowest potential of such a cost function refers to an equilibrium of these terms

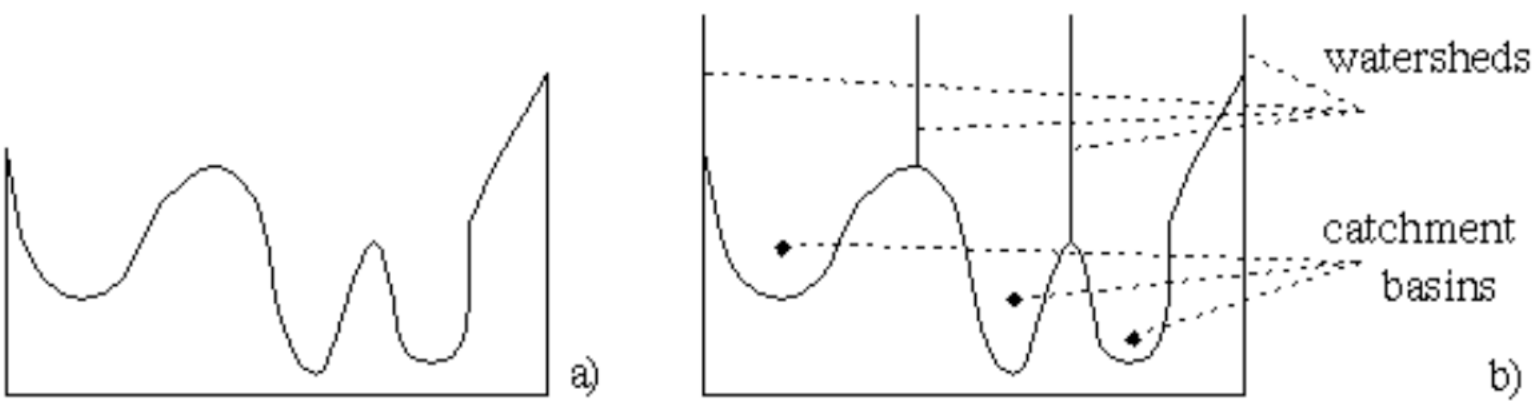
Active contours

$$E[(C)(p)] = \alpha \int_0^1 E_{int}(C(p))dp \ + \ \beta \int_0^1 E_{img}(C(p))dp \ + \ \gamma \int_0^1 E_{con}(C(p))dp$$



Watershed segmentation

- Classify pixels into three classes:
  - belonging to a local minimum
  - catchment basin or watershed: pixels at which a drop of water would flow to that local minimum
  - divide of watershed lines: pixels at which water would flow to two minima.



Watershed segmentation

a	b
c	d

FIGURE 10.46 (a) Image of blobs. (b) Image gradient. (c) Watershed lines. (d) Watershed lines superimposed on original image. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)