Image Analysis
Lecture 9.1 - Segmentation

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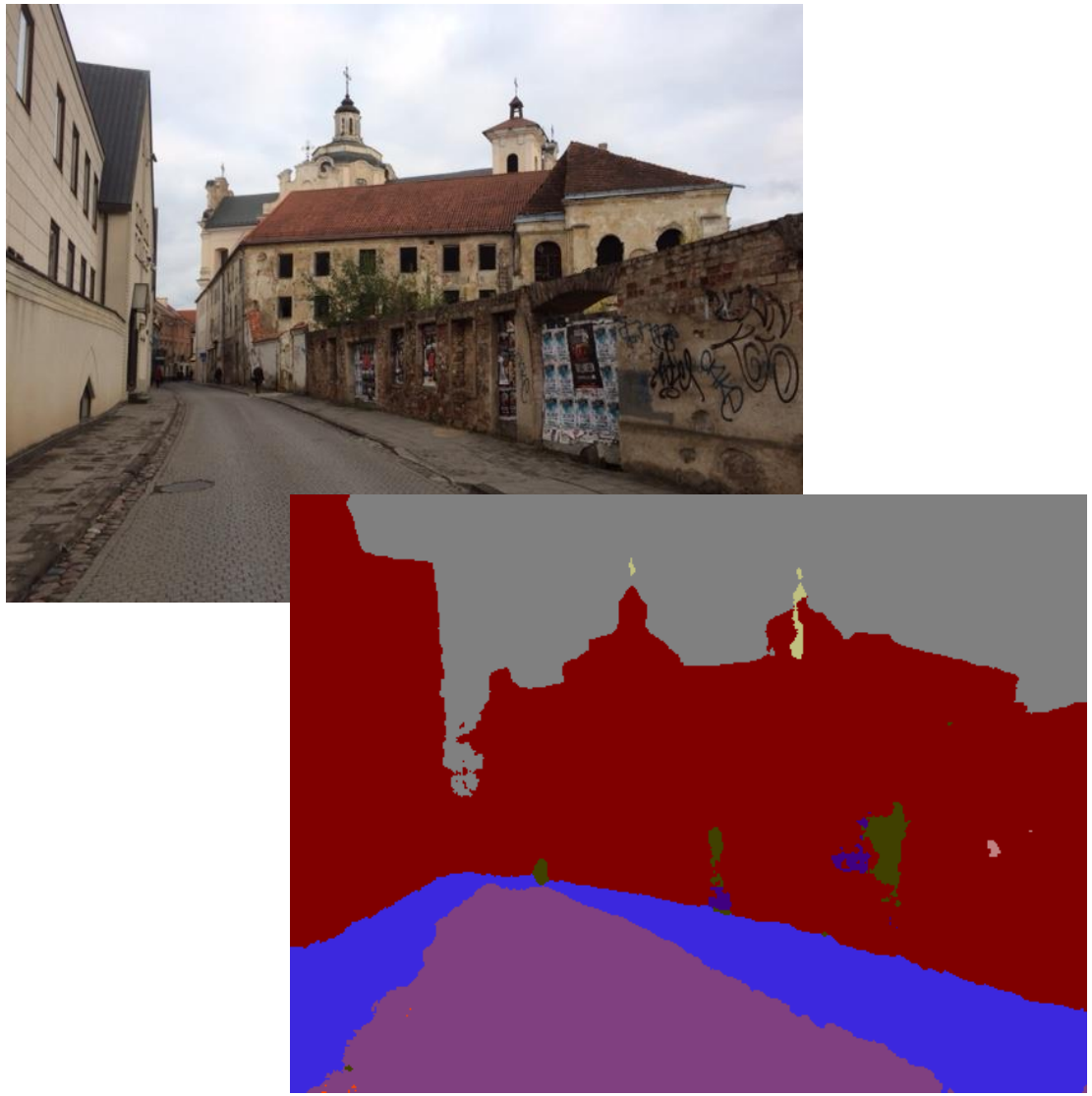
Segmentation

- Image segmentation is the process of partitioning a digital image into multiple parts, i.e. find groups of pixels that belong together
- The goal is to divide the image into meaningful and/or perceptually uniform regions
- Segmentation is typically used to locate objects and boundaries of physical entities in the scene
- The segmentation process utilize available image information (intensity, color, texture, pixel position, …).



Segmentation (2)

First step in image analysis:

- Going from pixels to objects or object parts (physical items or scene elements)
- Paves the way for object feature extraction followed by
- Object recognition (Classification)

Principles:

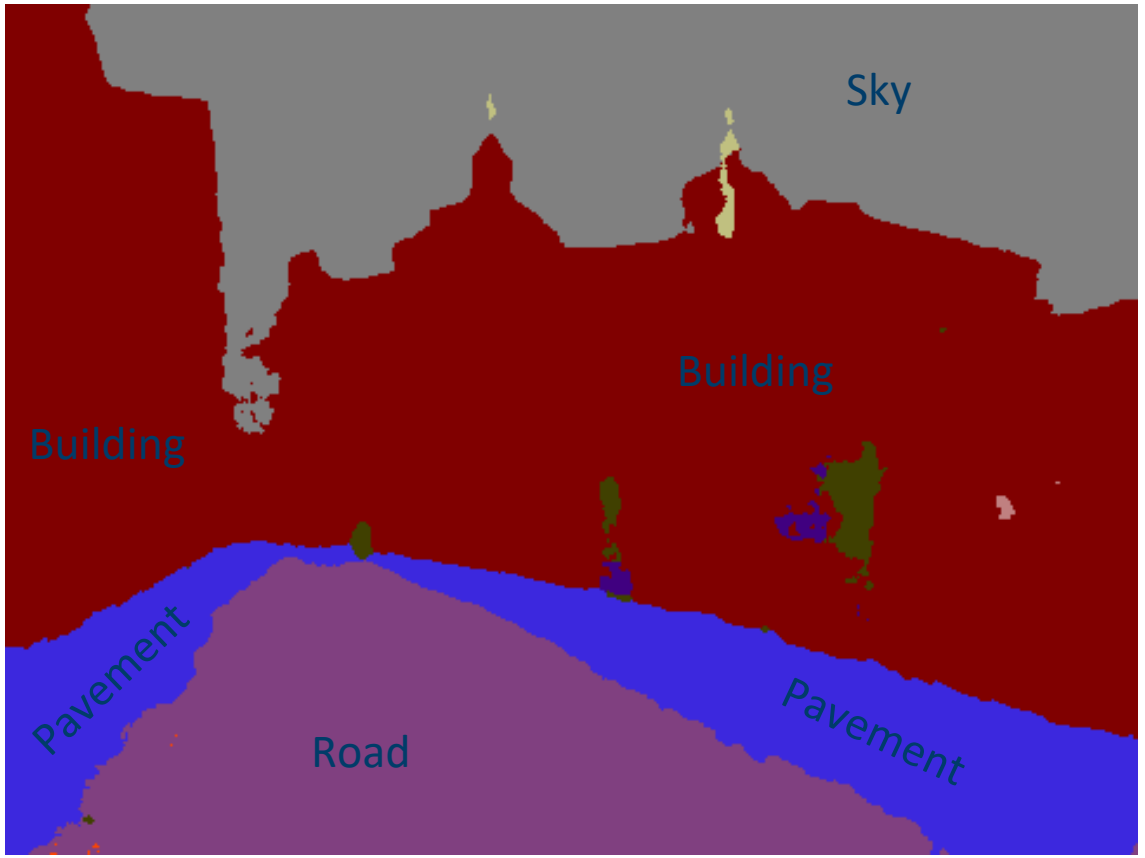
- Thresholding
- Edge based
- Region based
- Automatic (supervised) or interactive (unsupervised)

Color based segmentation - three categories

Original image

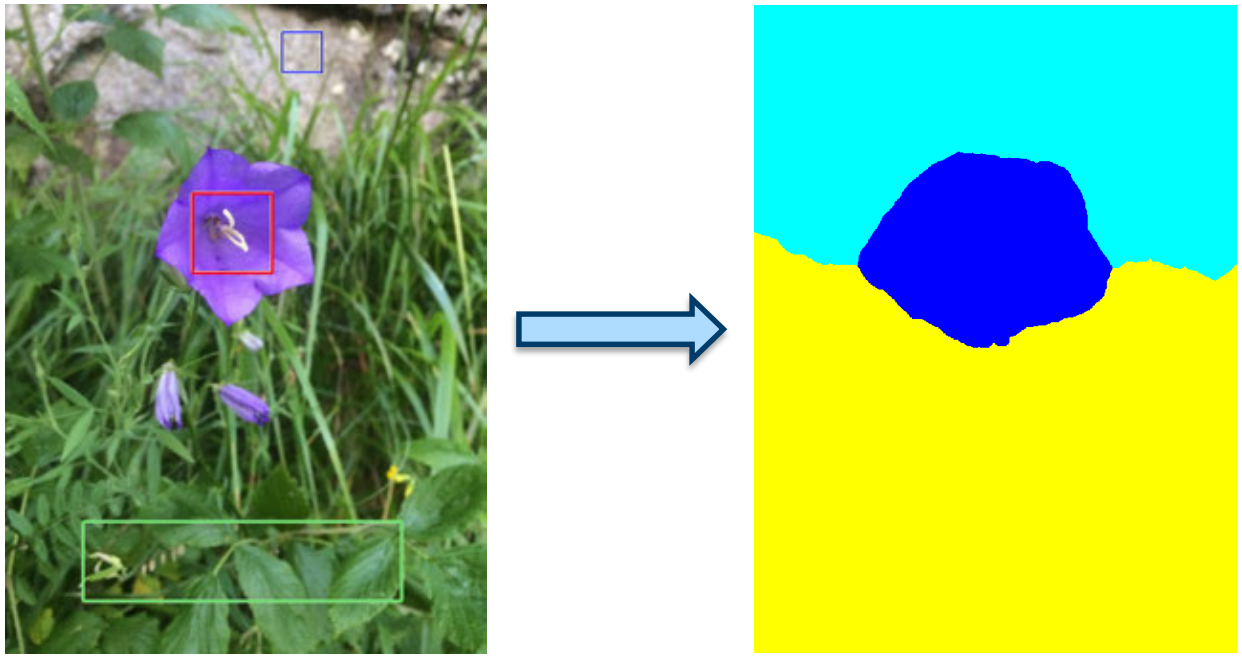
Segmented image

Semantic Segmentation (meaningful regions)



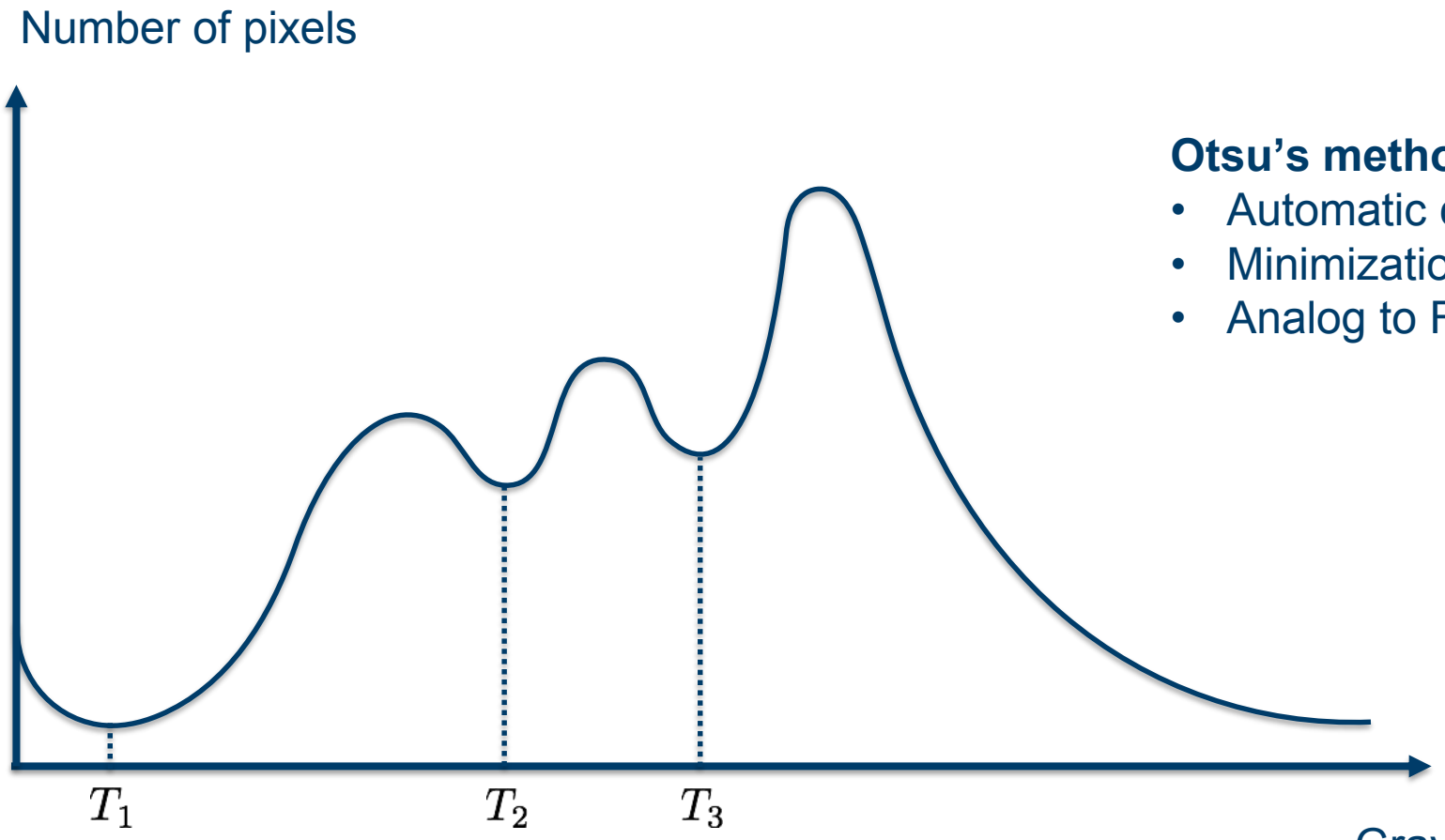
Segmentation methods

- Active contours (Snakes, Scissors, Level Sets)
- Split and merge (Watershed, Divisive & agglomerative clustering, Graph-based segmentation)
- Gray level thresholding
- K-means (parametric clustering)
- Mean shift (non-parametric clustering)
- Normalized cuts
- Graph cuts



Supervised color based segmentation (region growing)

Segmentation by thresholding



Otsu's method:

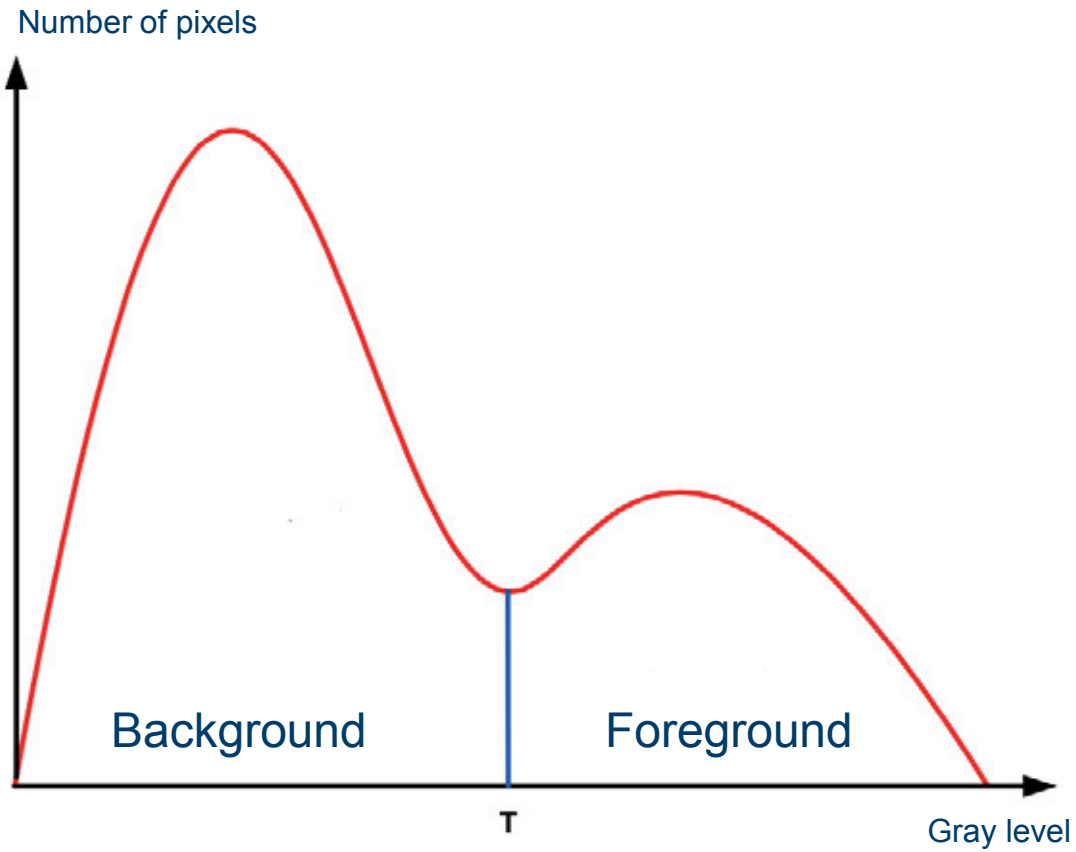
- Automatic clustering based thresholding
- Minimization of intra-class variance
- Analog to Fisher's Discriminant Analysis

Thresholding with Otsu's method

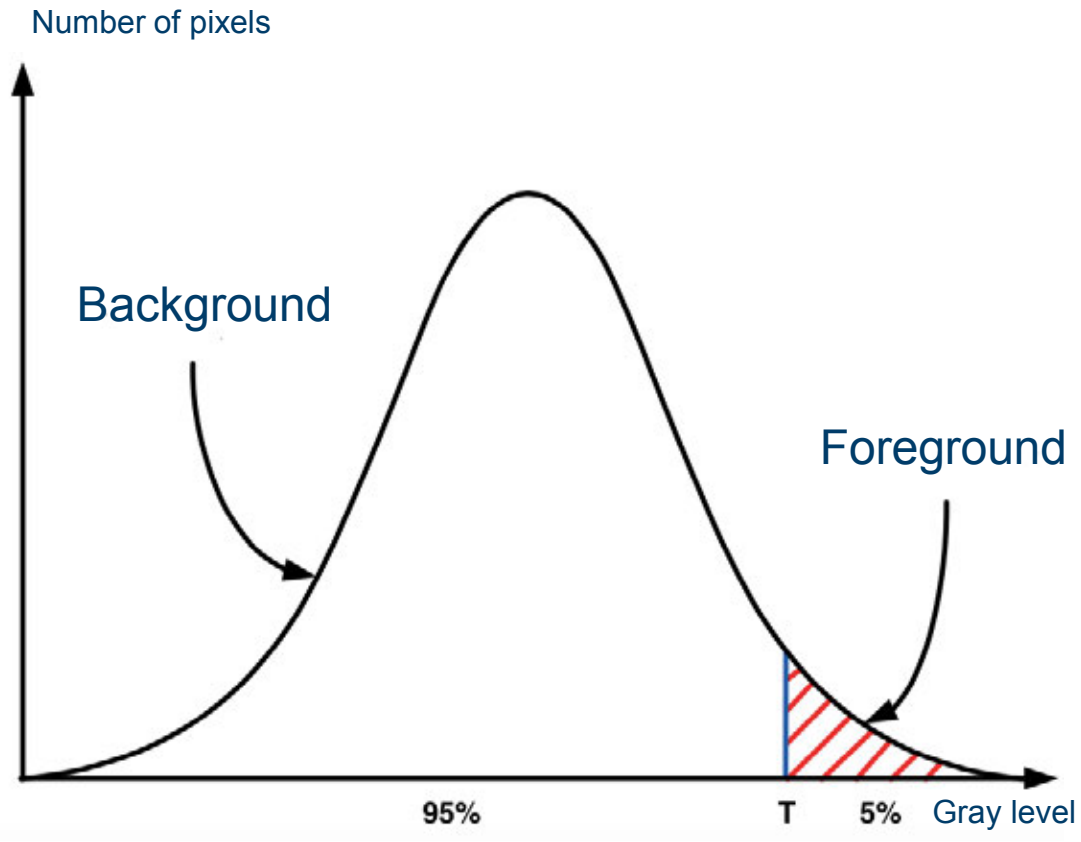
3 thresholds

4 classes

Binary segmentation – foreground vs. background



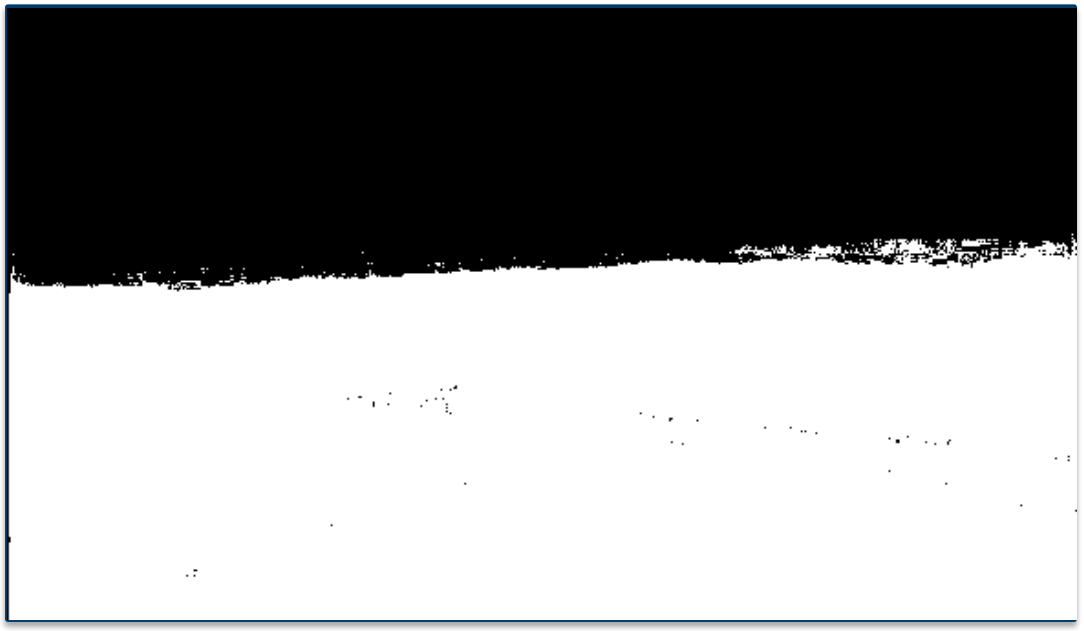
Threshold between two populations



Threshold at given percentile

Binary thresholding – Object detection

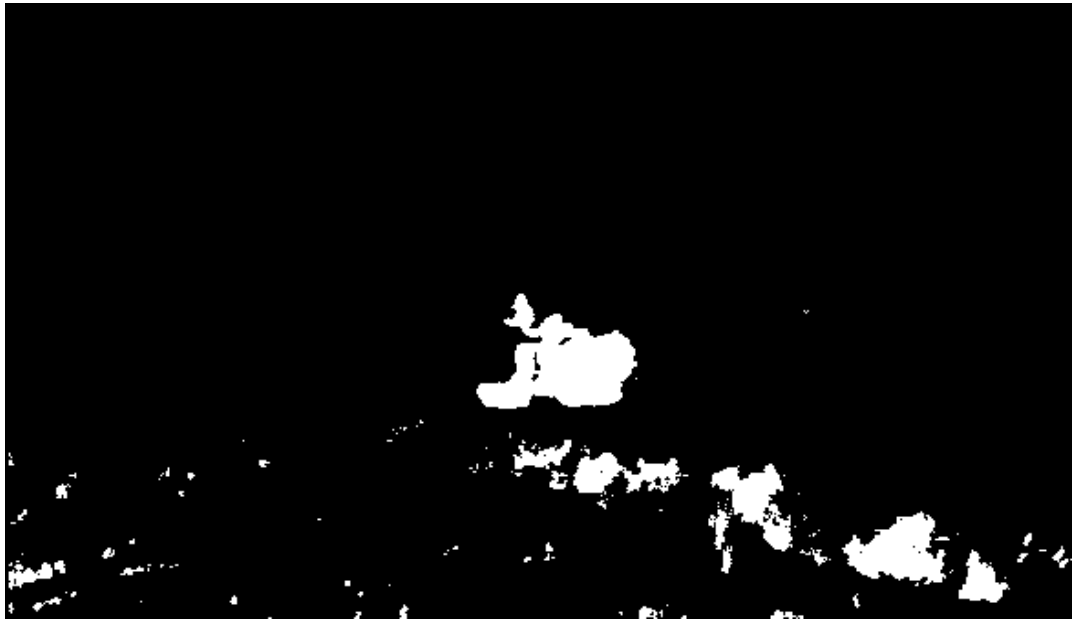
Thermal image



Thresholded image (Otsu's method)

Global threshold selection → threshold *too low* for detection of the object of interest

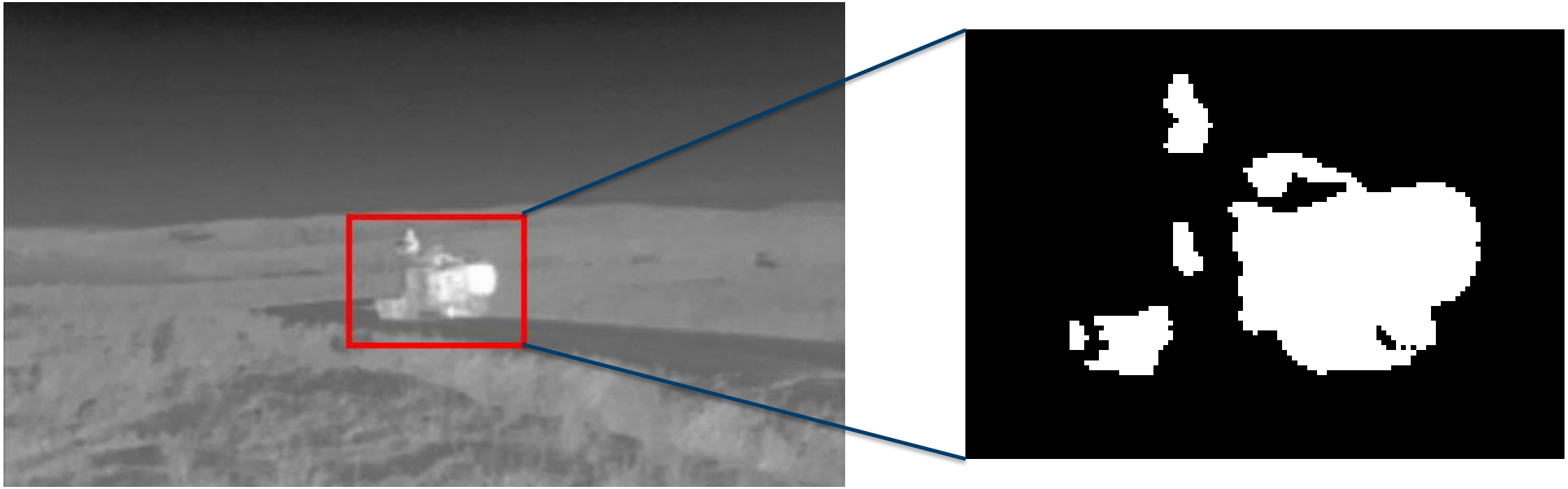
Manual thresholding



Medium threshold

High threshold

Local thresholding



Threshold computed from gray level statistics in selected window (Otsu's method)

Local thresholding using edge information

Edge image (Canny edge detector applied to selected window)

Threshold = average gray level along edges

Thresholded window

Object detection in video sequences (visible light)

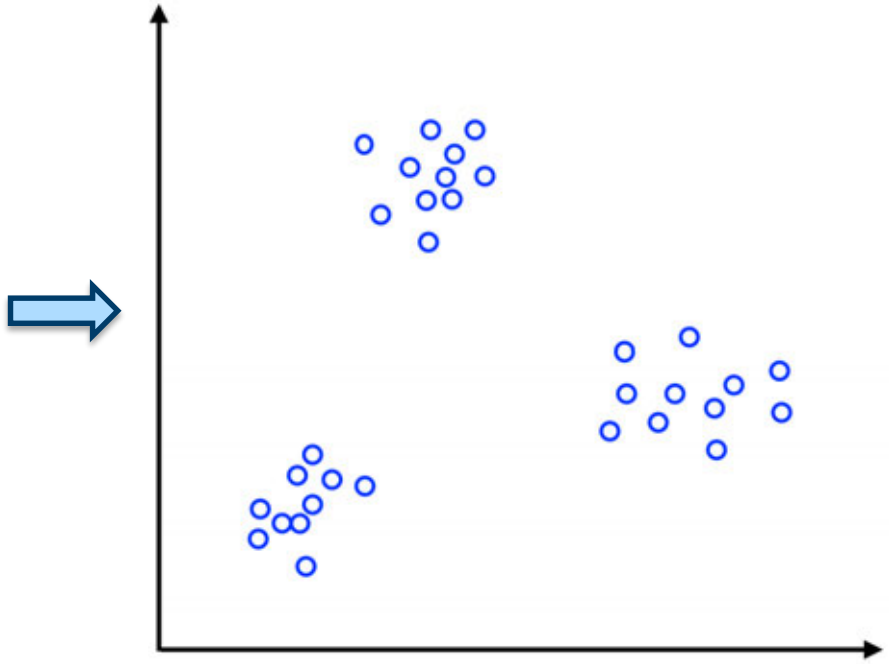
Daylight video frame

Thresholded difference image

- Change detection
- Absolute difference image (Current image - time averaged background image)
- Thresholding of difference image, i.e. Otsu's method
- Requires fixed camera (or registration of images)

Segmentation by clustering

Original image



Pixels represented as points in feature space

Segmented image

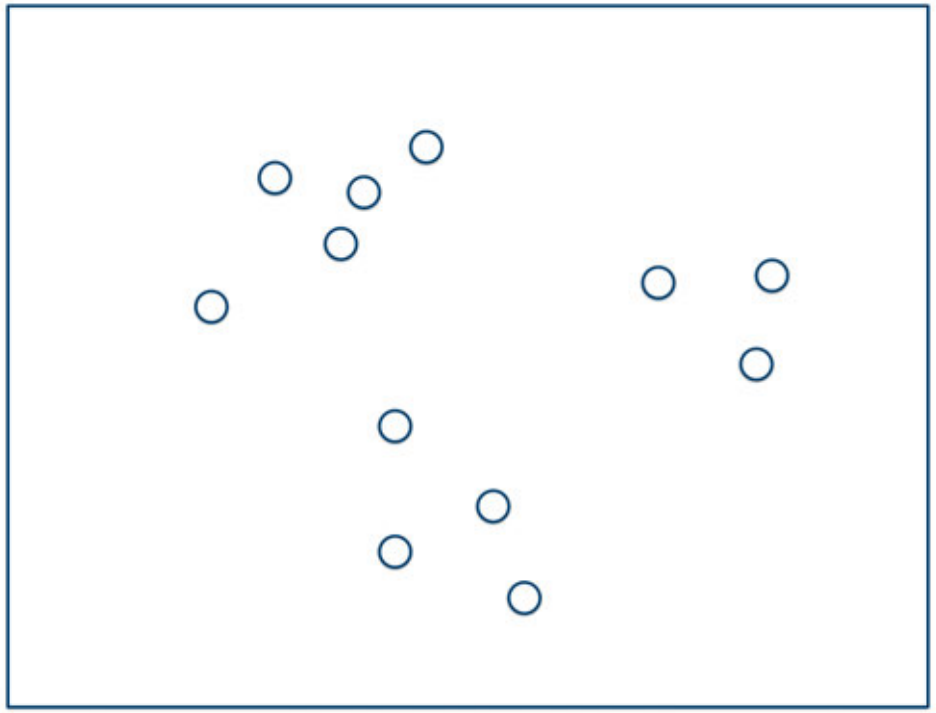
K-means (parametric) clustering

1. Select K points (for example randomly) as initial cluster centers

2. Assign each sample to nearest cluster center

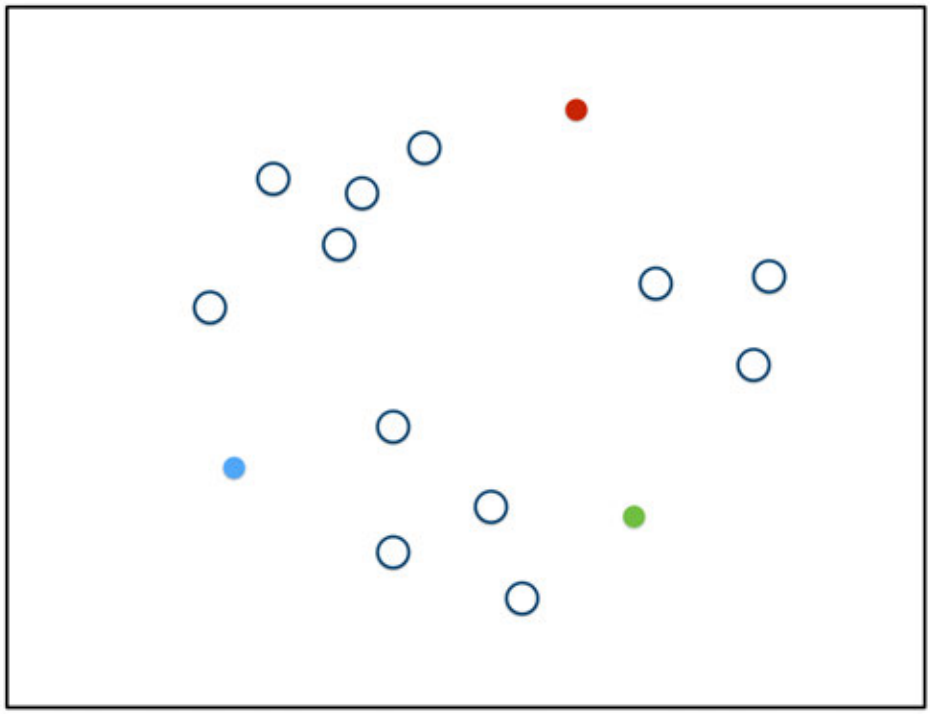
3. Compute new cluster centers (i.e. sample means)

4. Repeat steps 2 and 3 until no further re-assignments are possible.

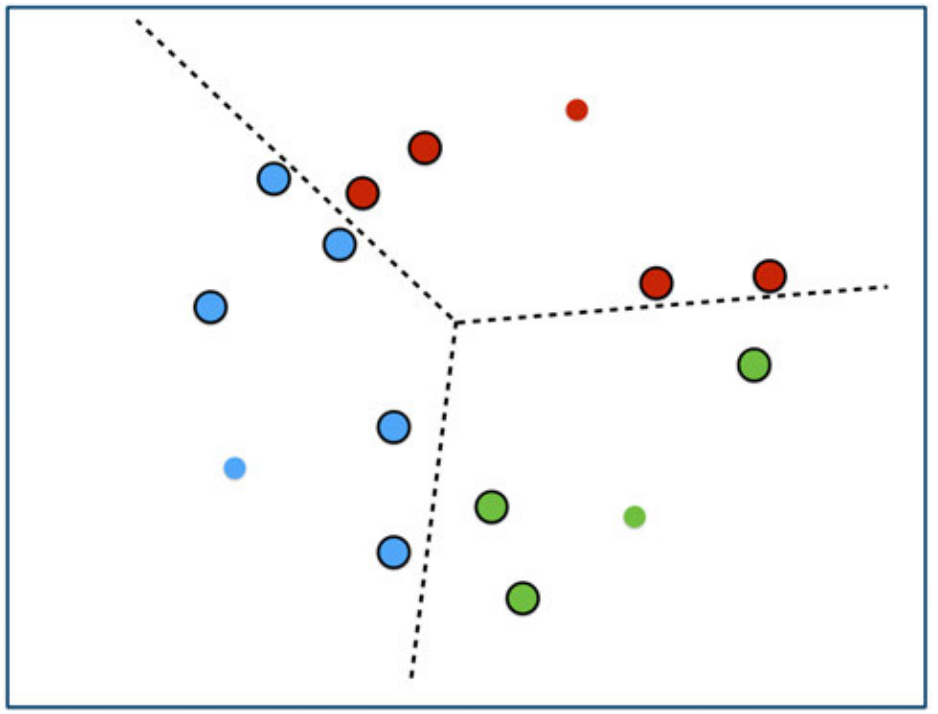


Unlabeled dataset

K-means clustering

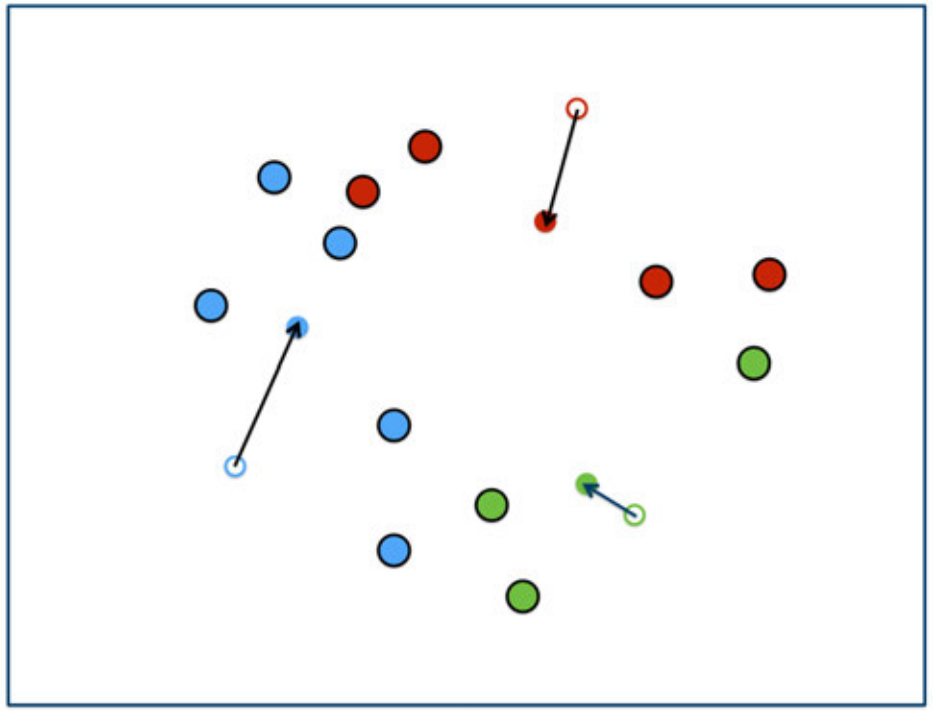


Initial cluster centers (red, green and blue points)

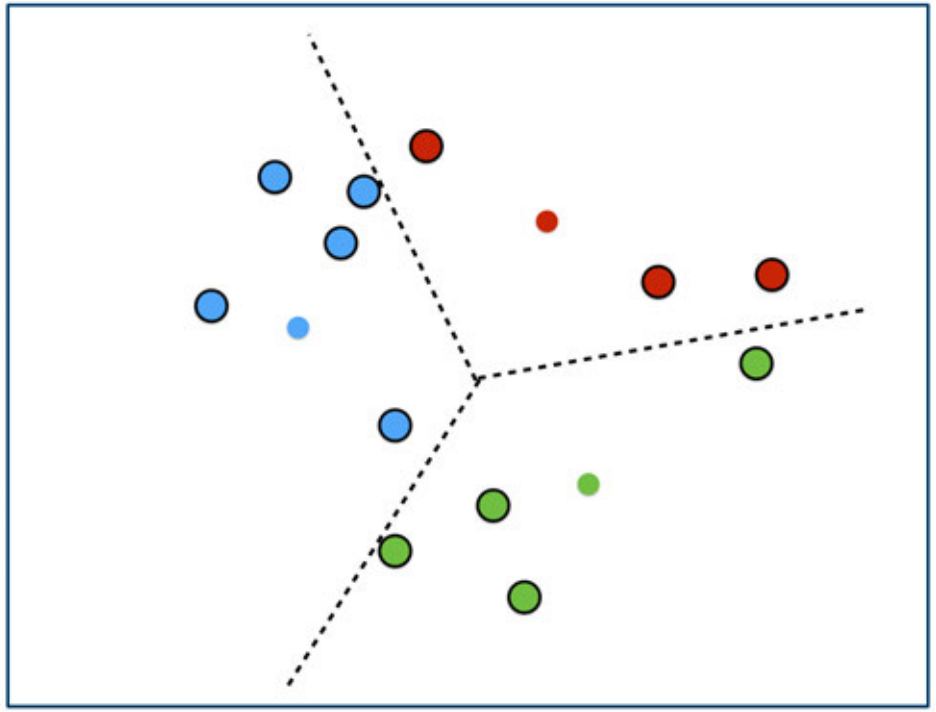


Samples assigned to nearest cluster center

K-means clustering

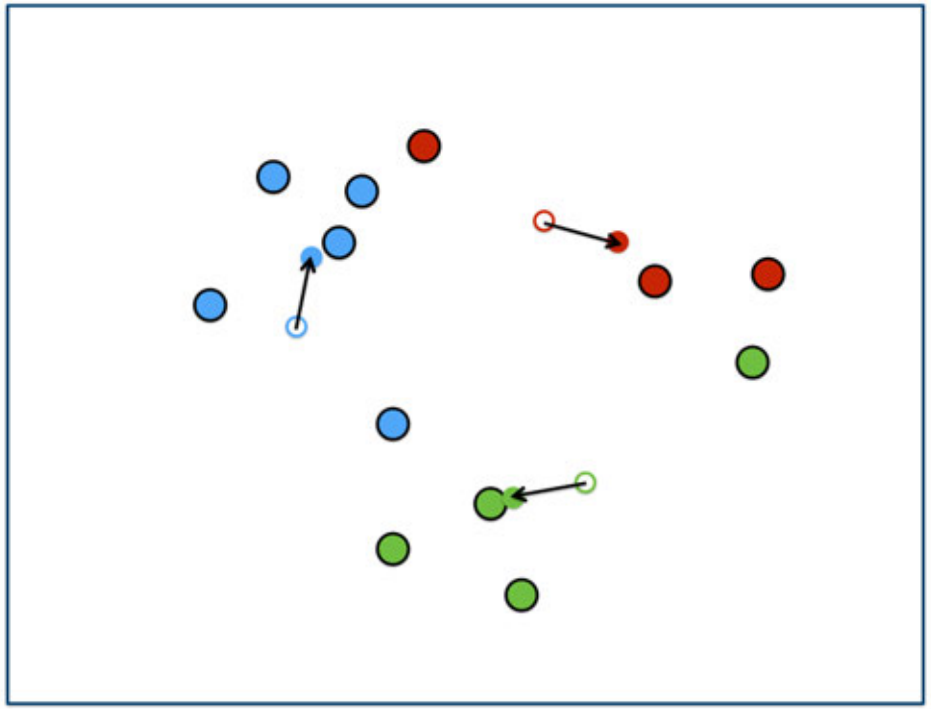


Re-computed cluster centers

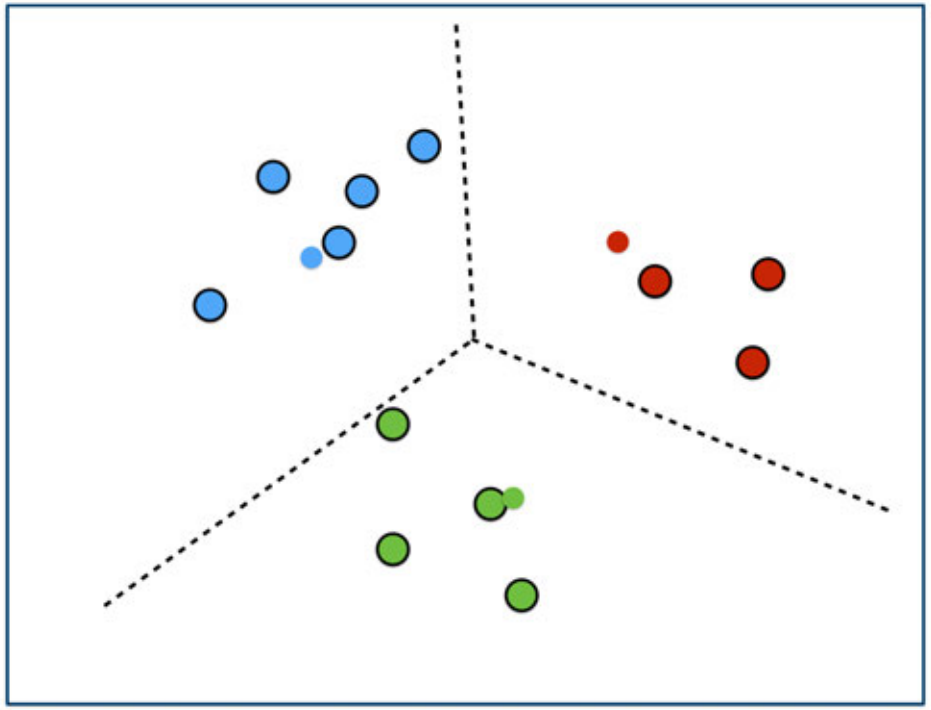


Samples re-assigned to new cluster centers

K-means clustering



Re-computed cluster centers



Final clustering

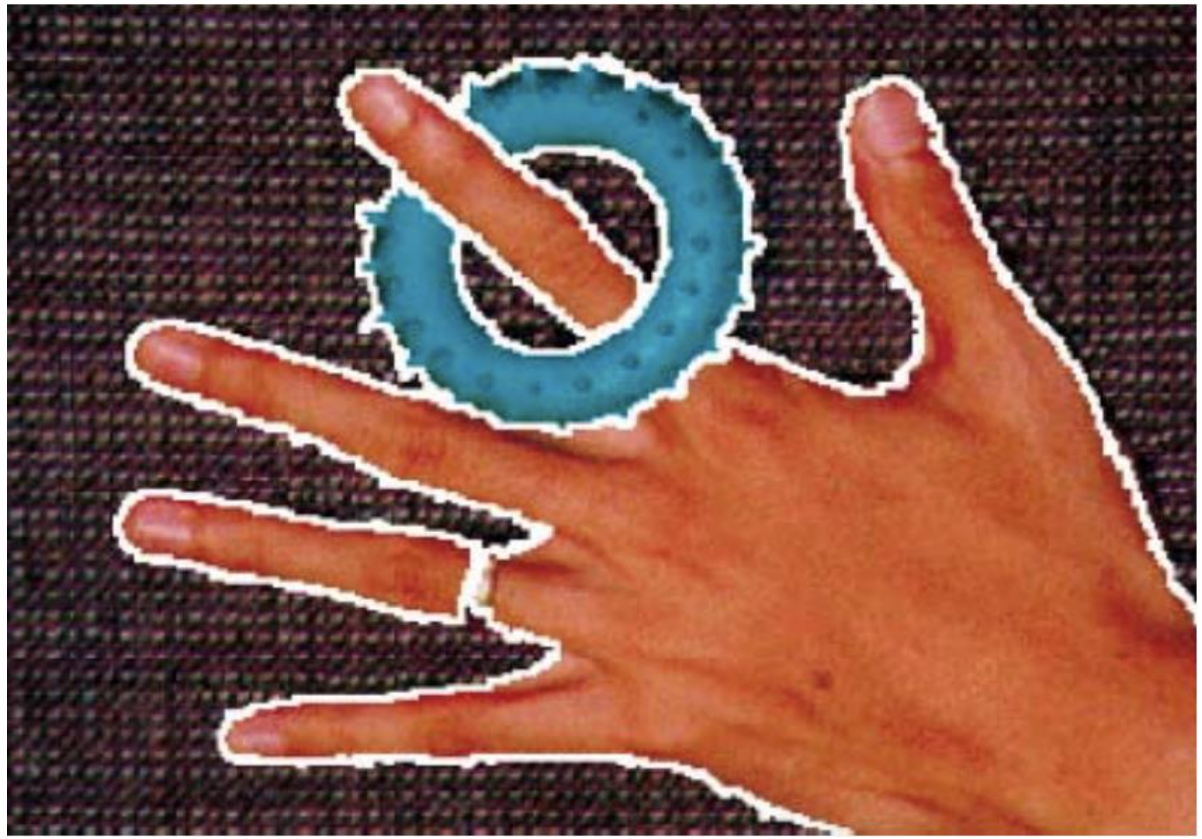
K-means clustering using color

Original image

Clustered image – 10 clusters

Mean shift (non-parametric) segmentation

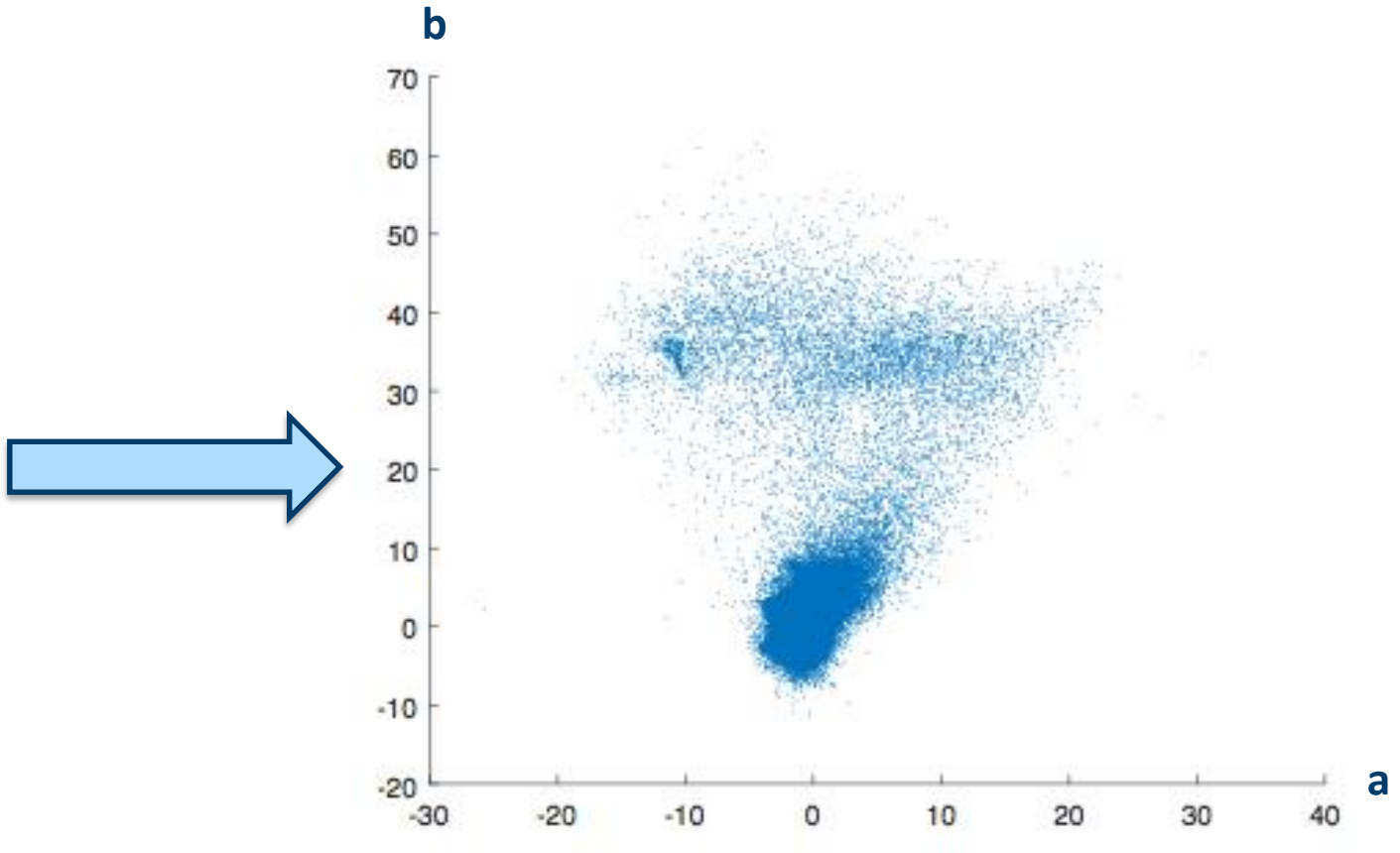
- Segmentation by clustering of the pixels in the image (e.g. using color and position)
- Non-parametric method (using the so called Parzen window technique) to find modes (i.e. peaks) in the density function
- All pixels climbing to the same peak are assigned to the same region.



(Szeliski: Computer Vision – Algorithms and Applications)

Mean shift segmentation

Original image



Plot of **a** vs. **b** for each pixel in **Lab** transformed image

Parzen Method

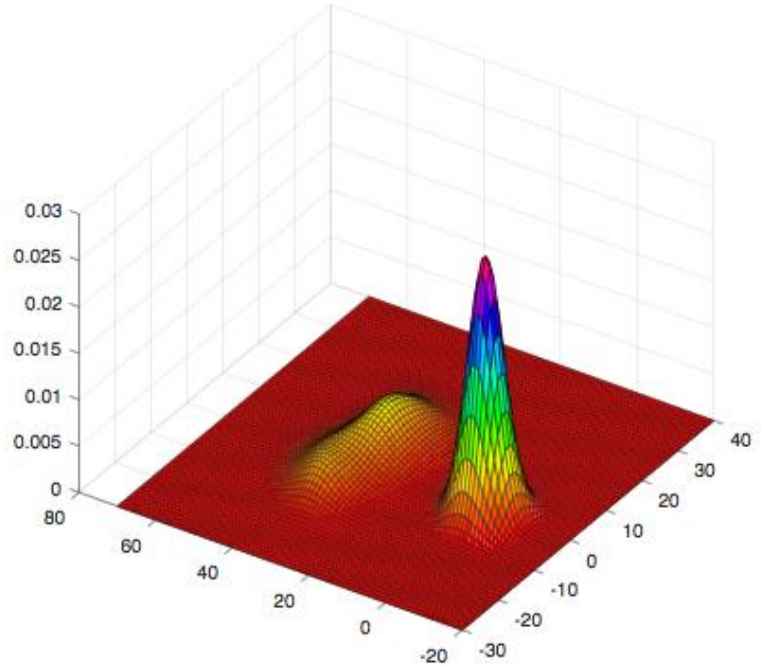
Density estimate (smoothing of point cloud):

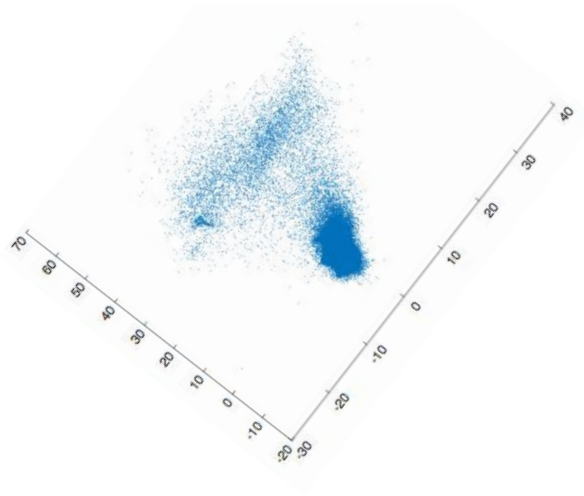
$$f(\boldsymbol{x}) = \frac{1}{nh^d} \sum_{i=1}^{n} \varphi\left(\frac{\boldsymbol{x} - \boldsymbol{x}_i}{h}\right)$$

Window (kernel) function: $\varphi(\boldsymbol{u})$

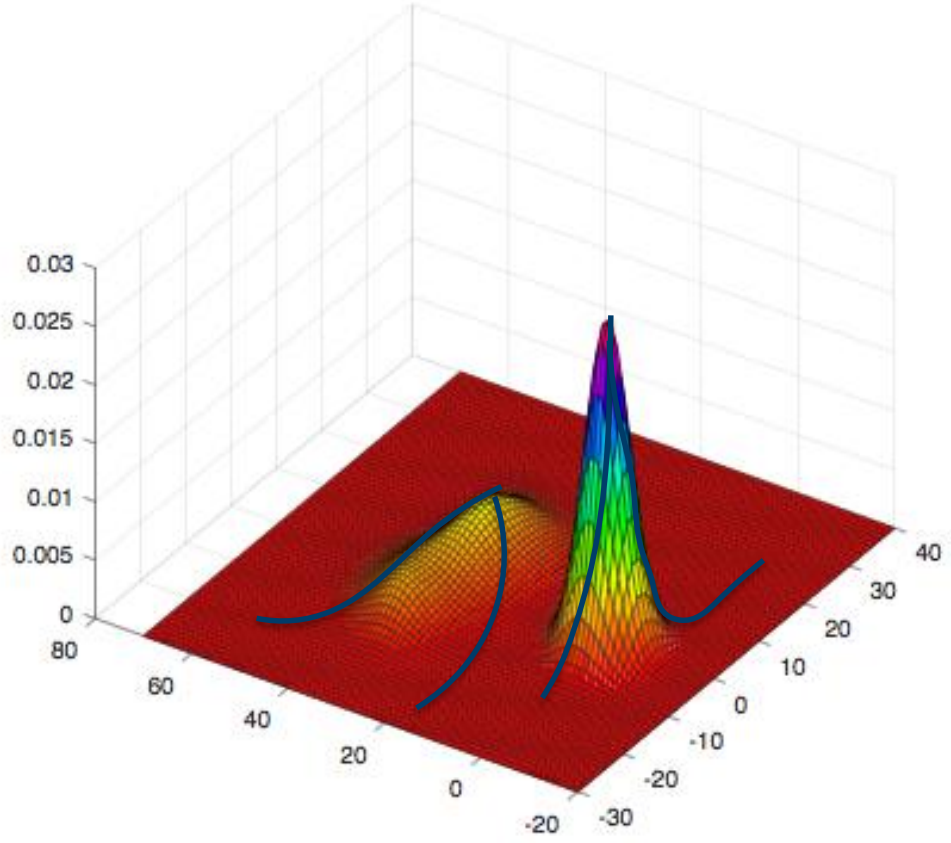
Example:

$$\varphi(\boldsymbol{u}) = \frac{1}{(2\pi)^{d/2}} e^{-\frac{1}{2}||\boldsymbol{u}||^2}$$

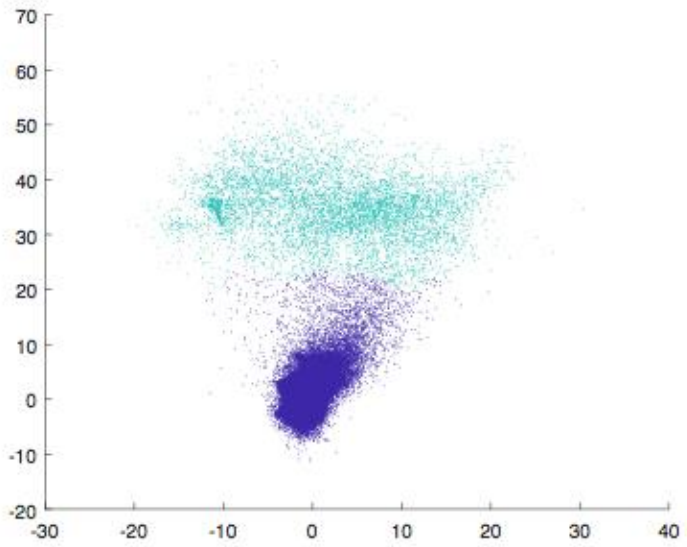




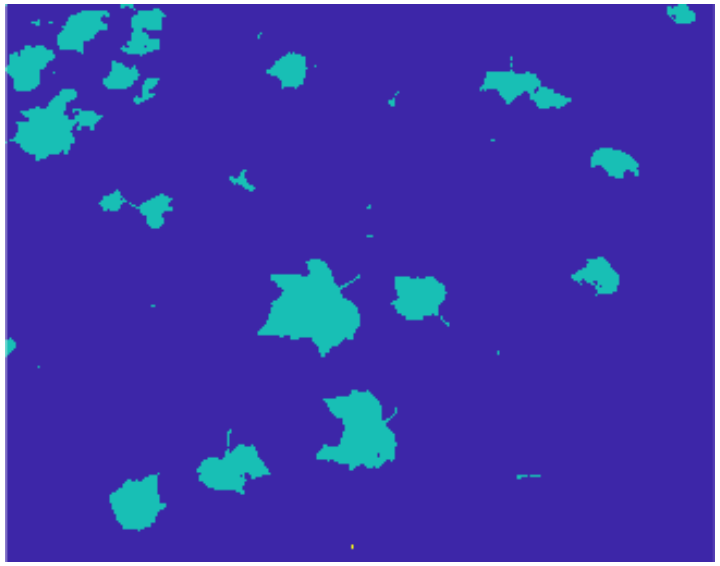
Mean shift segmentation



Gradient ascent (hill climbing)



Labeled point cloud



Segmented image

Mean Shift Segmentation - example

Original image

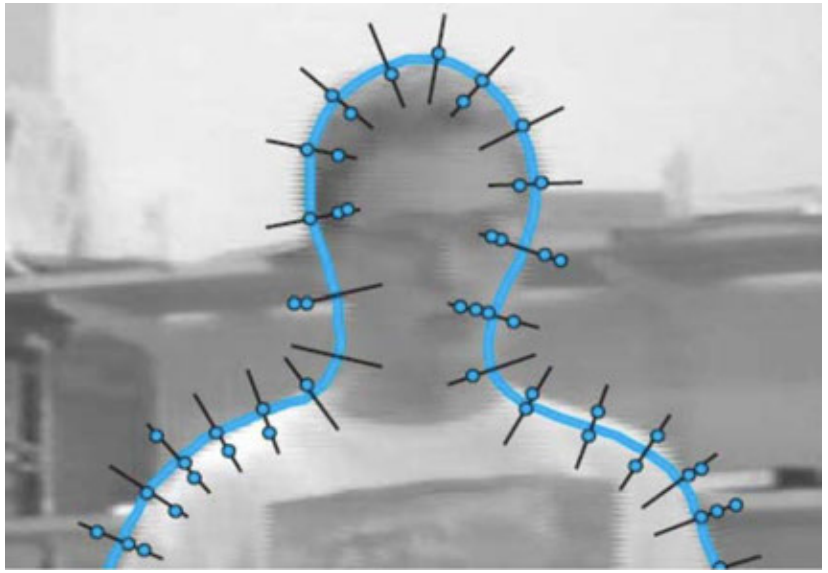
Segmented in five categories

Active contours

Fitting of curves to object boundaries:

- Snakes (fitting of spline curves to strong edges)
- Intelligent scissors (interactive specification of curves clinging to object boundaries)
- Level set techniques (evolving boundaries as the zero set of a characteristic function).

These methods iteratively move towards a final solution.



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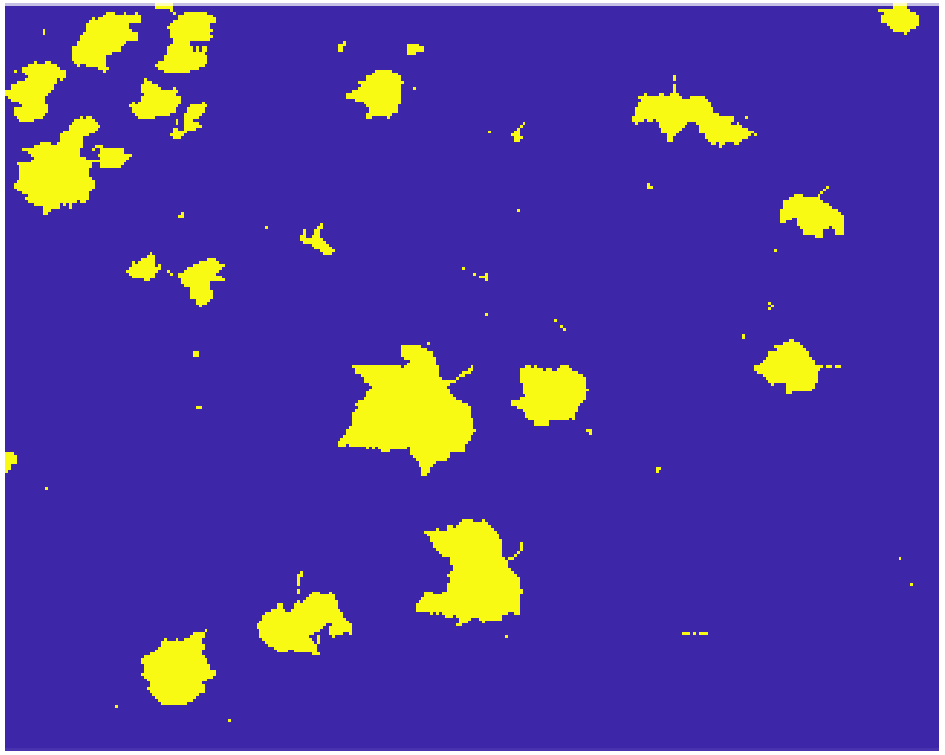
Active Contours - example

Original image



Segmented image

Split and merge methods

Principles:

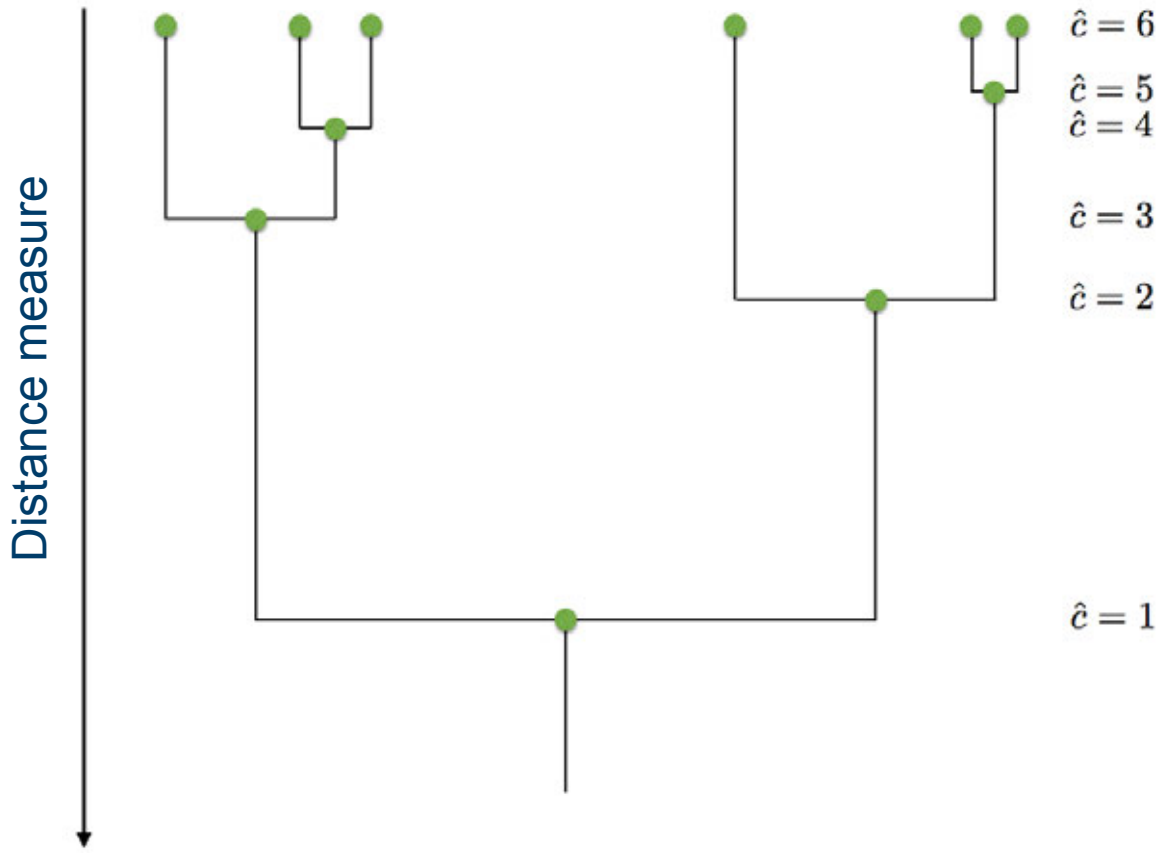
- Region based methods
- Recursive splitting of the image based on region statistics
- Hierarchical merging of pixels and regions
- Combined splitting and merging

Methods:

- Watershed segmentation
- Region splitting (divisive clustering)
- Region merging (agglomerative clustering)
- Graph-based segmentation

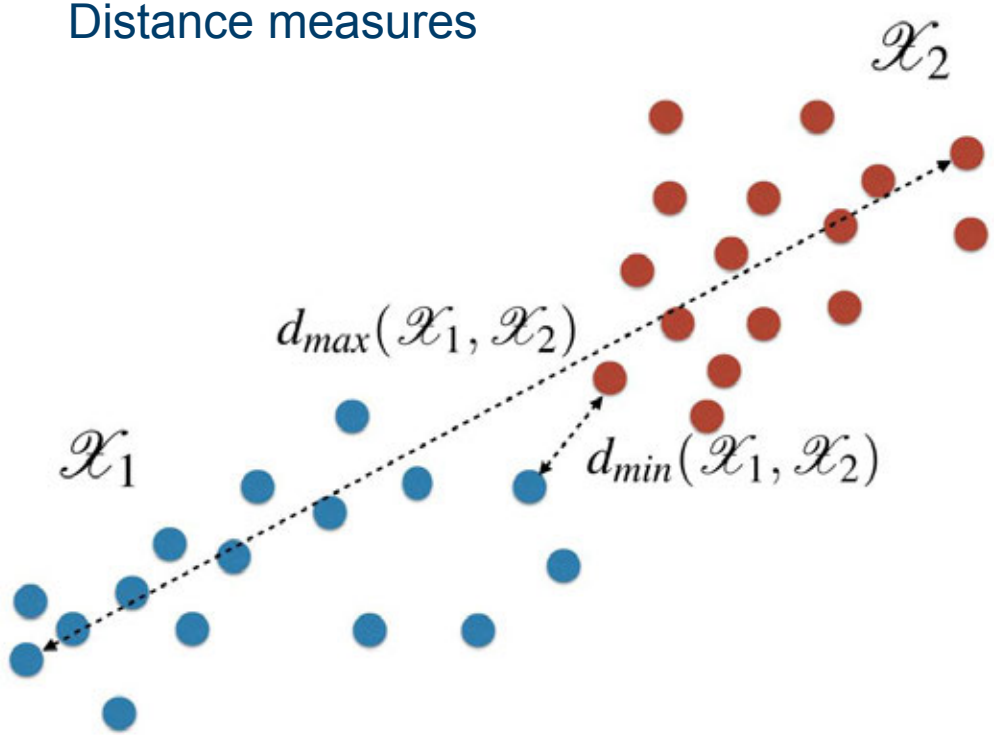
(Szeliski: Computer Vision – Algorithms and Applications)

Agglomerative clustering



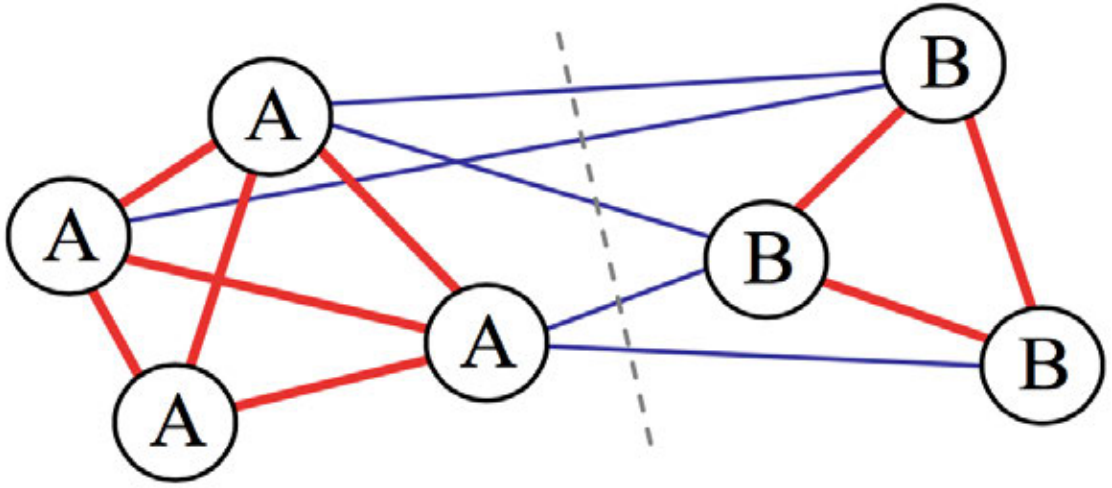
Dendrogram

Distance measures



Normalized cuts

Separation of groups with weak affinities (similarities) between nearby pixels



(Szeliski: Computer Vision – Algorithms and Applications)

Graph cuts

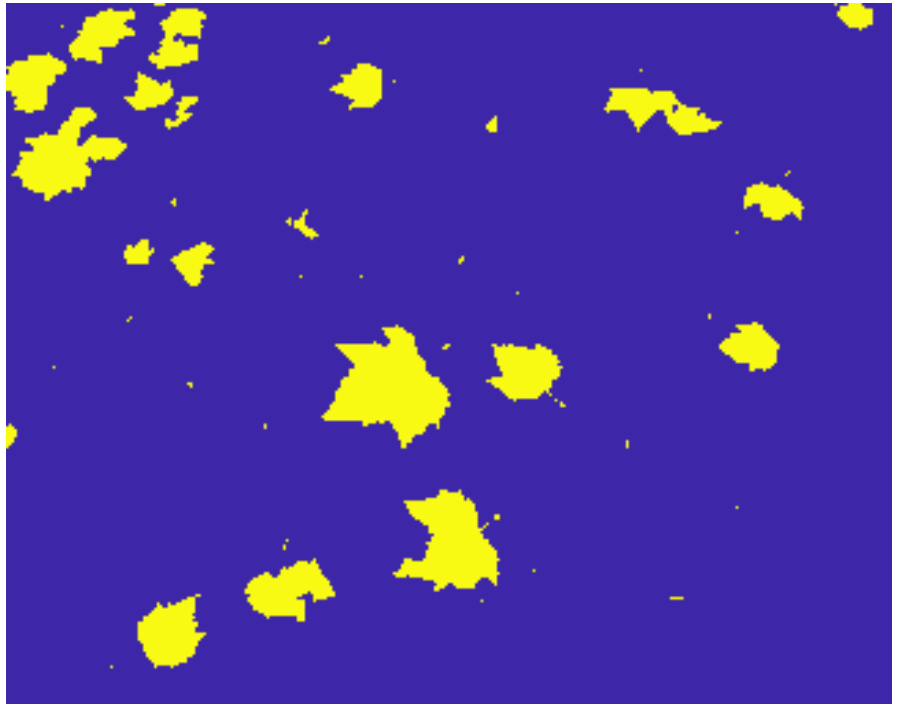
(Szeliski: Computer Vision – Algorithms and Applications)

Energy-based methods for binary segmentation:

- Grouping of pixels with similar statistics
- Minimization of pixel-based energy function
- Region-based and boundary-based energy terms
- Image represented as a graph
- Cutting of weak edges, i.e. low similarity between corresponding pixels.

Graph cuts - example

Original image



Segmented image

Morphological operations

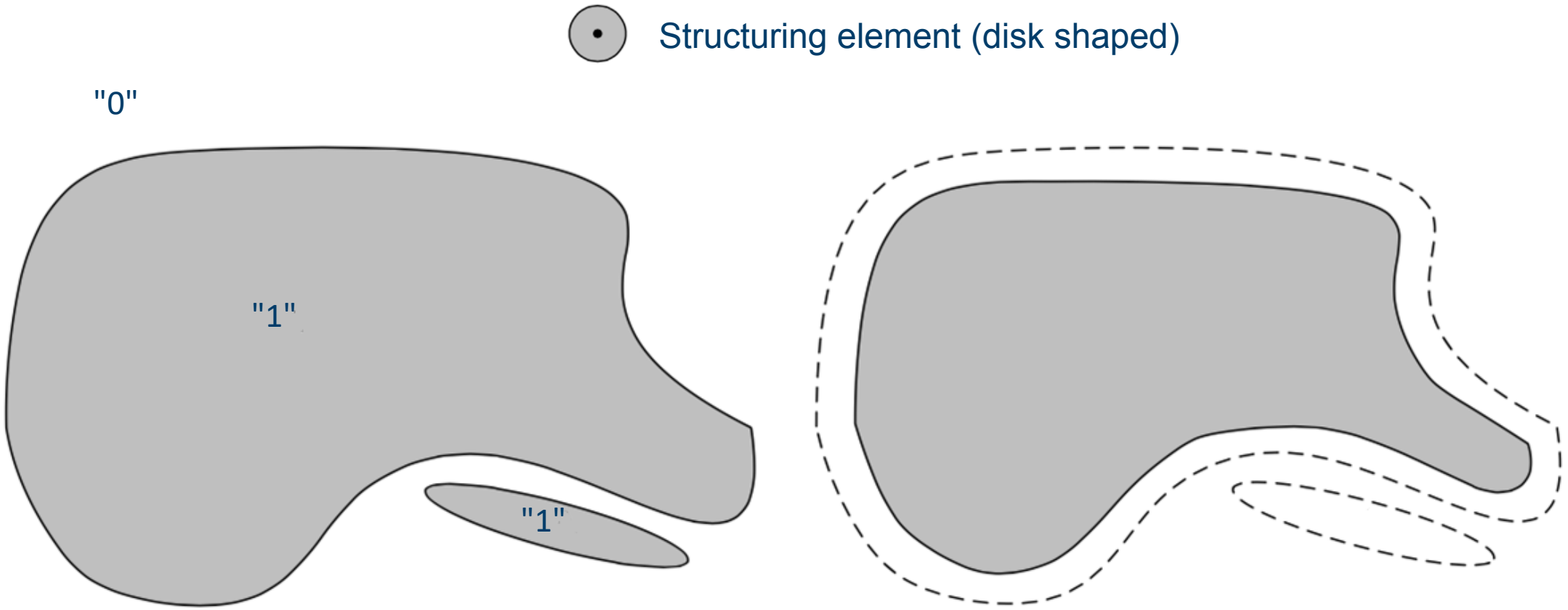
- Non-linear filtering
- Typically used to clean up binary images
- Erosion: replace pixel value with minimum in local neighborhood
- Dilation: replace pixel value with maximum in local neighborhood
- Structuring element used to define the local neighborhood:

0	1	0
1	1	1
0	1	0

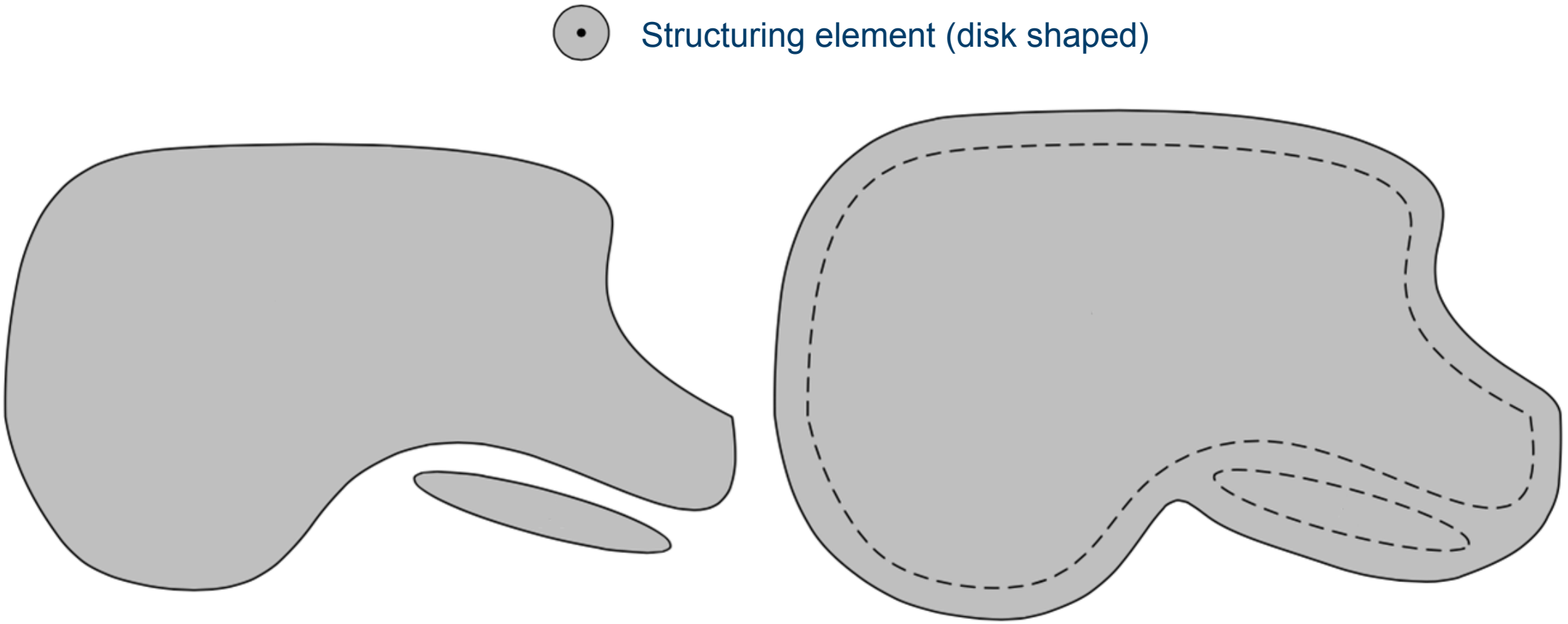
(Renato Keshet 2008)

A shape (in blue) and its morphological dilation (in green) and erosion (in yellow) by a diamond-shaped structuring element.

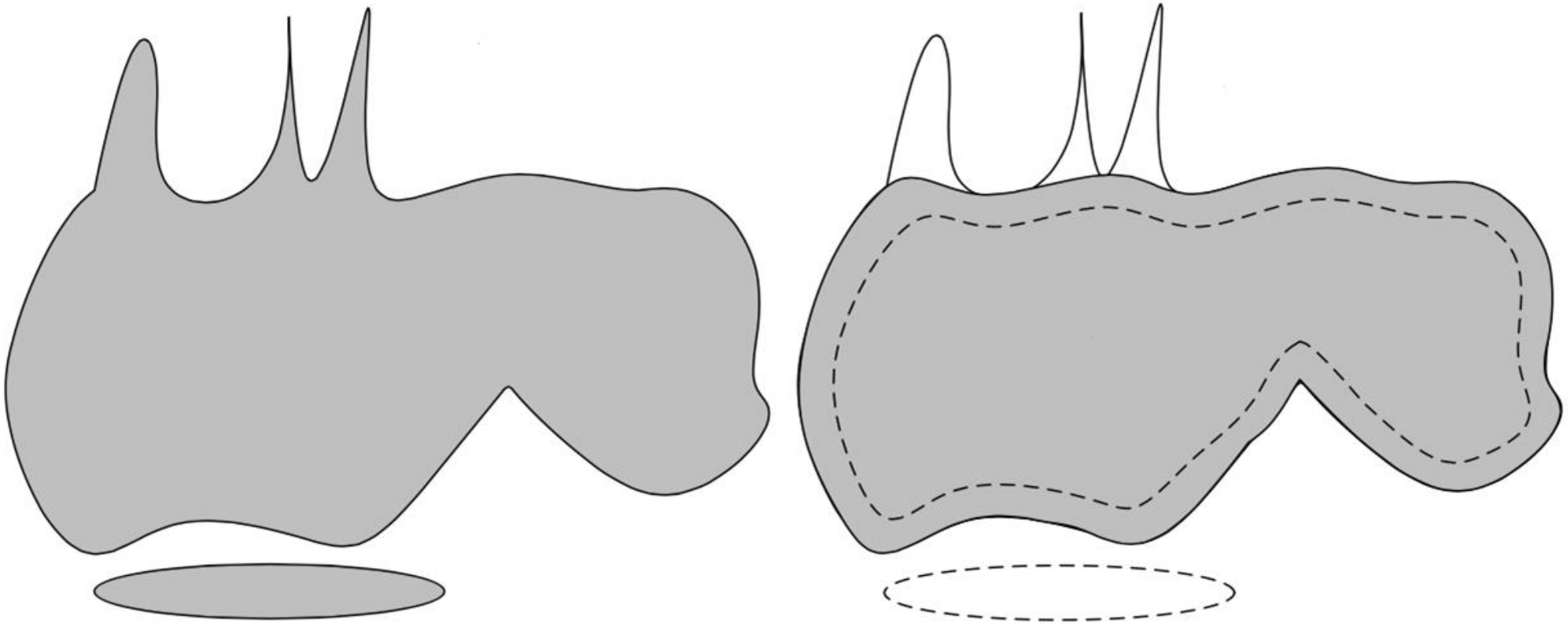
Morphological operations - Erosion



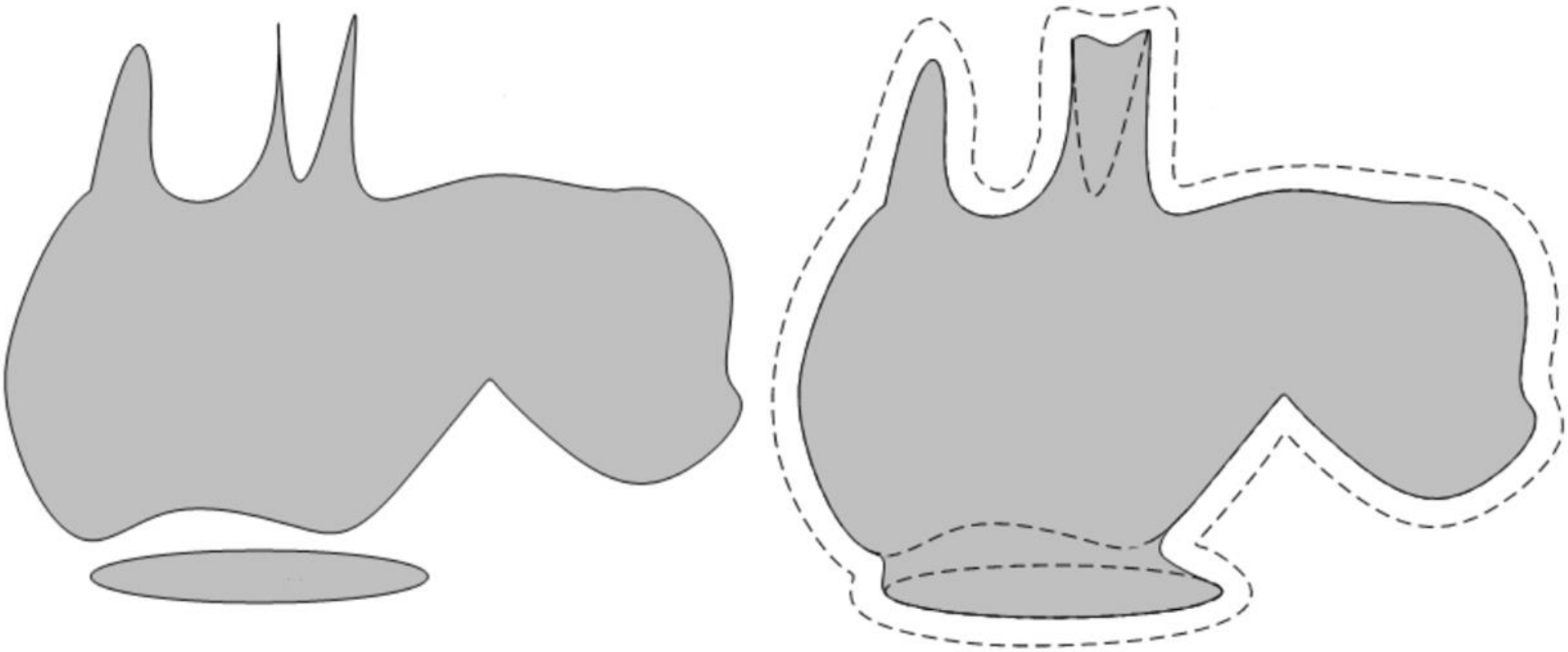
Morphological operations - Dilation



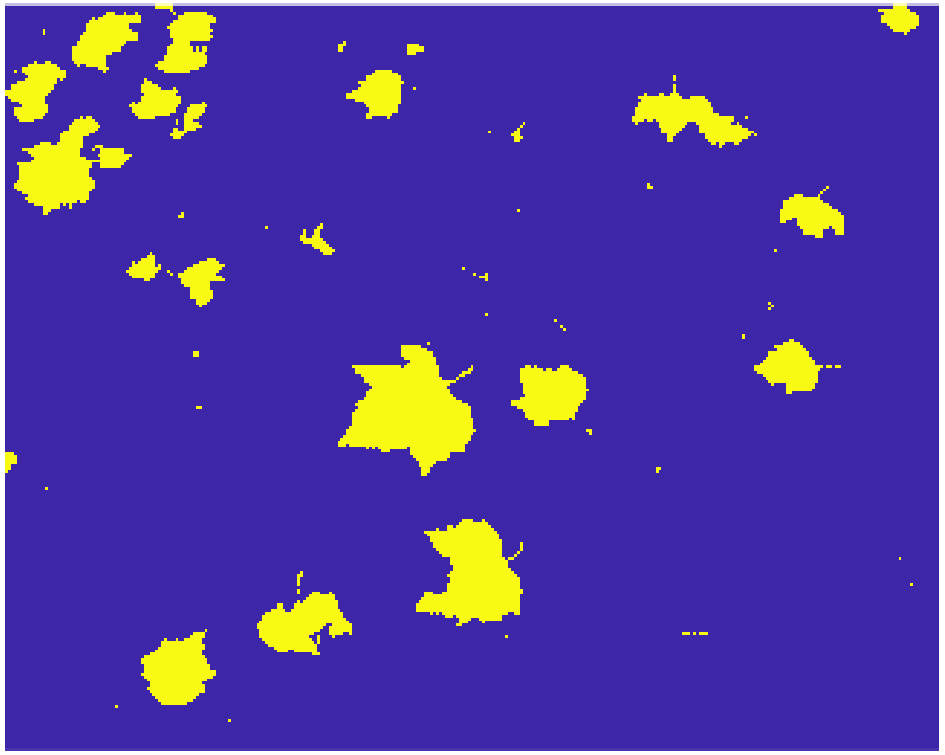
Opening = Erosion + Dilation



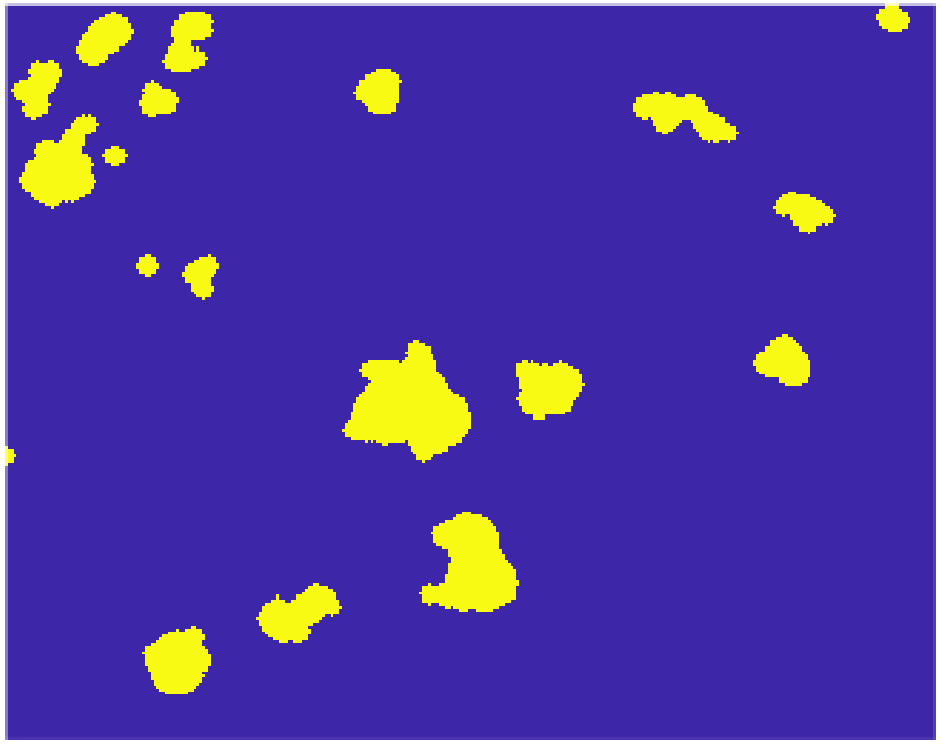
Closing = Dilation + Erosion



Opening - example

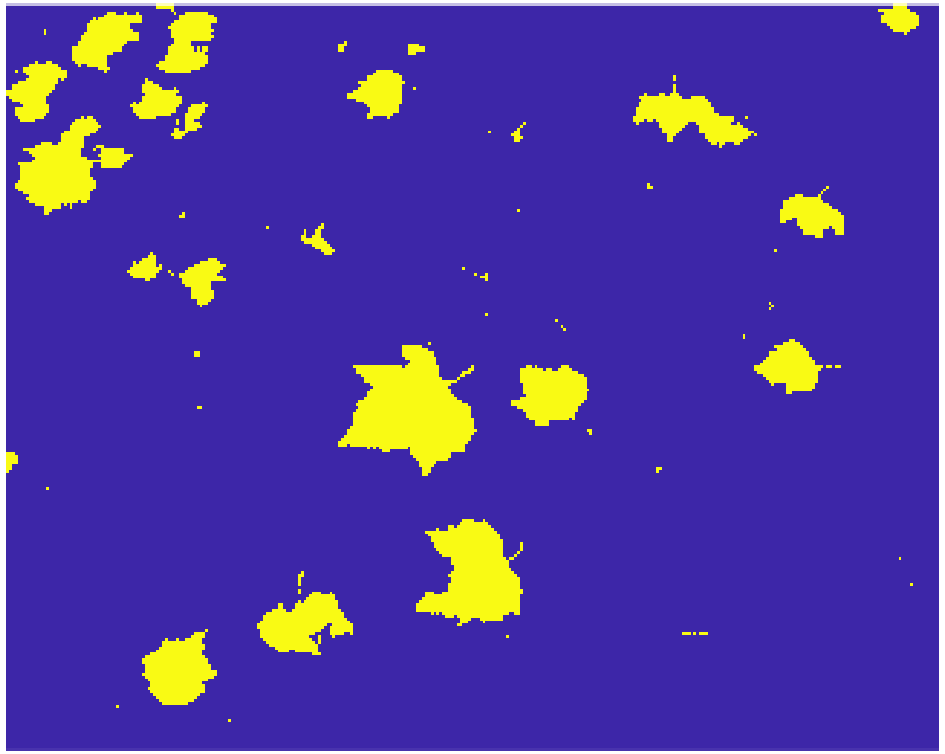


Segmented image (Active Contours)

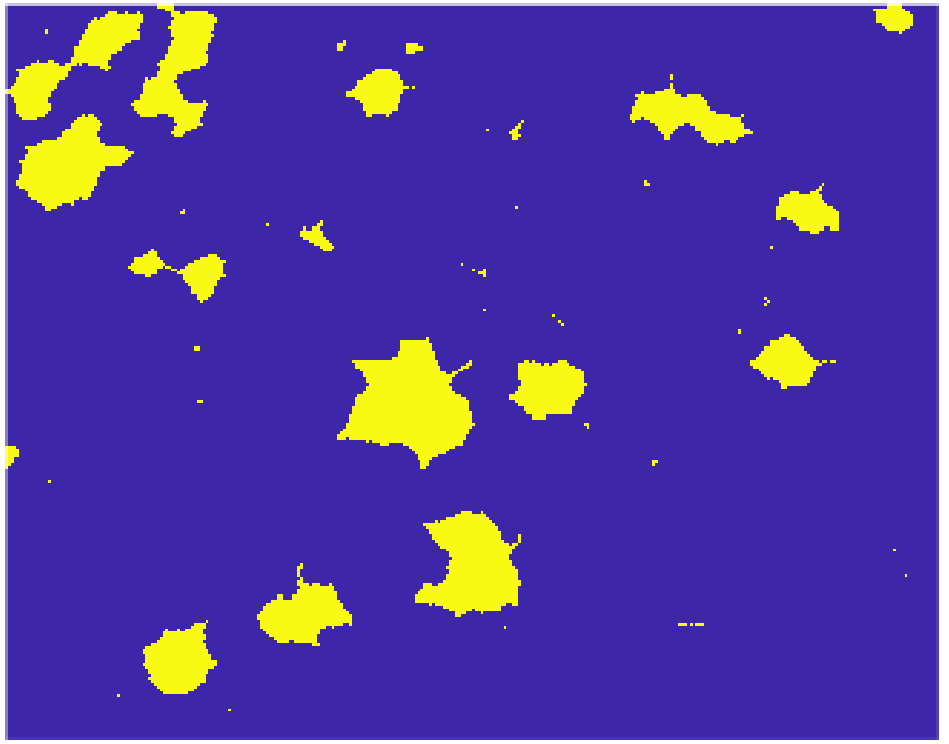


Result of opening

Closing - example



Segmented image



Result of closing

Summary

Image Segmentation:

- Thresholding techniques
- Clustering methods for segmentation
- Morphological operations

More information:

Szeliski 3.3.2 and 5.1 - 5.5