Image Analysis
Lecture 9.1 - Segmentation

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Segmentation

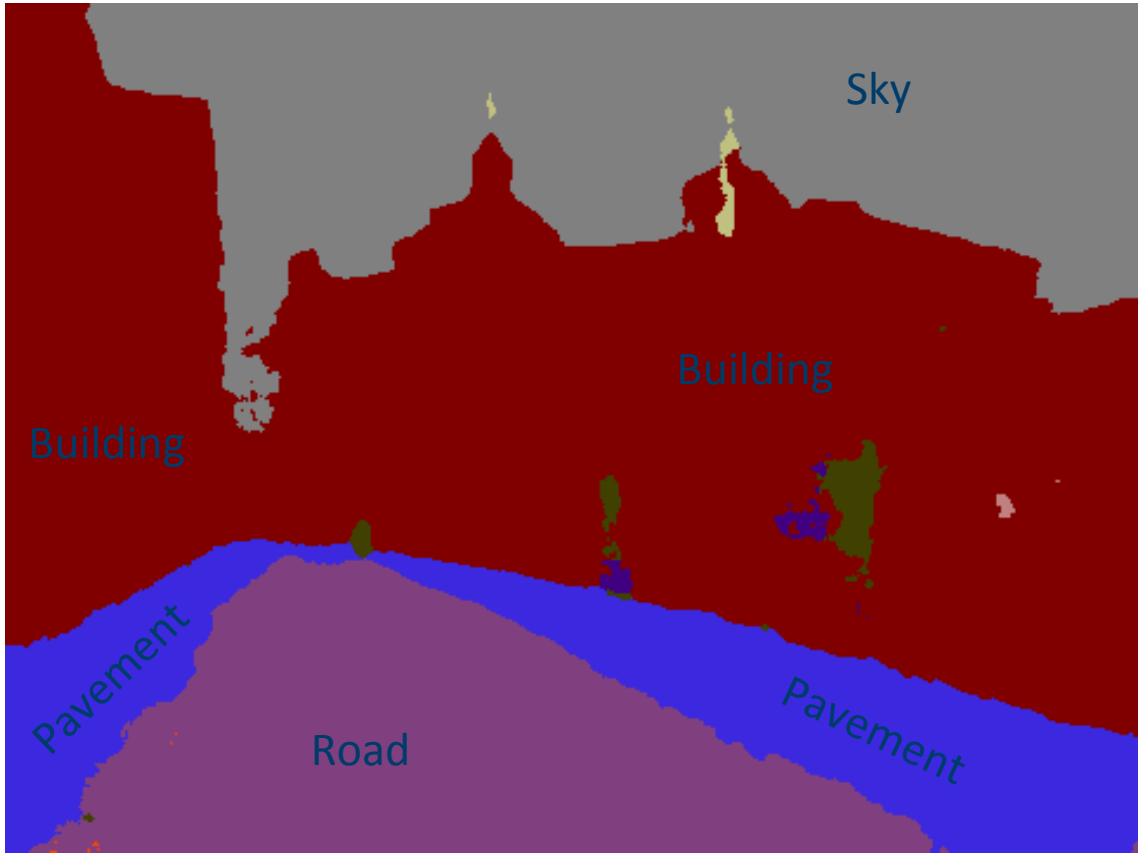
- Image segmentation is the process of partitioning a digital image into multiple parts
- The goal is to divide the image into meaningful and/or perceptually uniform regions
- Segmentation is typically used to locate objects and boundaries of physical entities in the scene
- The segmentation process utilizes available image information (graylevel, colour, texture, pixel position, …).

Segmentation into three categories

Original image

Segmented image

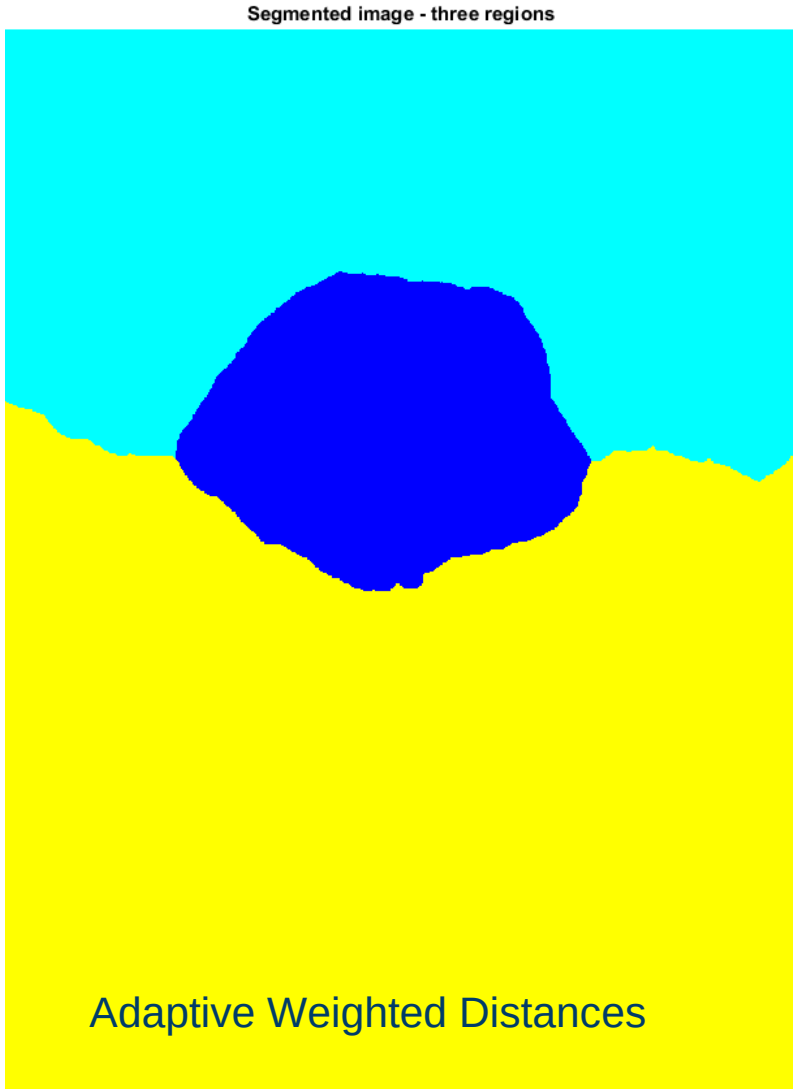
Semantic Segmentation (meaningful regions)



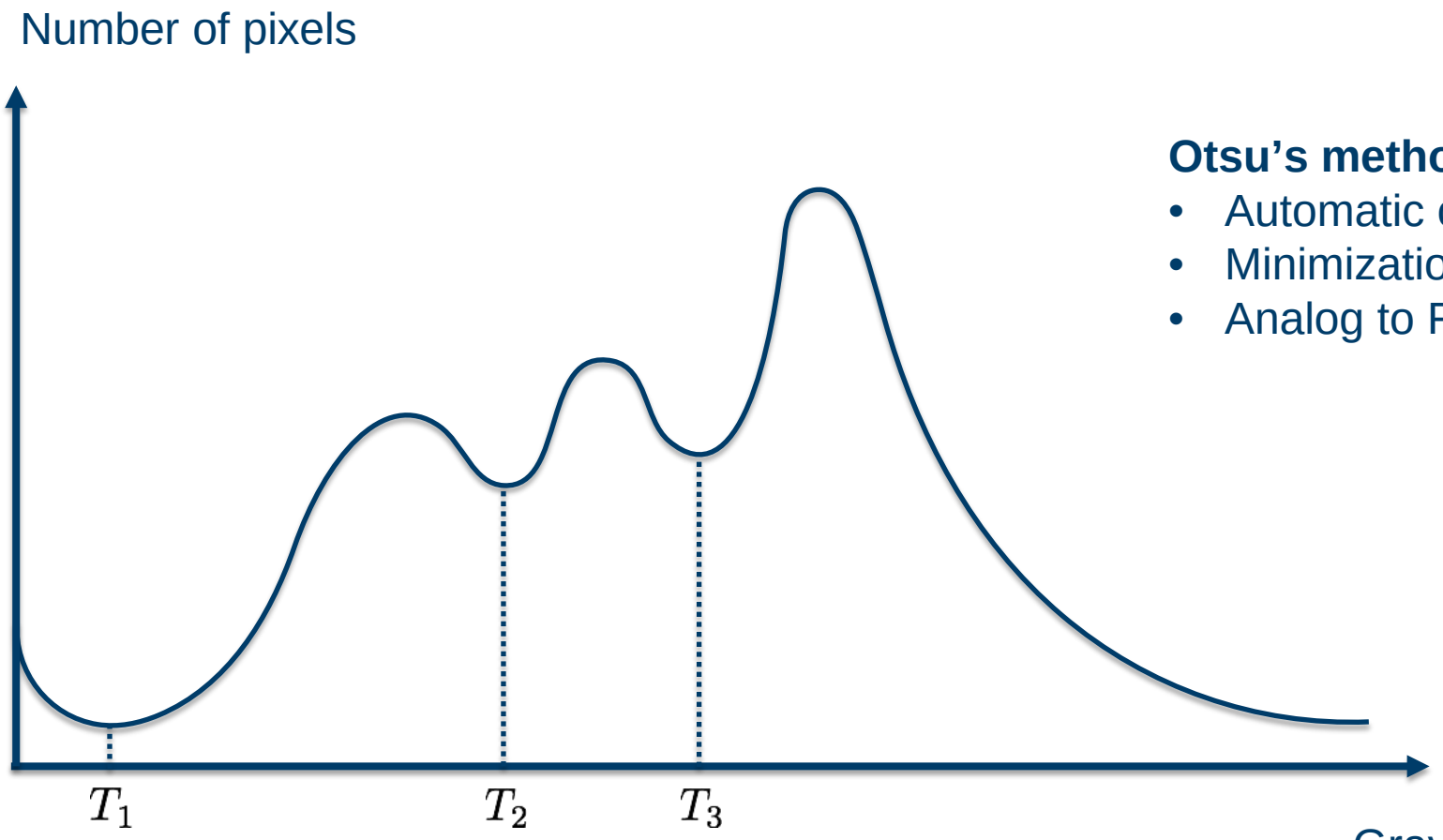
Segmentation methods

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

Colour Segmentation - Example



Segmentation by thresholding



Otsu's method:

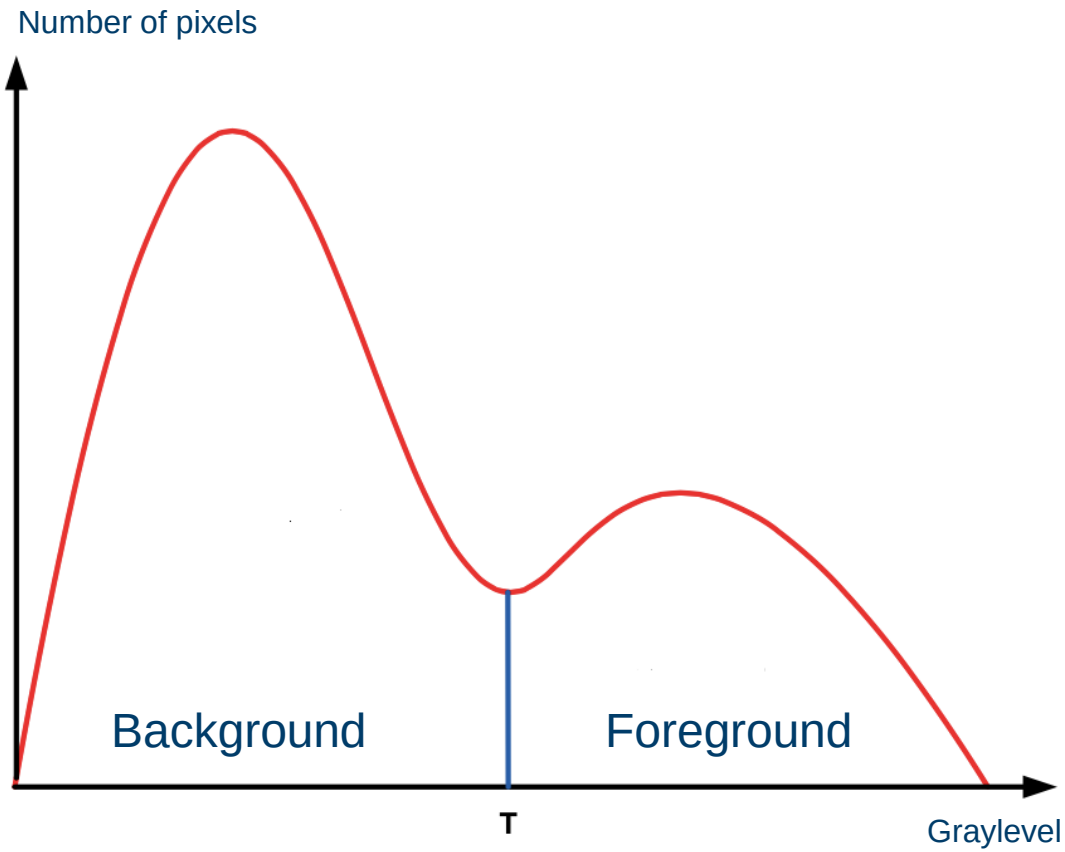
- Automatic clustering-based thresholding
- Minimization of intra-class variance
- Analog to Fisher's Discriminant Analysis

Thresholding with Otsu's method

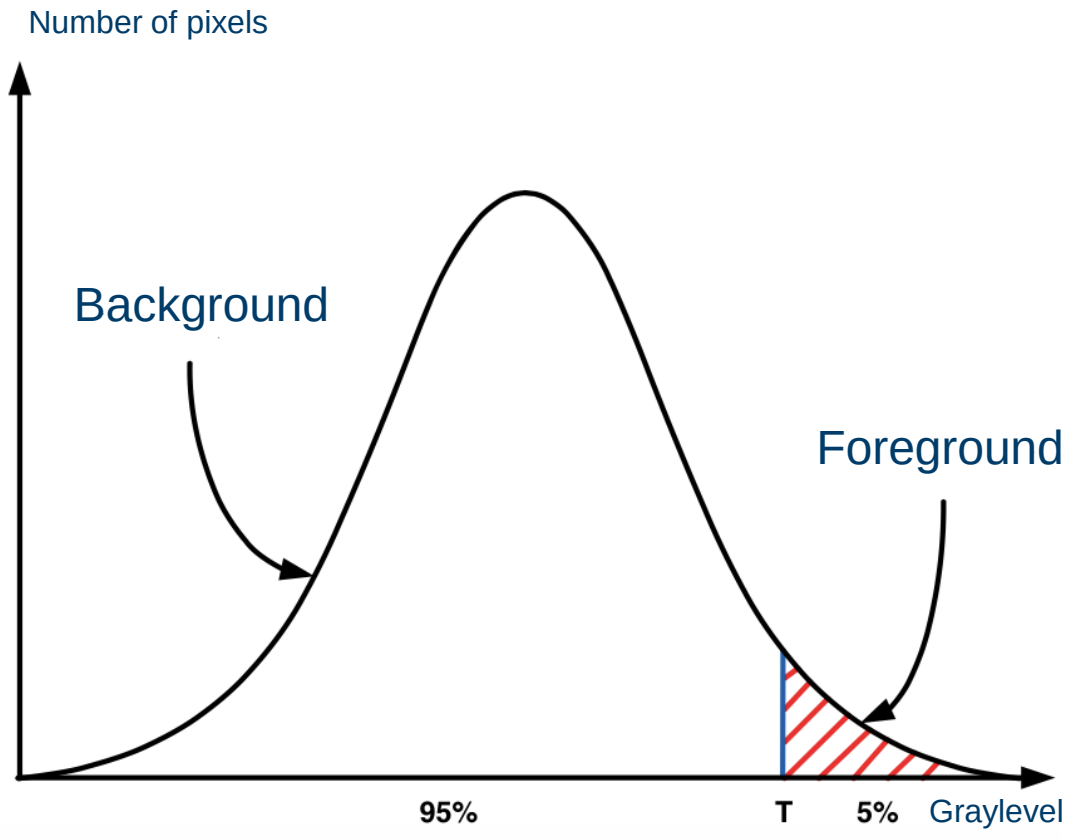
3 thresholds

4 classes

Binary segmentation – foreground vs. background

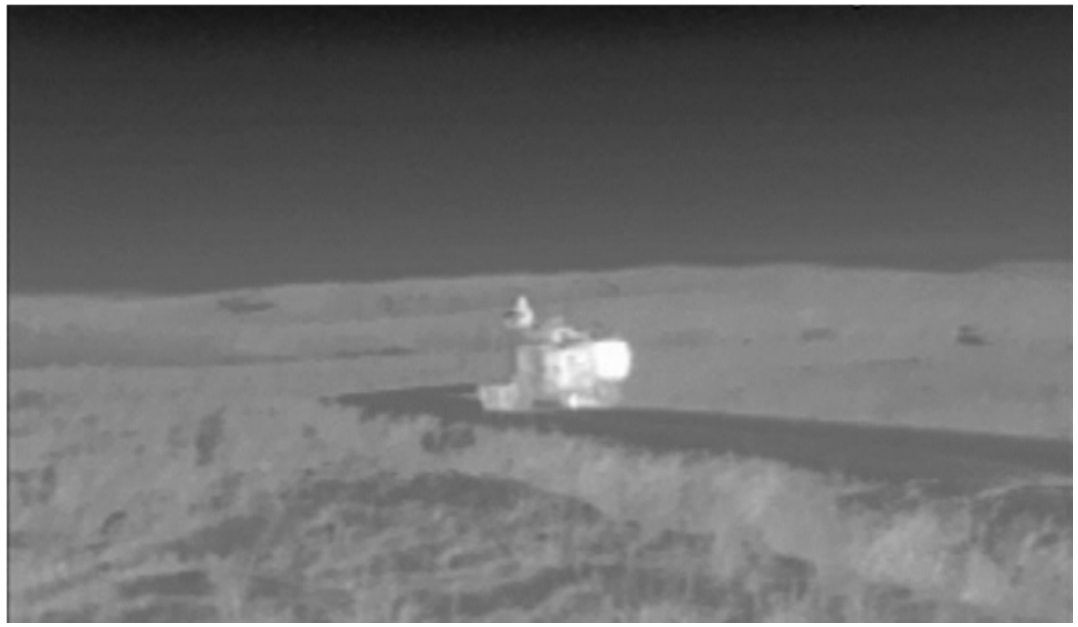


Threshold between two populations

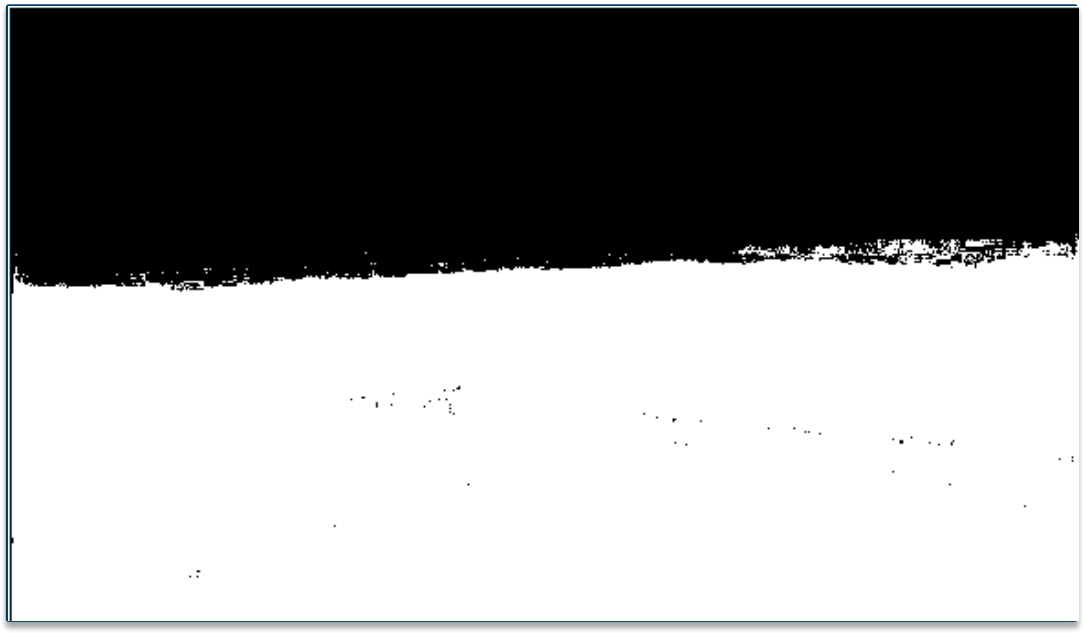


Threshold at given percentile

Binary thresholding – Object detection



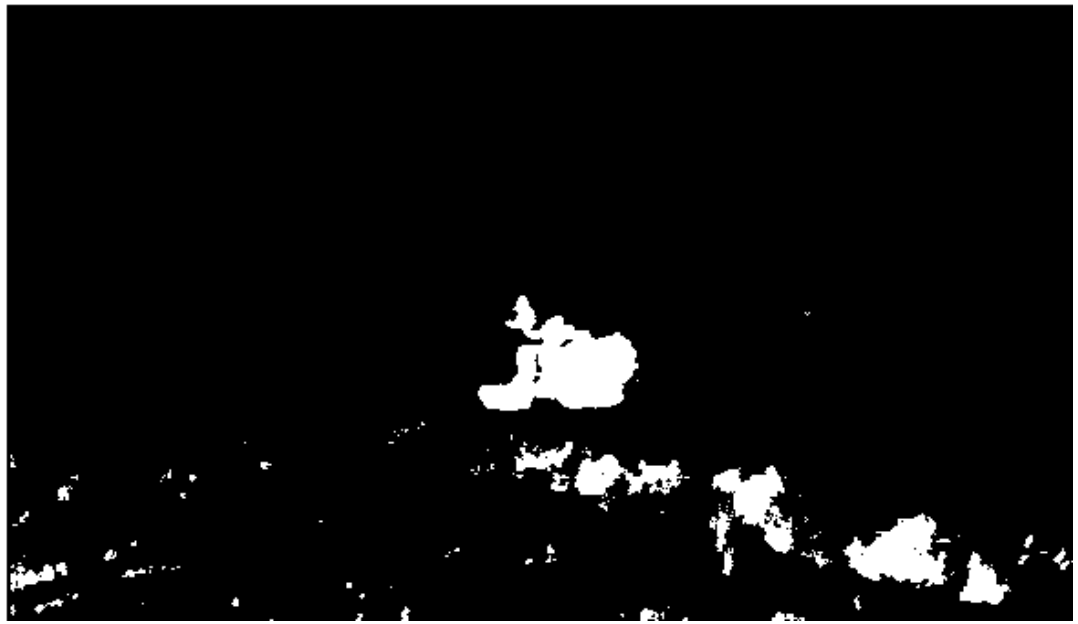
Thermal image



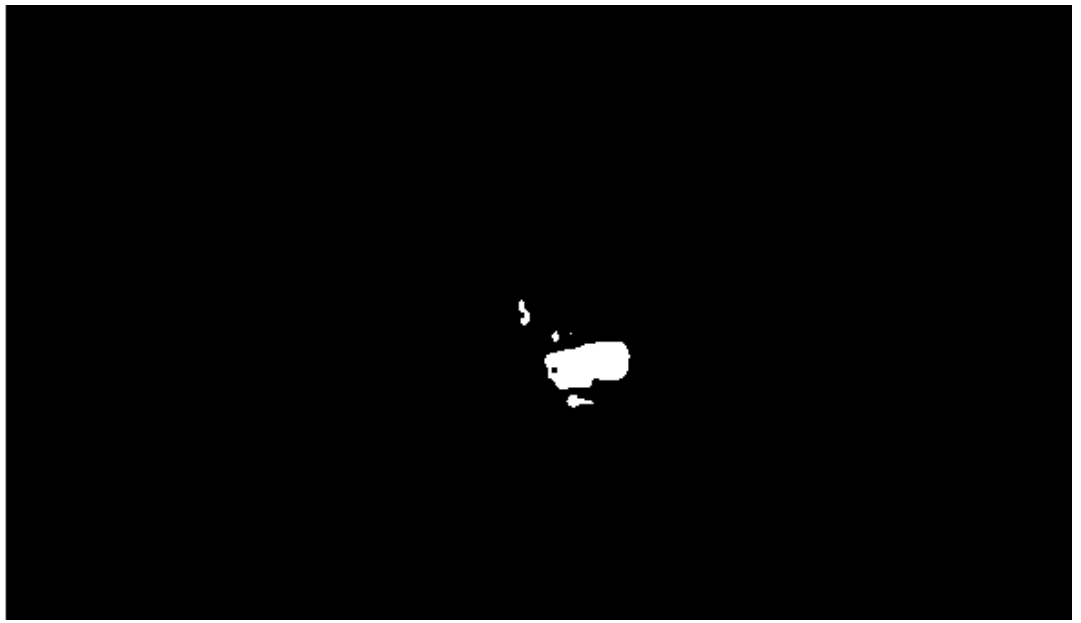
Thresholded image (Otsu's method)

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

Manual thresholding

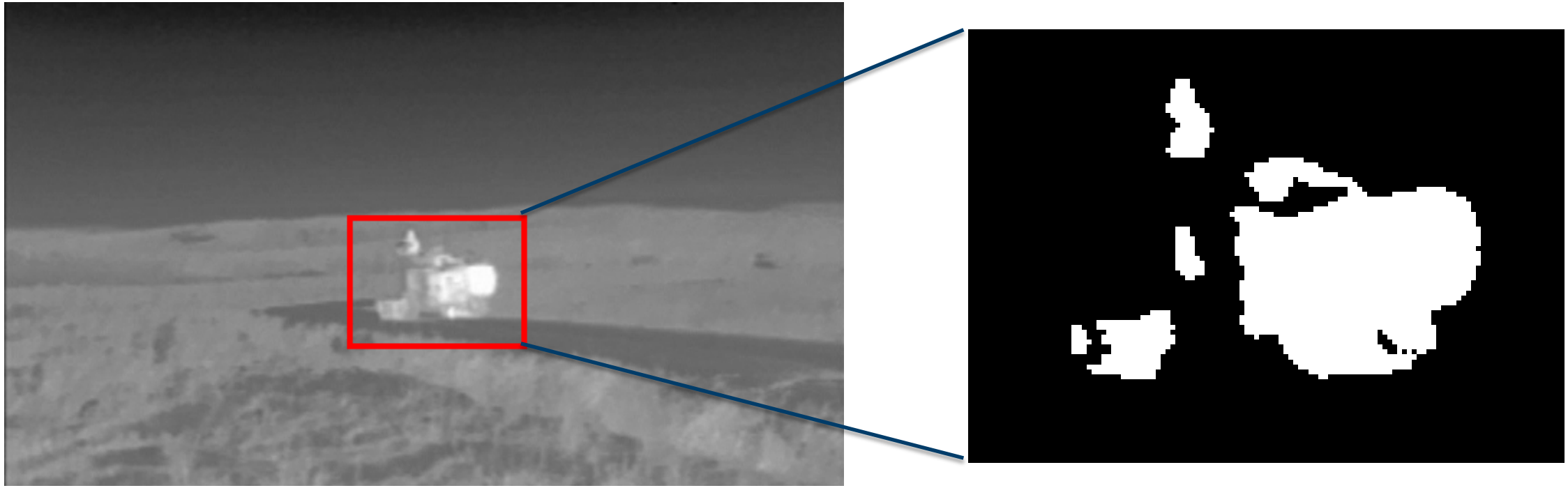


Medium threshold



High threshold

Local thresholding



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

Local thresholding using edge information

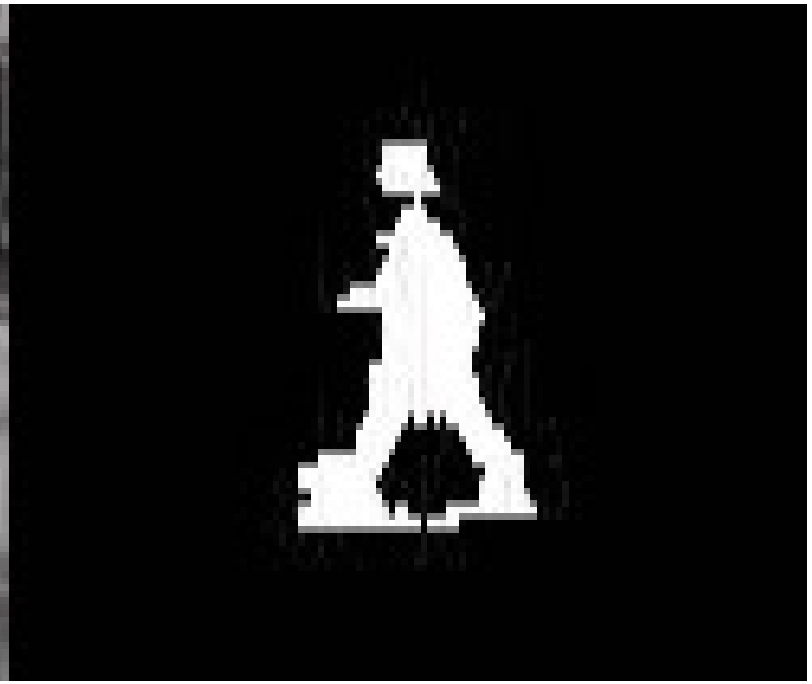
Edge image (Canny edge detector applied to selected window)

Threshold = average graylevel along edges

Thresholded window

Object detection in video sequences (visible light)

Daylight video frame

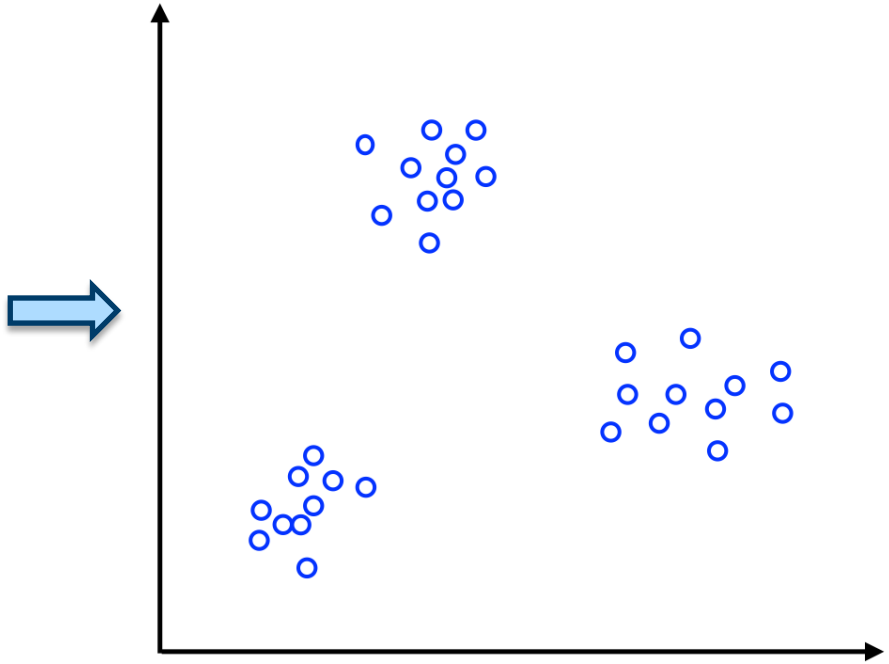


Thresholded difference image

- 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

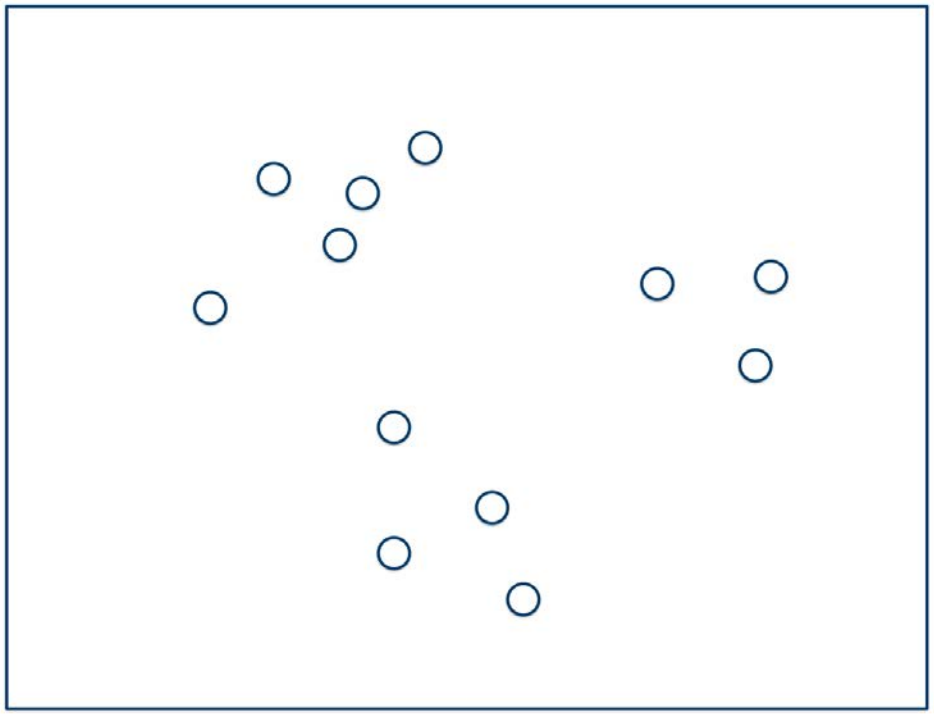


Pixels represented as points in feature space

Segmented image

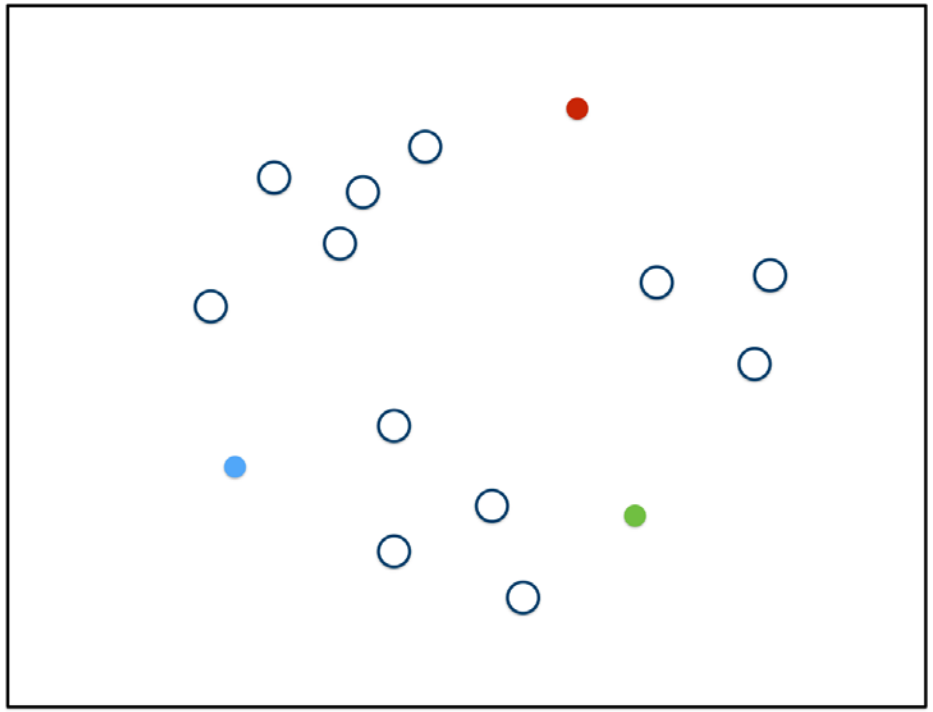
K-means (parametric) clustering

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.

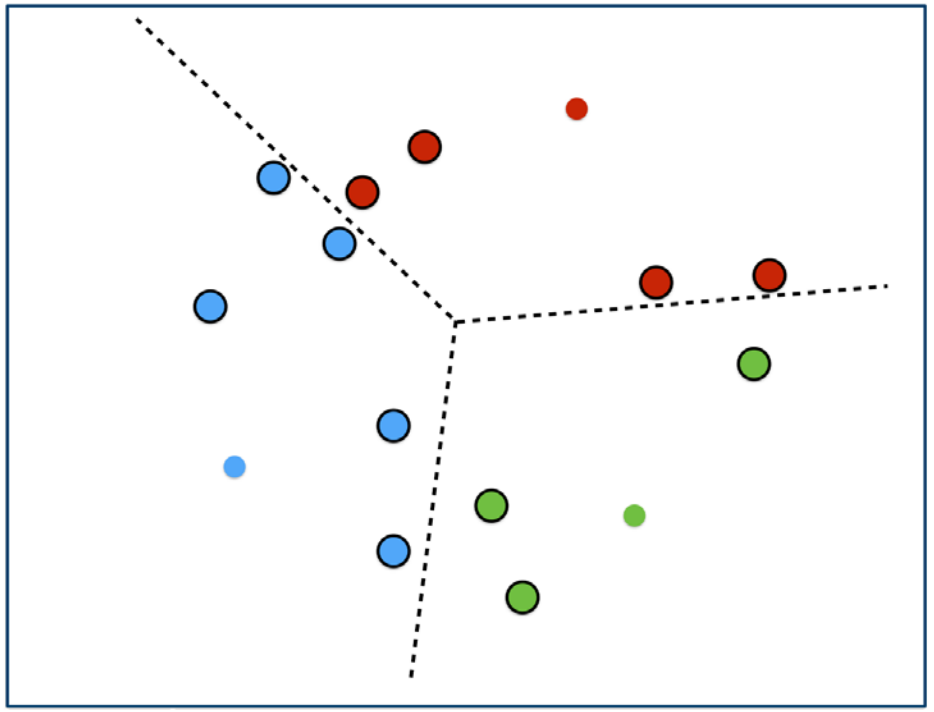


Unlabeled dataset

K-means clustering

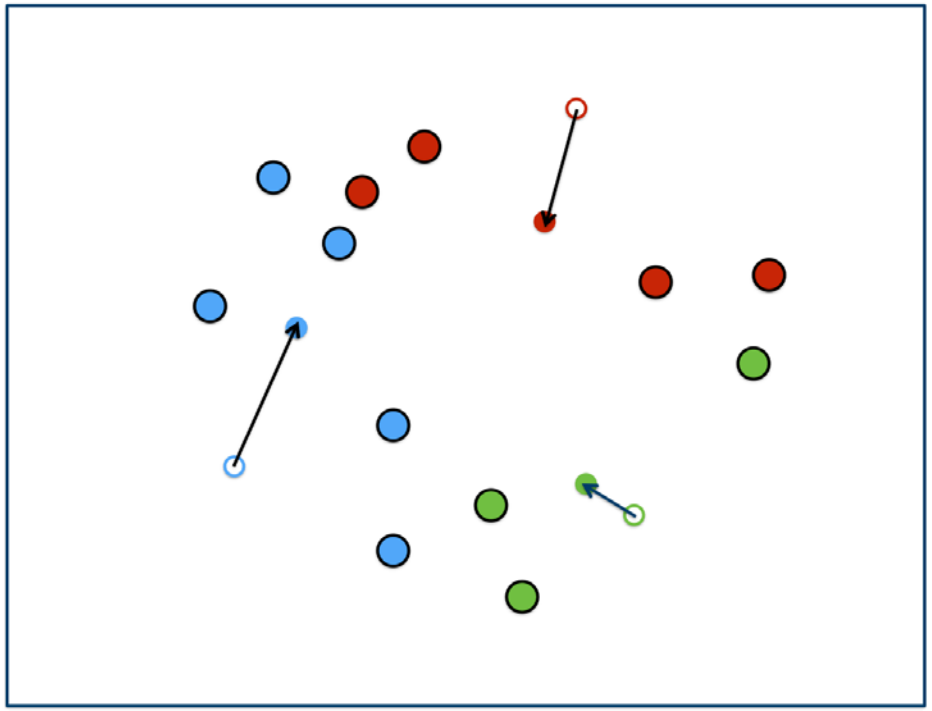


Initial cluster centers (red, green and blue points)

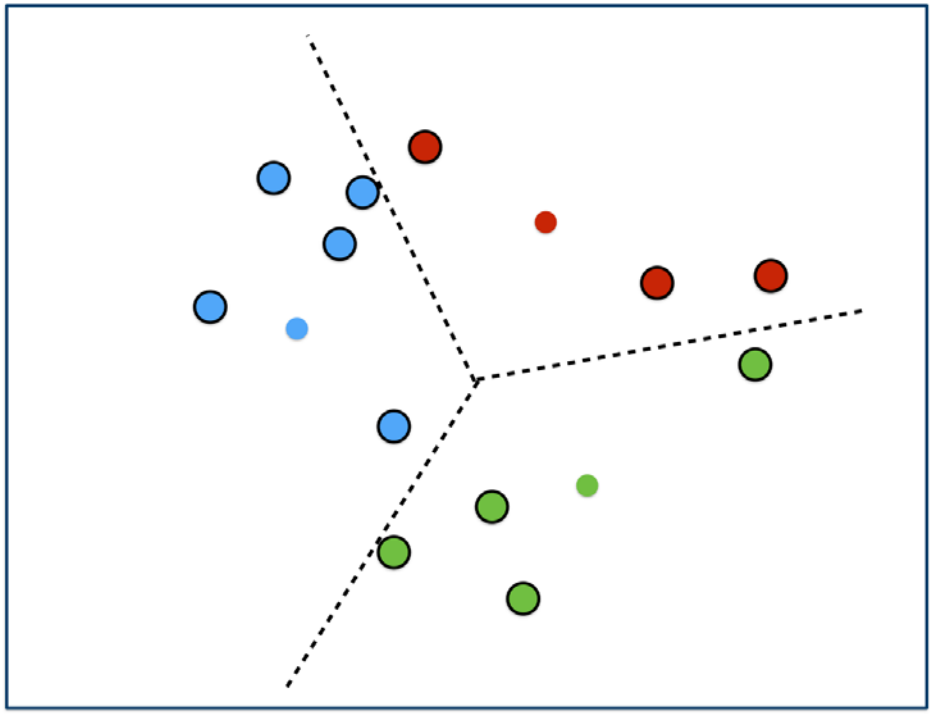


Samples assigned to nearest cluster center

K-means clustering

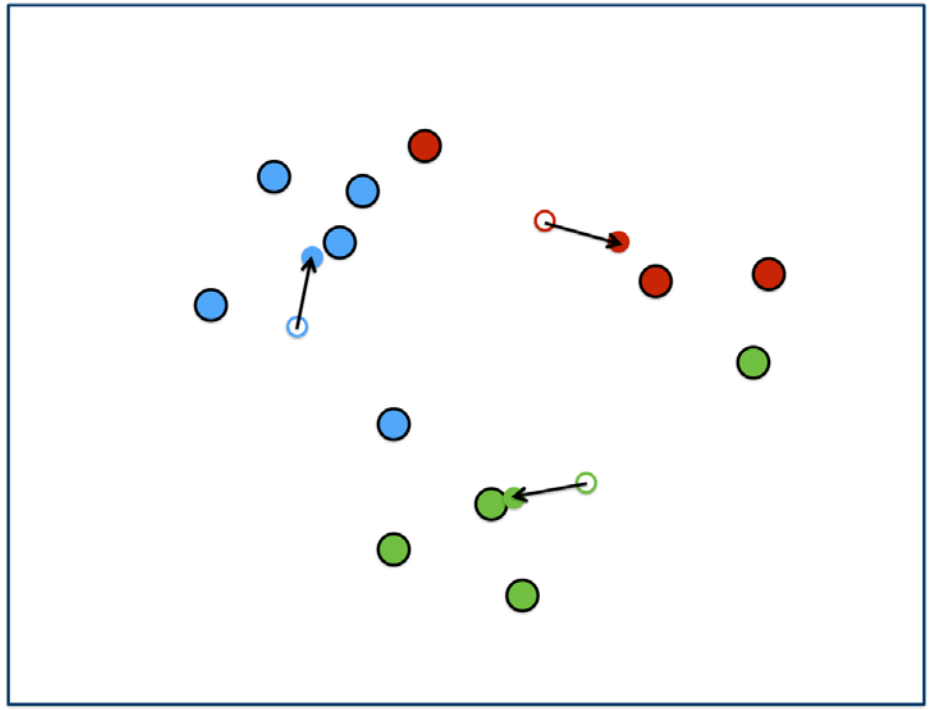


Re-computed cluster centers

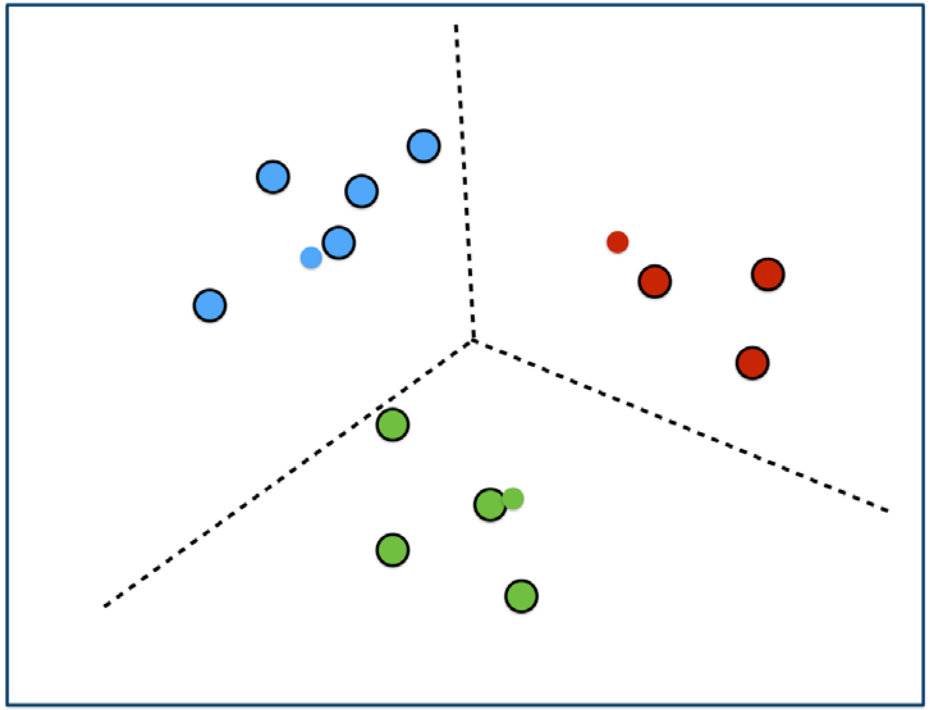


Samples re-assigned to new cluster centers

K-means clustering



Re-computed cluster centers



Final clustering

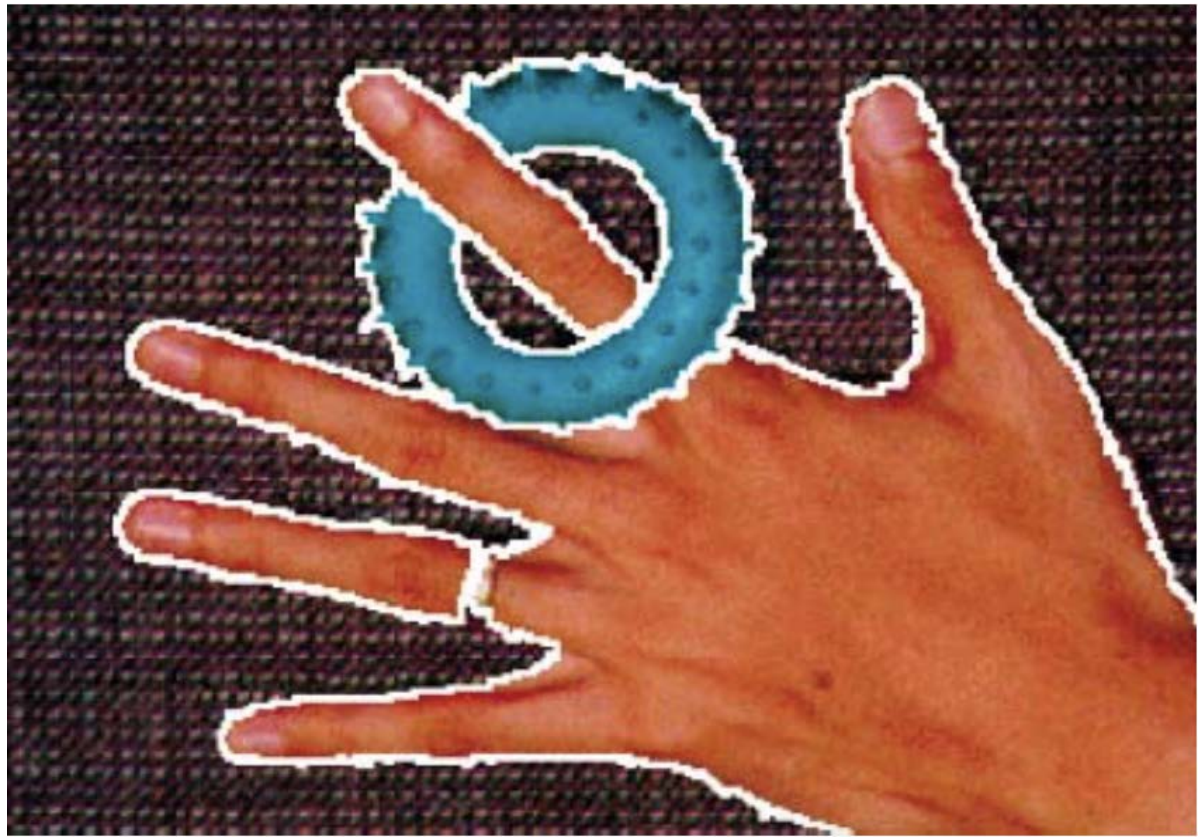
K-means clustering using colour

Original image

Clustered image – 10 clusters

Mean shift (non-parametric) segmentation

- Segmentation by clustering of the pixels in the image (colour and position)
- Non-parametric method (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.



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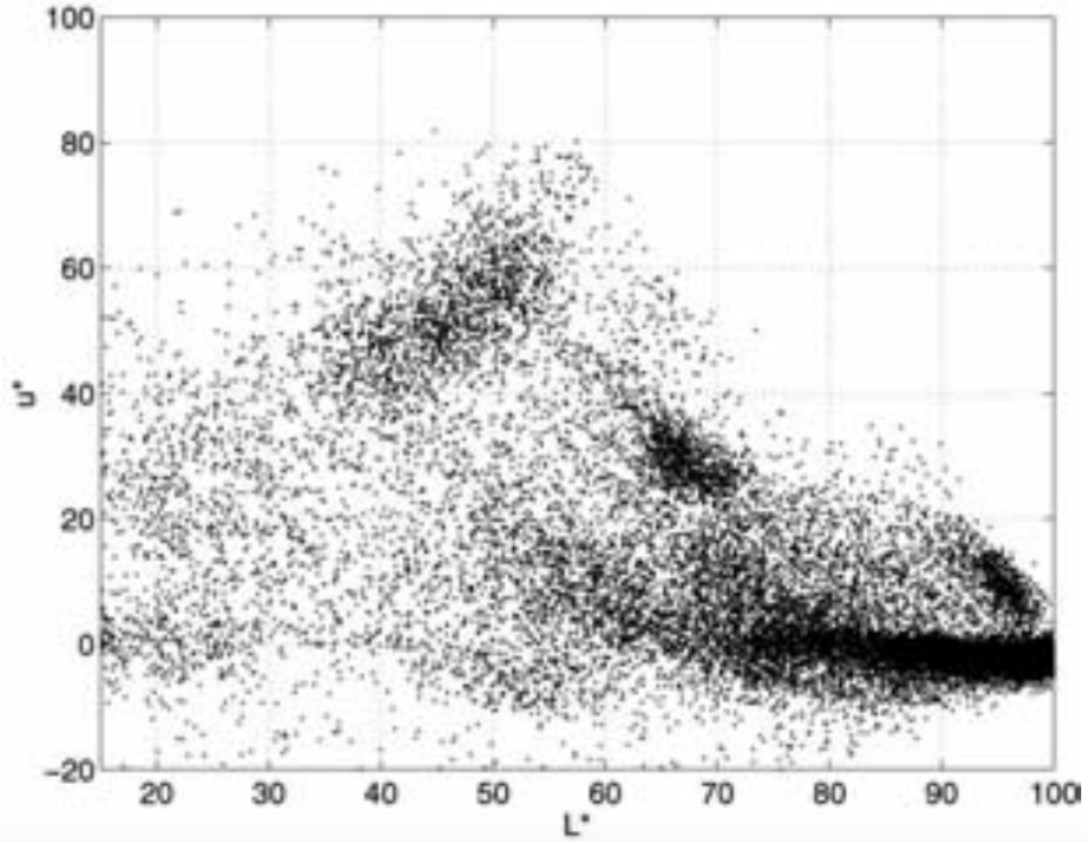
Mean shift segmentation



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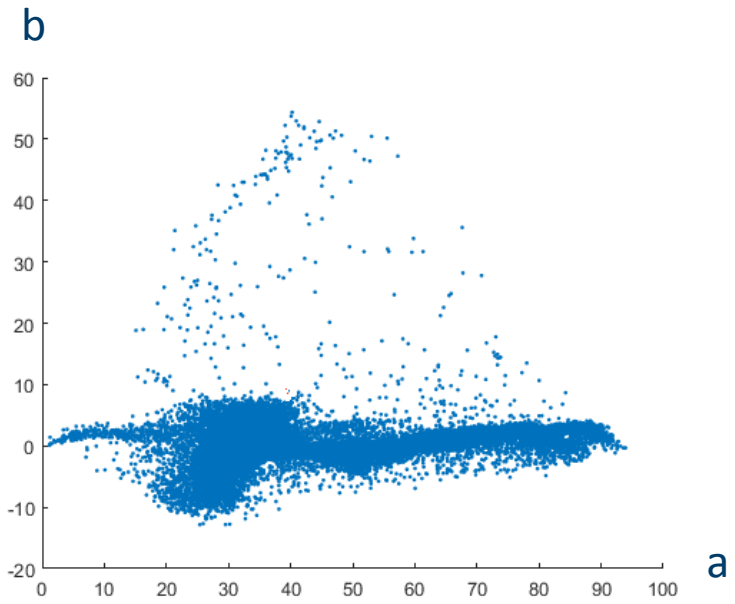
Parzen method

Original image



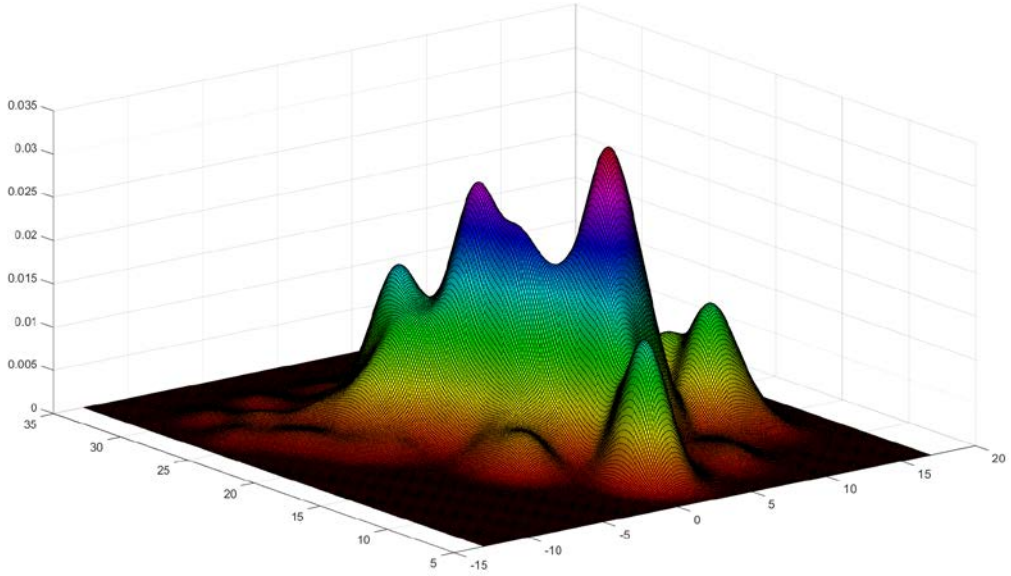
Plot of a vs. b for each pixel in Lab transformed image

Density estimate (smoothing of point cloud):

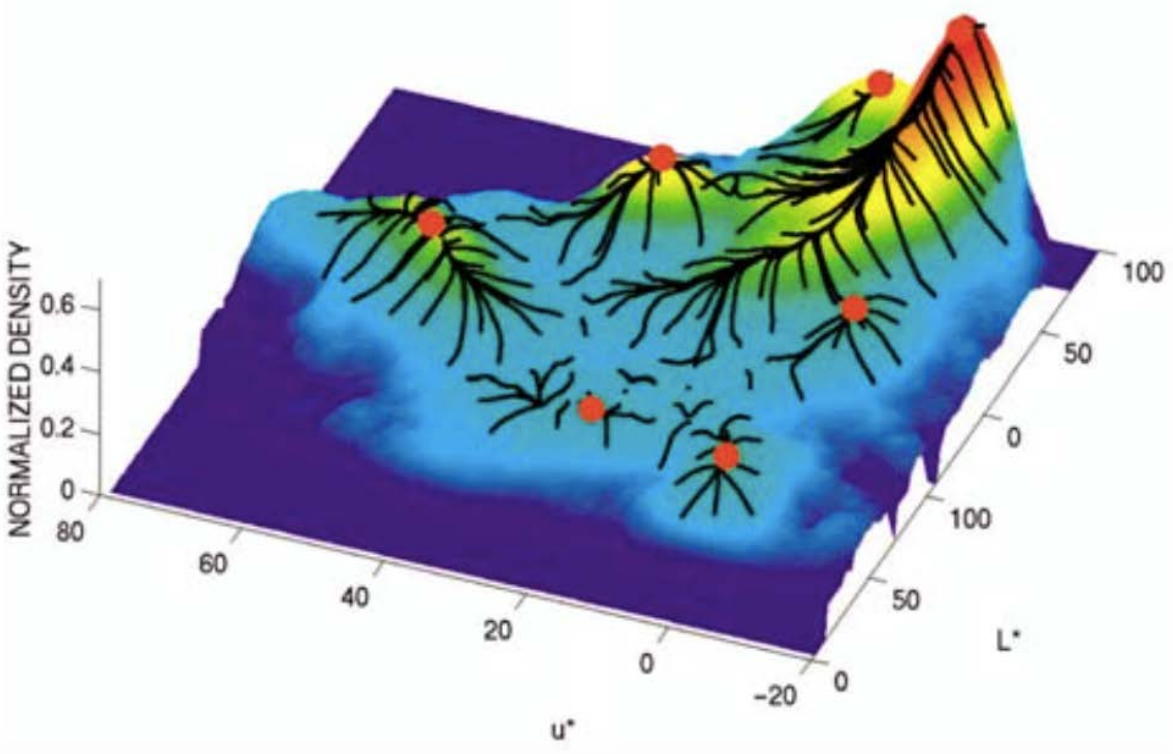
$$f(\boldsymbol{x}) = \frac{1}{nh^d} \sum_{i=1}^{n} \varphi\left(\frac{\boldsymbol{x} - \boldsymbol{x}_i}{h}\right)$$

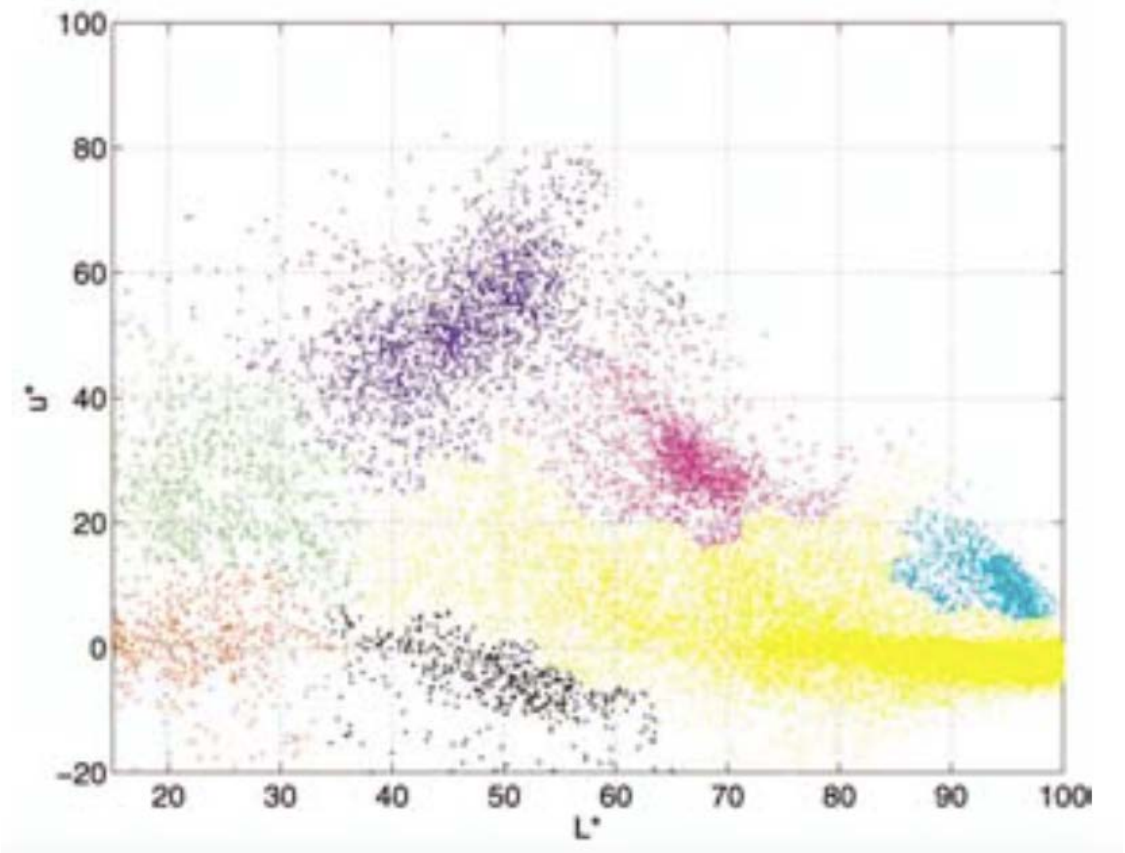
Window (kernel) function: $\varphi(\boldsymbol{u})$

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



Mean shift segmentation





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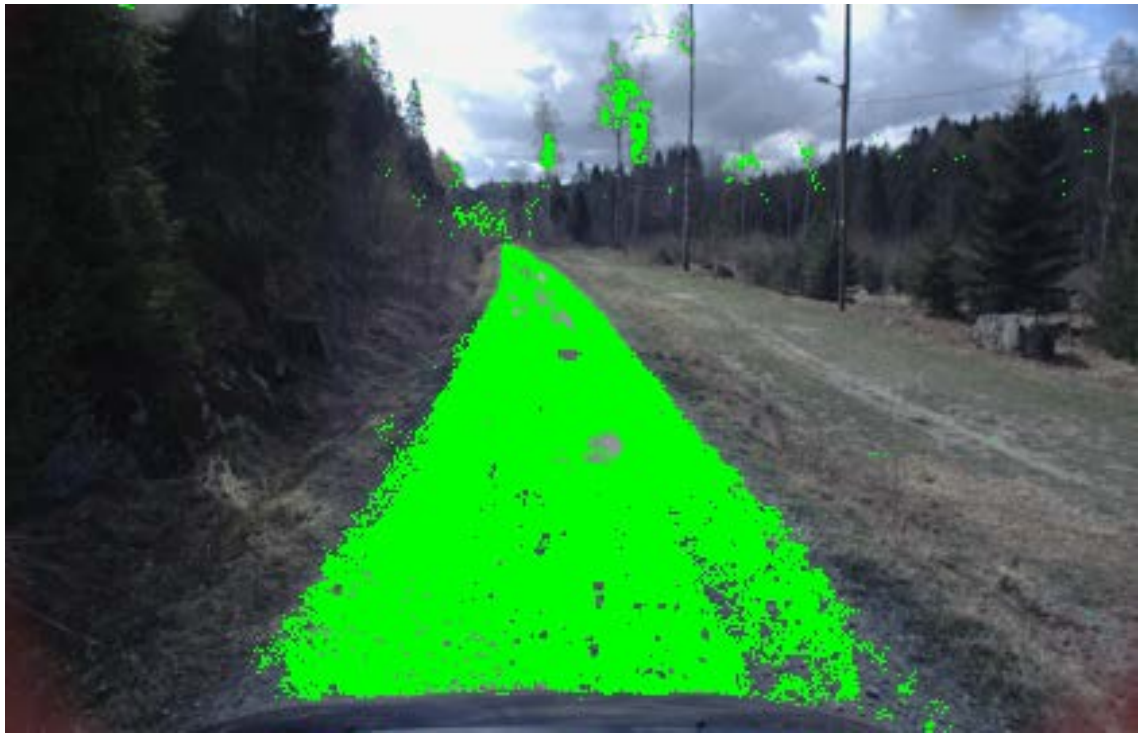
Mean Shift Segmentation - example

Original image

Segmented in five categories

Road segmentation for autonomous vehicles

Image data (graylevel, colour, local texture) from trapezoidal region is used to build a Gaussian model of the road surface.



Pixels with sufficiently high probability density with respect to the model are assigned to the road class (marked in green).

Road segmentation – alternative approach

Original RGB image converted to an illumination invariant colour space (reduced variation due to sunlight and shadows). From this image a local entropy image is derived (Matlab: entropyfilt).

Segmentation by region growing of the local entropy image (Matlab: grayconnected) using the green dots (left image) as seed pixels.

Morphological operations

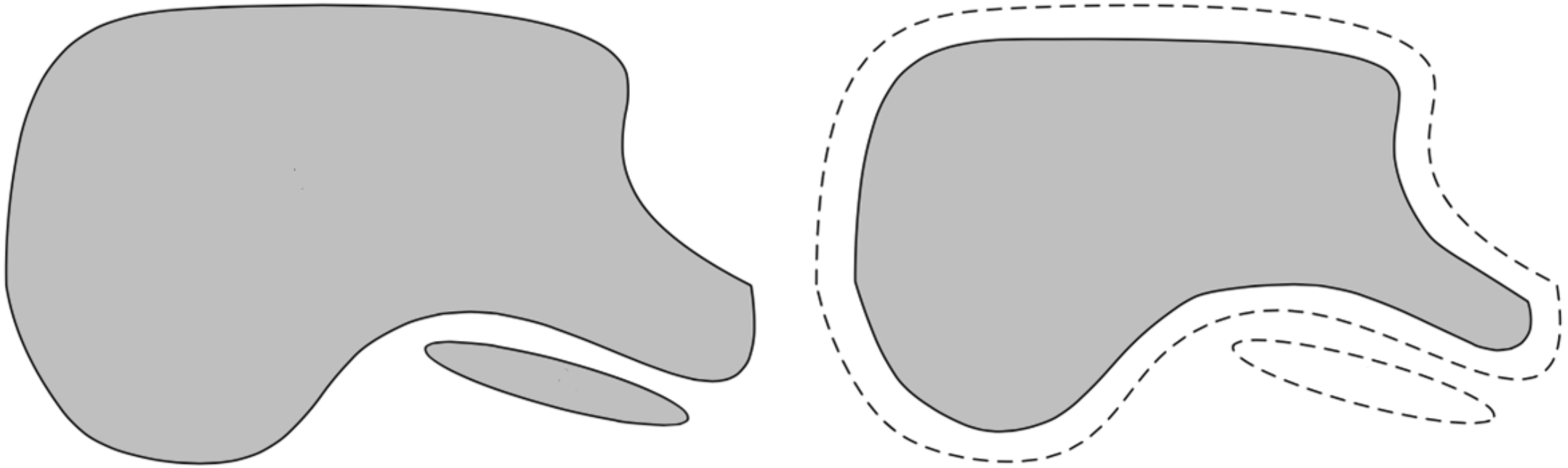
- Non-linear filtering
- Typically used to clean up binary images
- Erosion: replace pixel value with minimum in local neighborhood
- Dilation: replace pixel value with maximum in local neighborhood
- Structuring element used to define the local neighborhood:

0	1	0
1	1	1
0	1	0

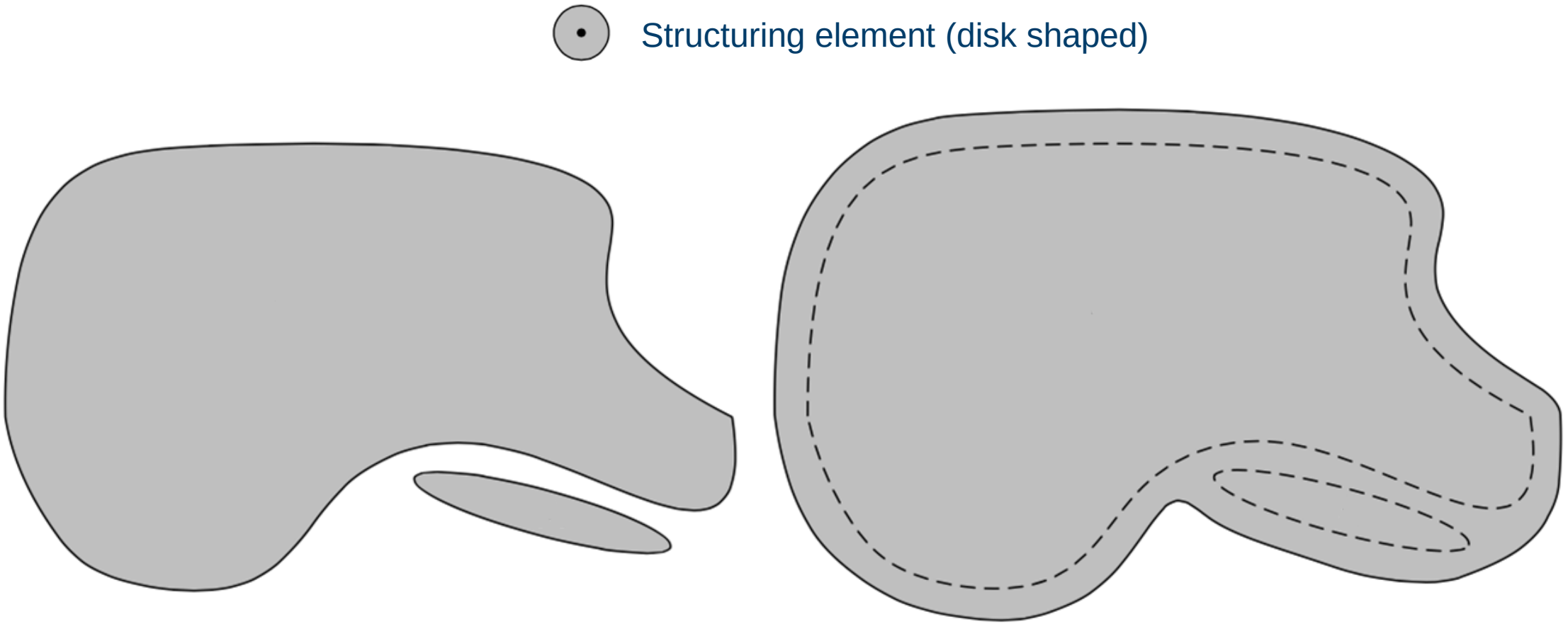
A shape (in blue) and its morphological dilation (in green) and erosion (in yellow) by a diamond-shape structuring element.

Morphological operations - Erosion

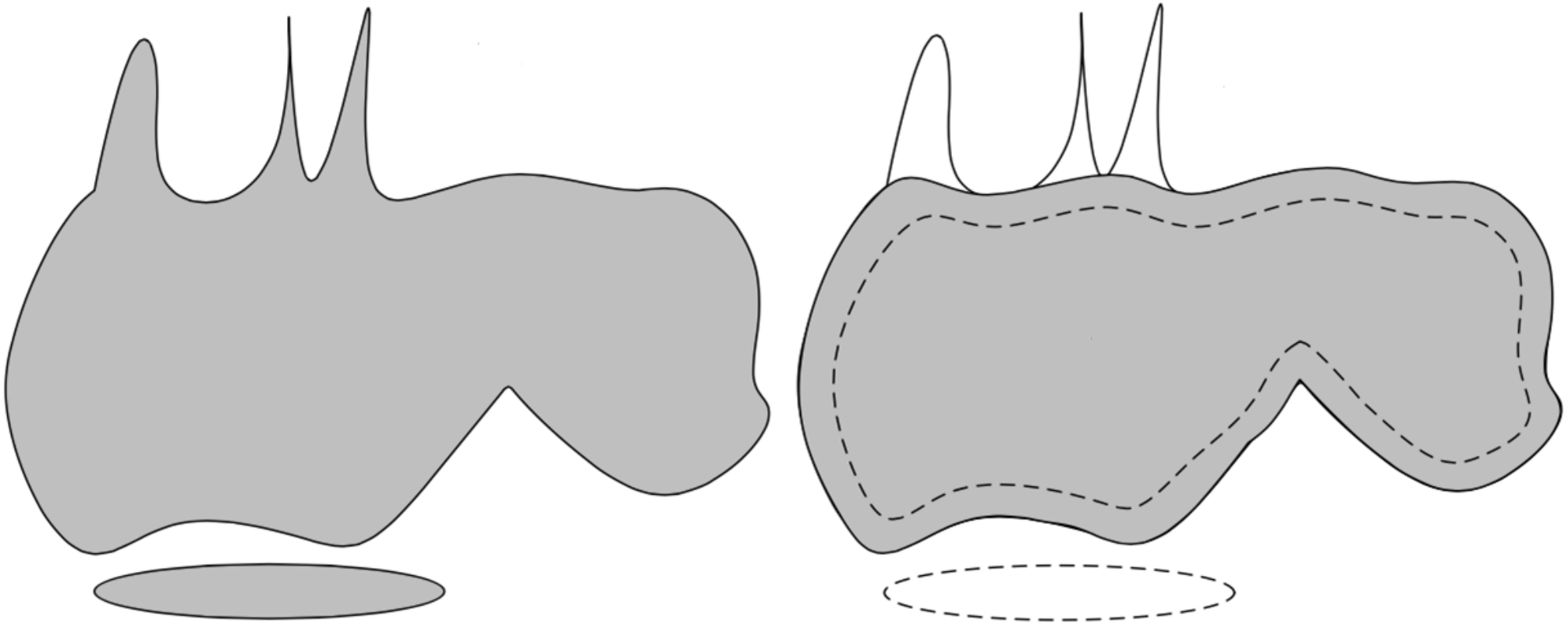
Structuring element (disk shaped)



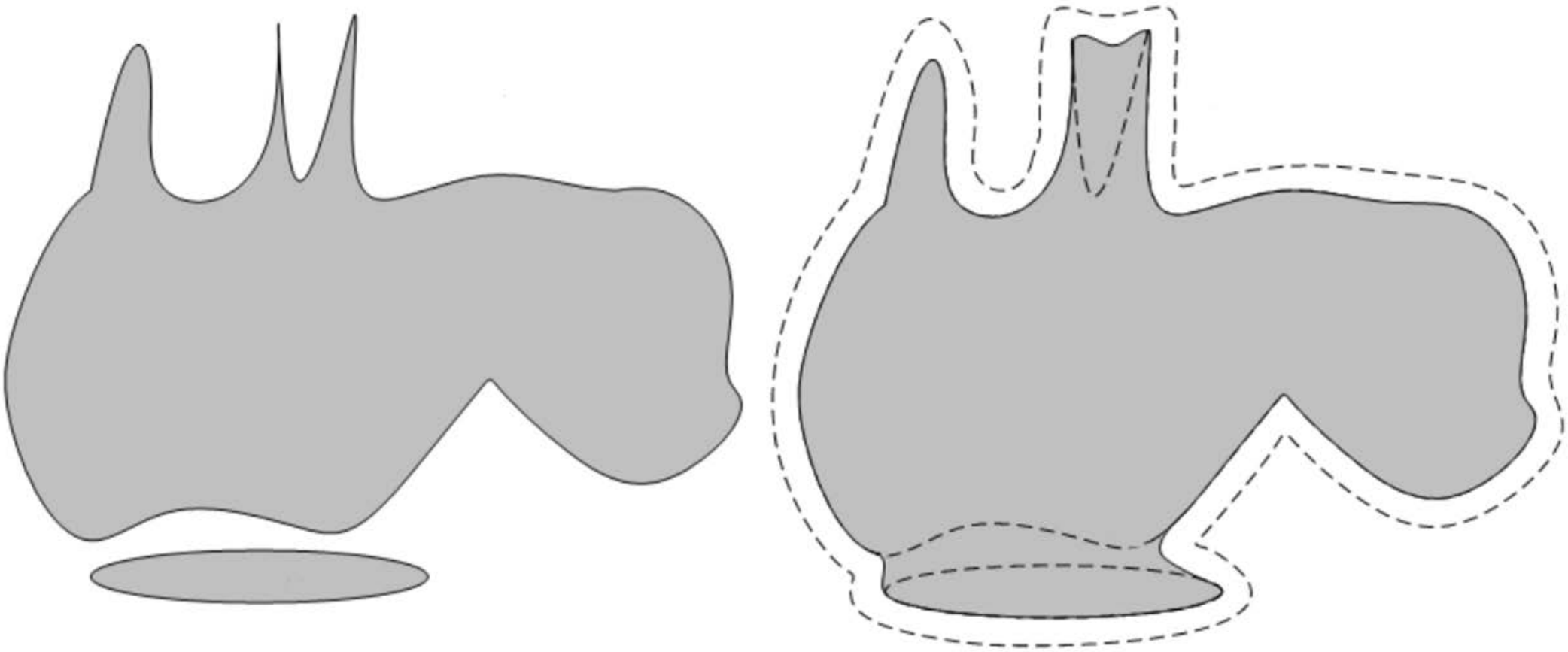
Morphological operations - Dilation



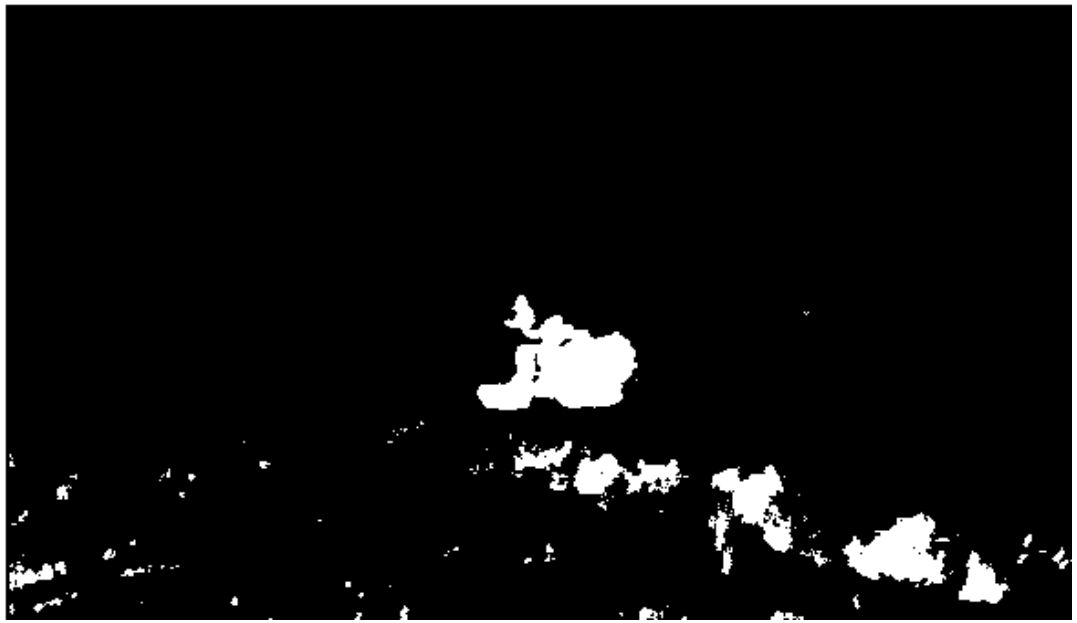
Opening = Erosion + Dilation



Closing = Dilation + Erosion



Opening - example

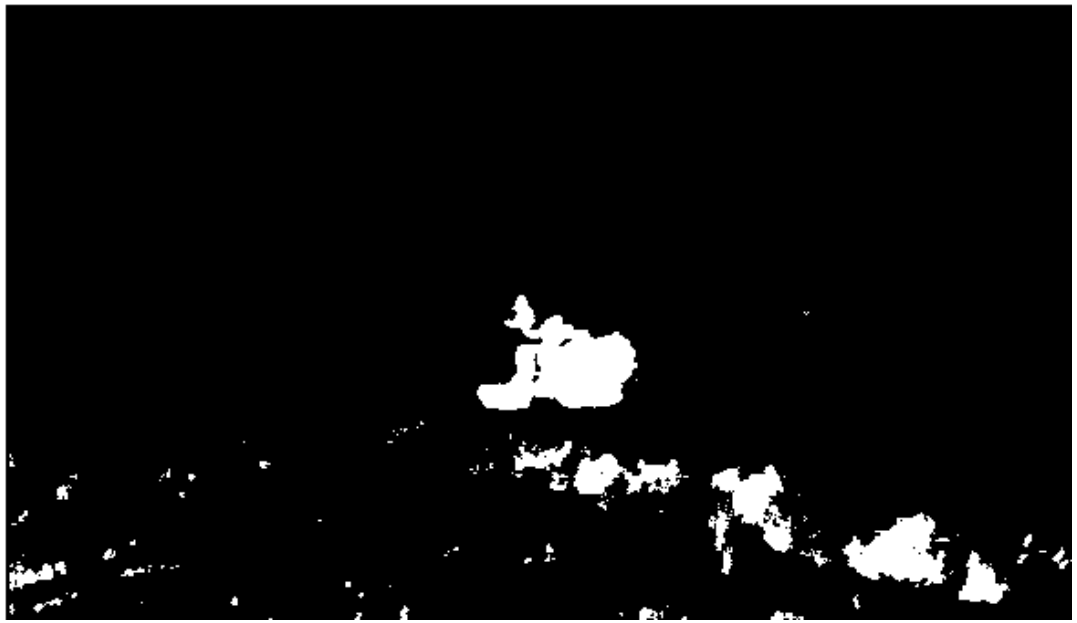


Thresholded image

Result of opening

Disk shaped structuring element with radius = 2 pixels (5 x 5 filter mask)

Closing - example



Thresholded image

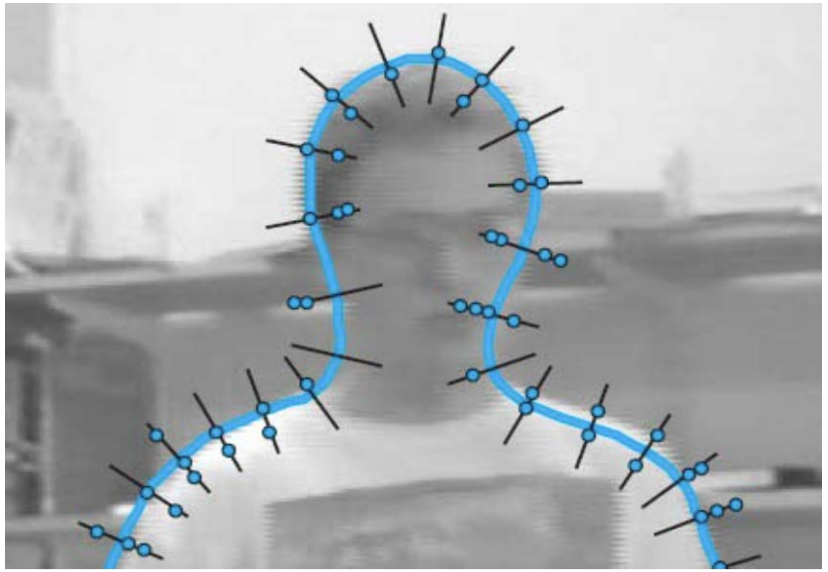
Result of opening

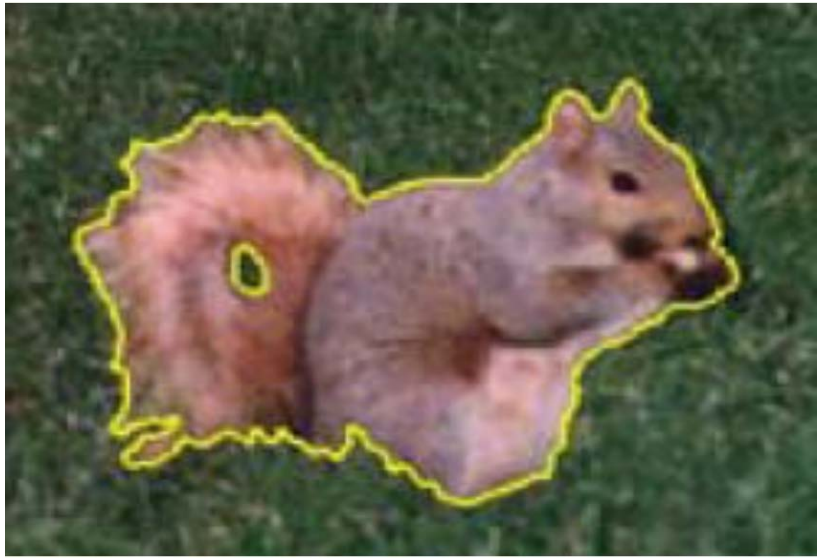
Disk shaped structuring element with radius = 2 pixels (5 x 5 filter mask)

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).





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Split and merge methods

Principles:

- 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

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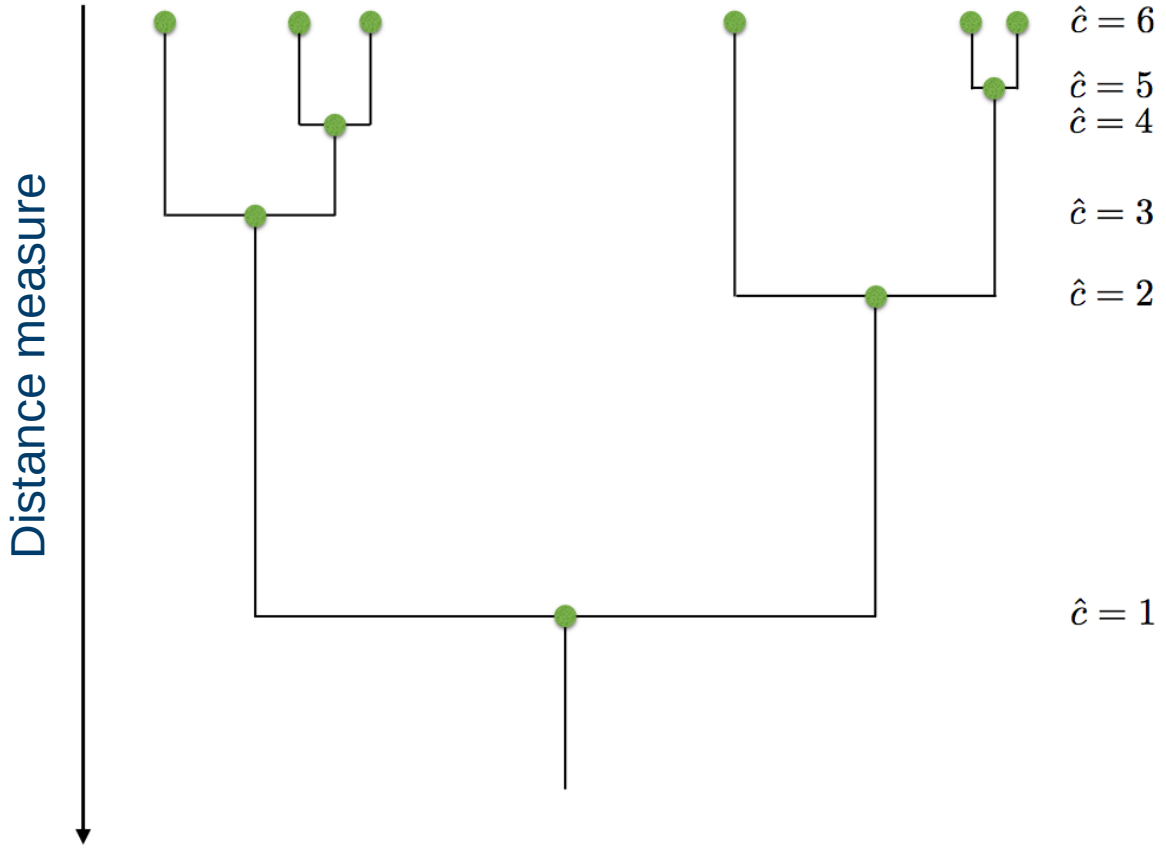
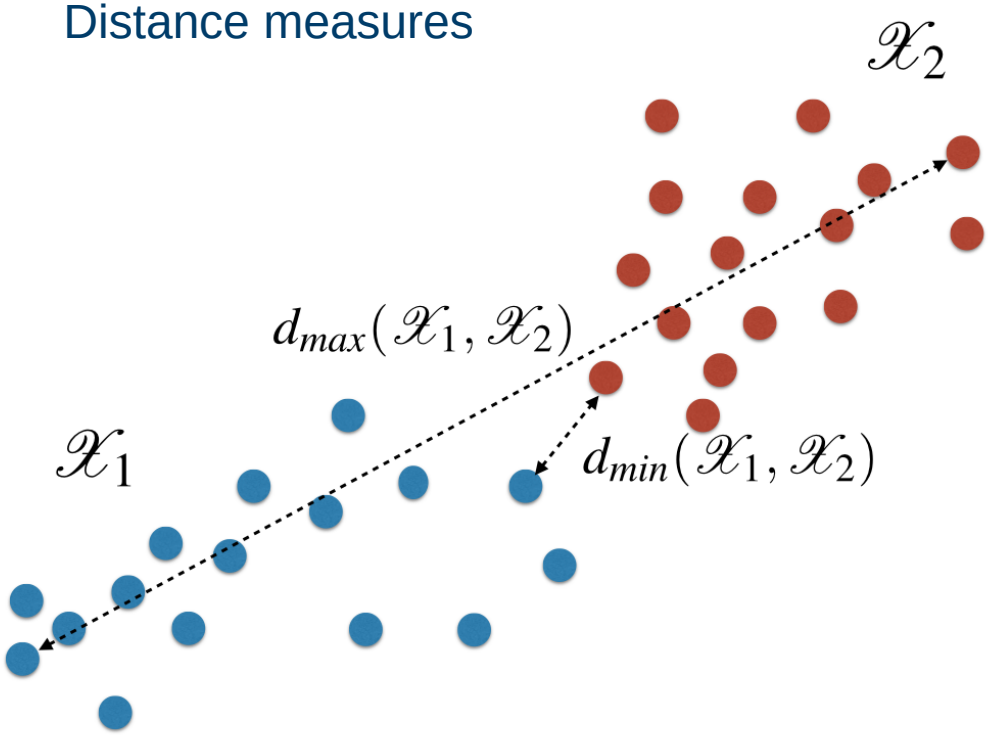
Agglomerative clustering



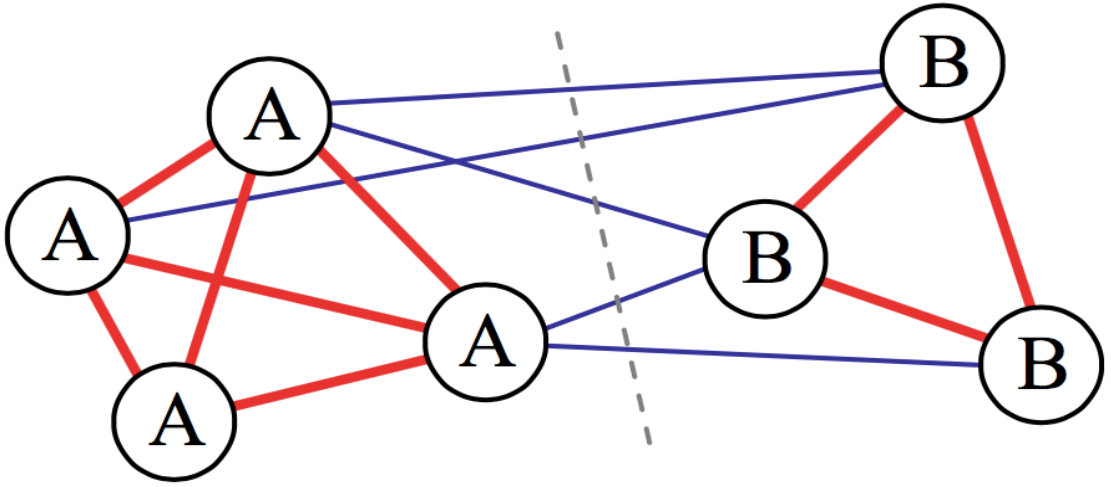
Dendrogram

Distance measures



Normalized cuts

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



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Graph cuts

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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.

Summary

Image Segmentation:

- Thresholding techniques
- Clustering methods for segmentation
- Morphological operations

More information: Szeliski 5.1 - 5.5