Photogrammetry & Robotics Lab

Image Segmentation using Mean Shift

Cyrill Stachniss

Slides partially by: Comaniciu, Hayes, Hoiem, Meer, Moore and others

Motivation

Can we identify similar image regions?

Image courtesy: Stefanski

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Motivation

Clustering is the problem of grouping similar data points (and represent them with a single token)

Clustering is important for image processing and Image understanding

Clustering for Image Segmentation

Goal: Break up the image into similar regions **without training data**

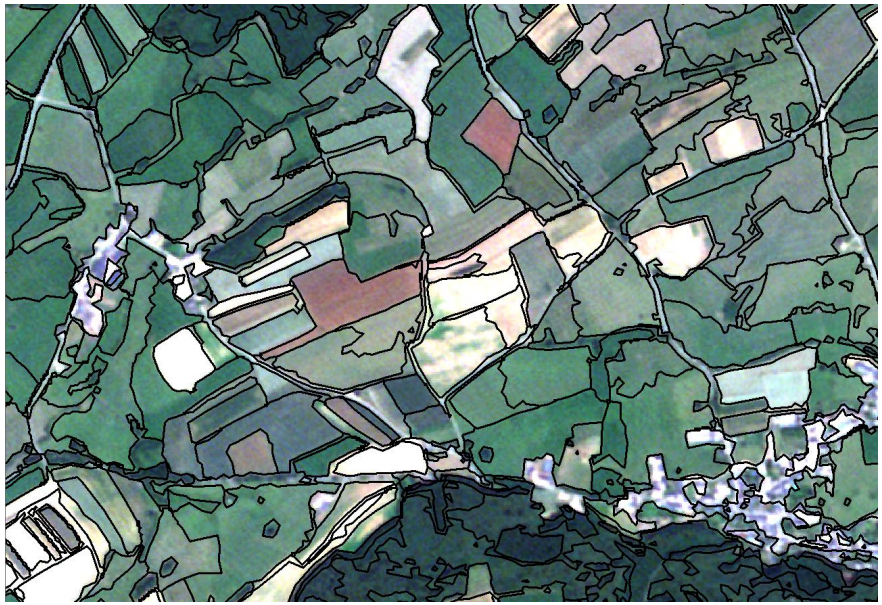


Image courtesy: Stefanski, Hoiem

Key Challenges in Clustering

Clustering is the problem of grouping similar data points and represent them with a single token

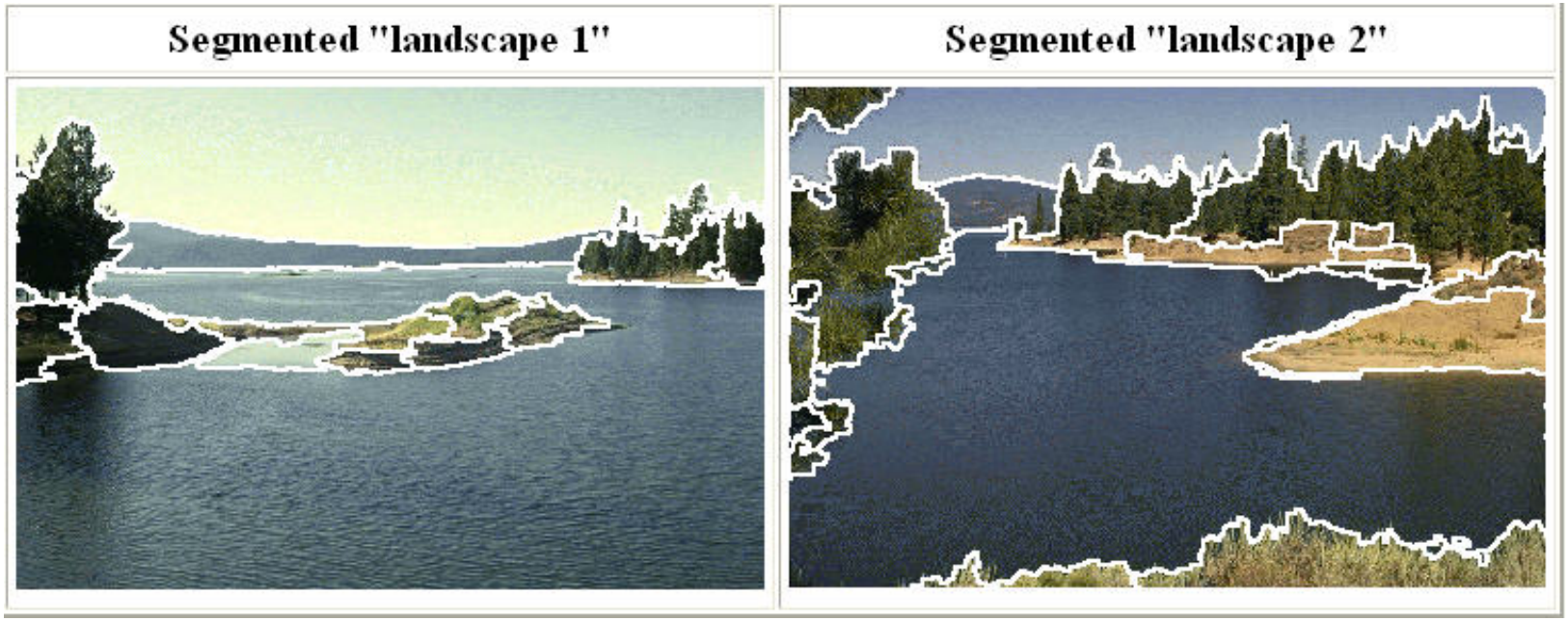
Key Challenges

- What makes two data points or areas in an areas similar?
- How do we compute an overall grouping from pairwise similarities?

Mean Shift Segmentation

Mean Shift Segmentation

Versatile technique for clustering-based segmentation of image data

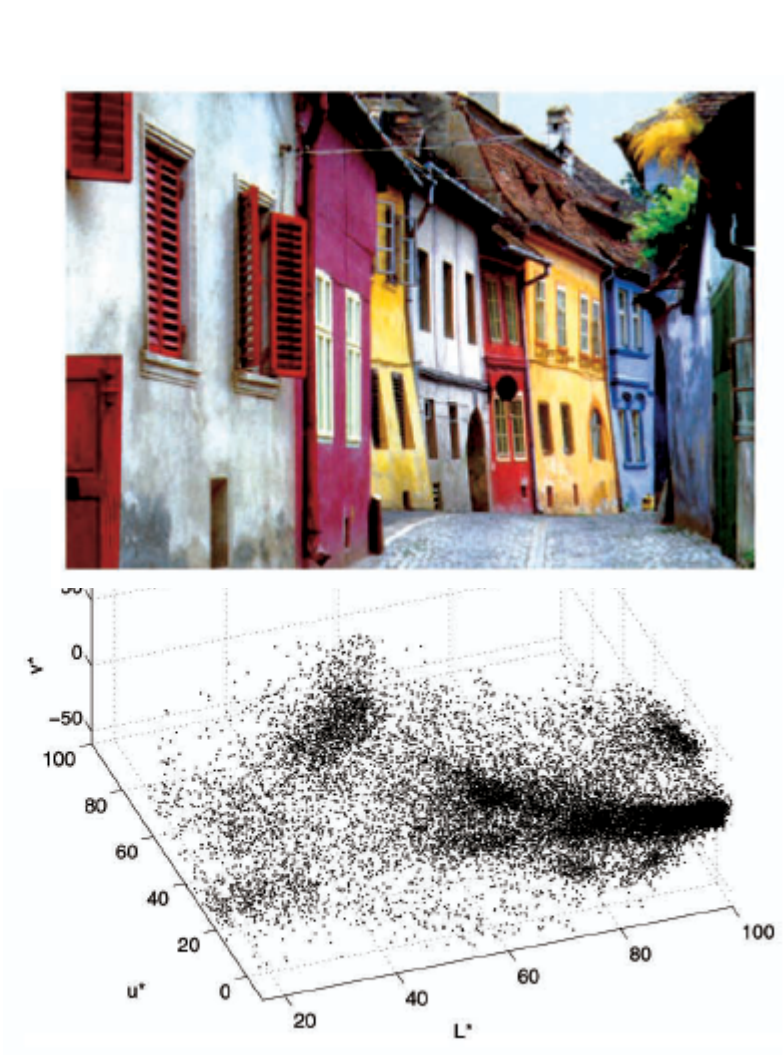


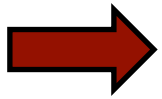
D. Comniciu and P. Meer, Mean Shift: A Robust Approach toward Feature Space Analysis, PAMI 2002.

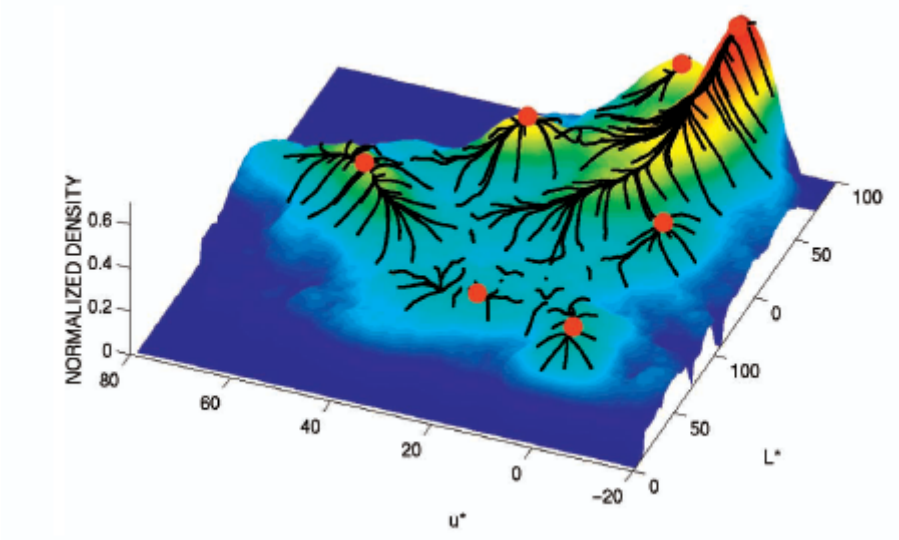
Image courtesy: Comaniciu and Meer

Mean Shift Algorithm

Try to find modes of a non-parametric density







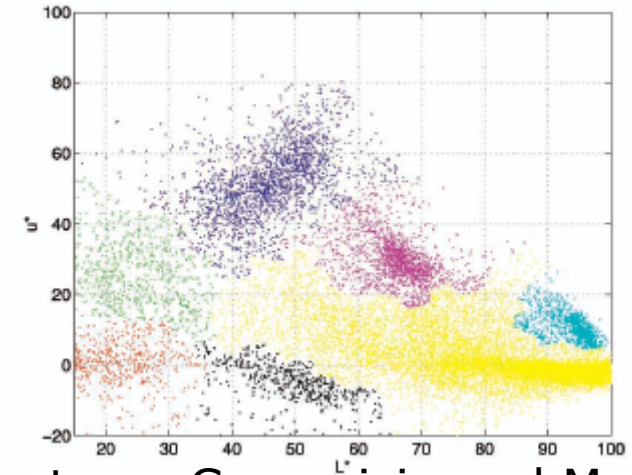
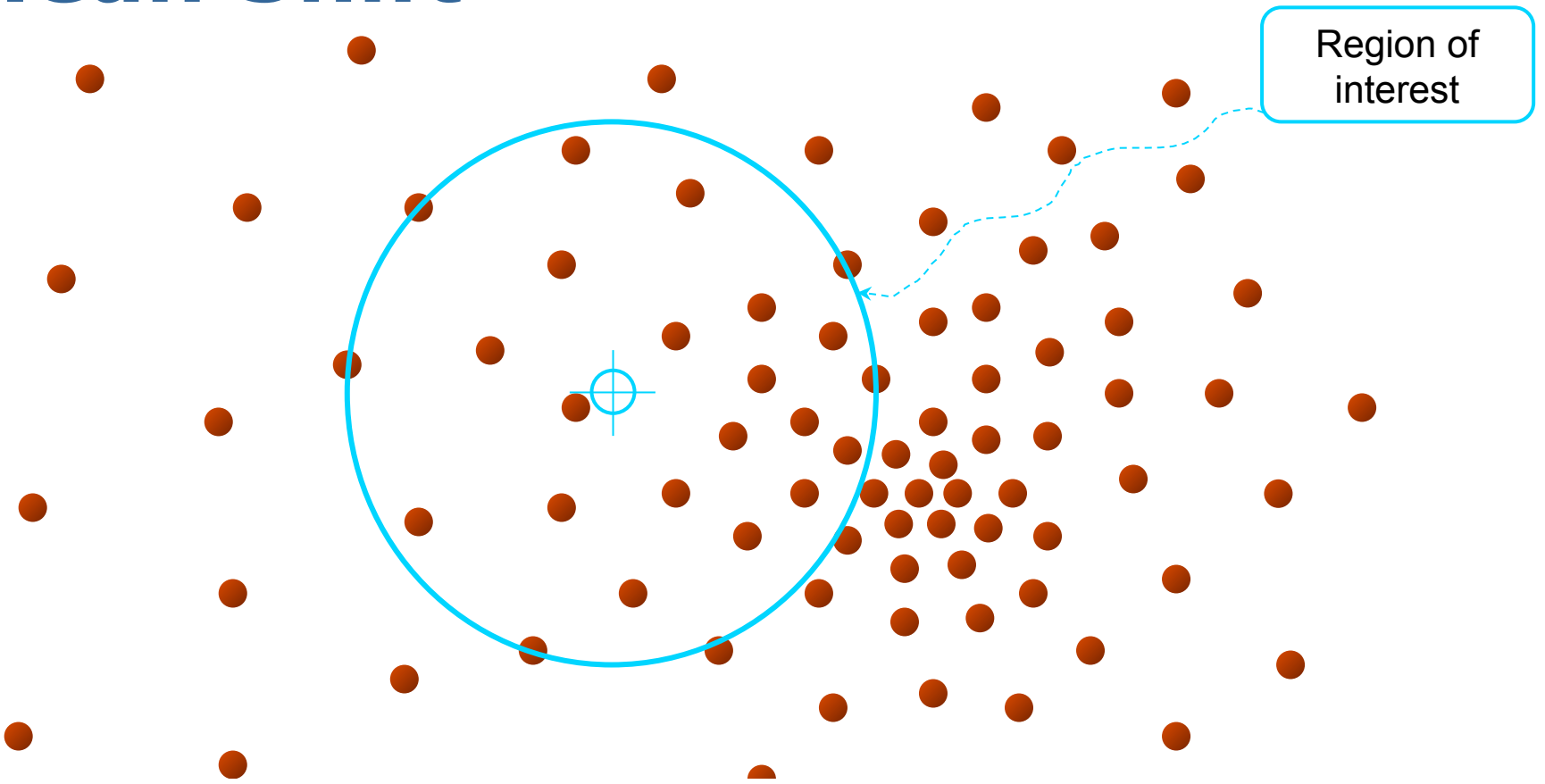


Image courtesy: Comaniciu and Meer

Idea: Estimating the PDF and Finding the Maxima

- Non-parametric approach to density estimation ("how many data points are in a certain region?")
- Find the local modes of this density
- All points that "belong" or "lead" to the same mode form a cluster

Mean Shift



How to estimate a PDF in a non-parametric way?

Slide courtesy: Ulkrainitz & Sarel

Kernel Density Estimation (Parzen Window Technique)

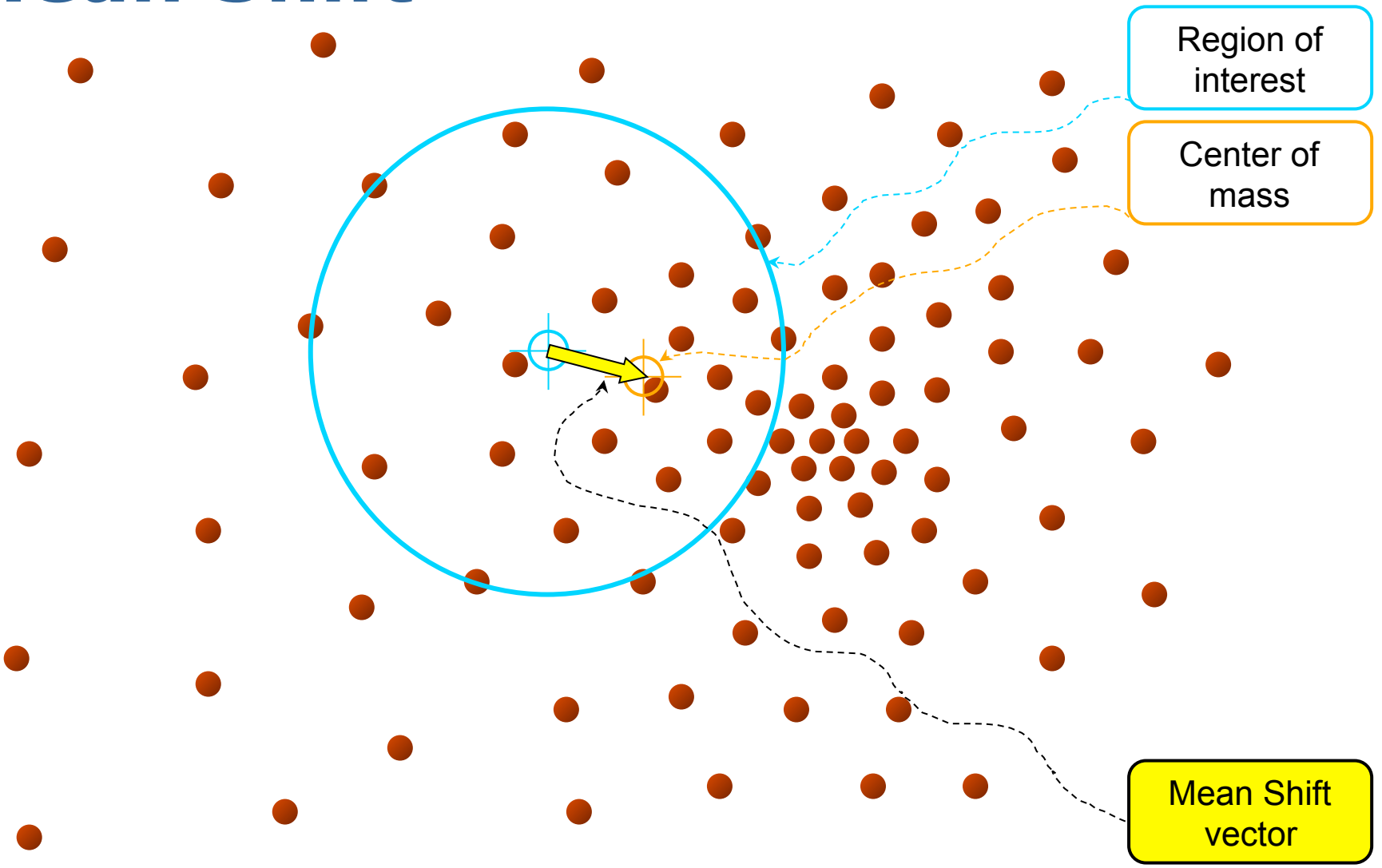
- Use a smoothing kernel

$$f(\boldsymbol{x}) = \sum_m K(\boldsymbol{x} - \boldsymbol{x}_m) = \sum_m k\left(\frac{\boldsymbol{x} - \boldsymbol{x}_m}{h}\right)$$

- Standard choice: Gaussian kernel

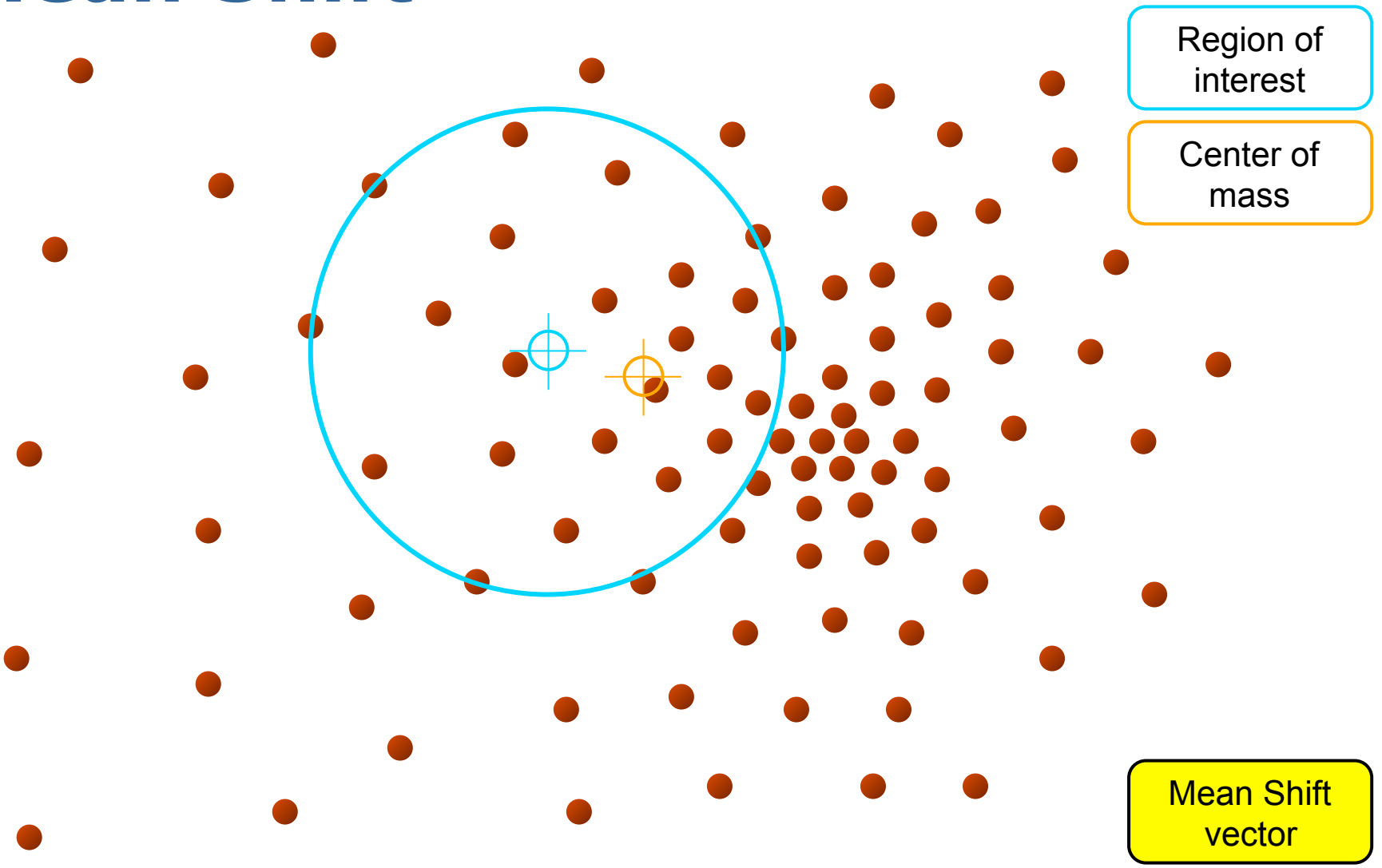
$$k(\boldsymbol{x}) = (2\pi)^{-d/2} \exp\left(-\frac{1}{2}||\boldsymbol{x}||^2\right)$$

Mean Shift



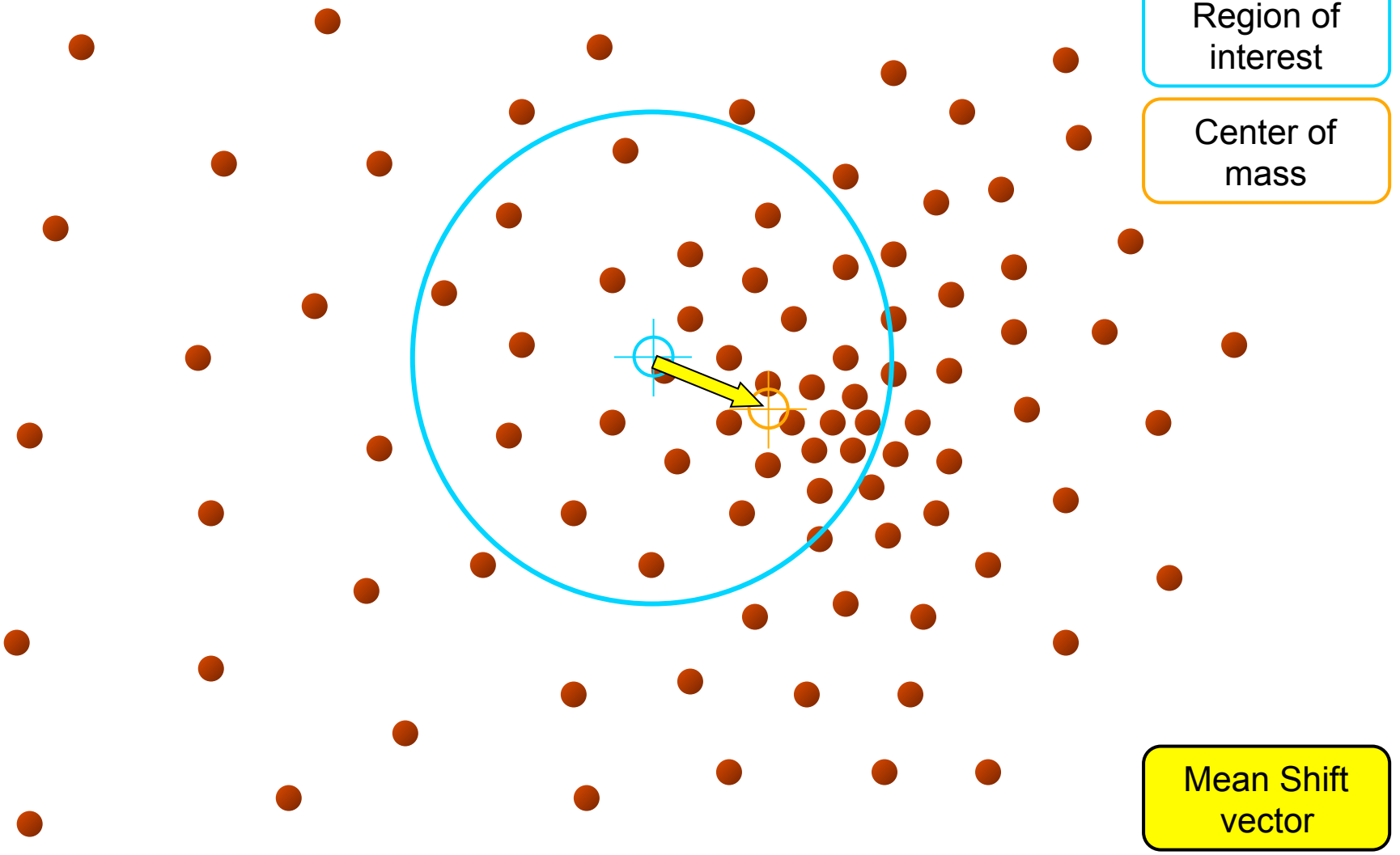
Slide courtesy: Ulkrainitz & Sarel

Mean Shift



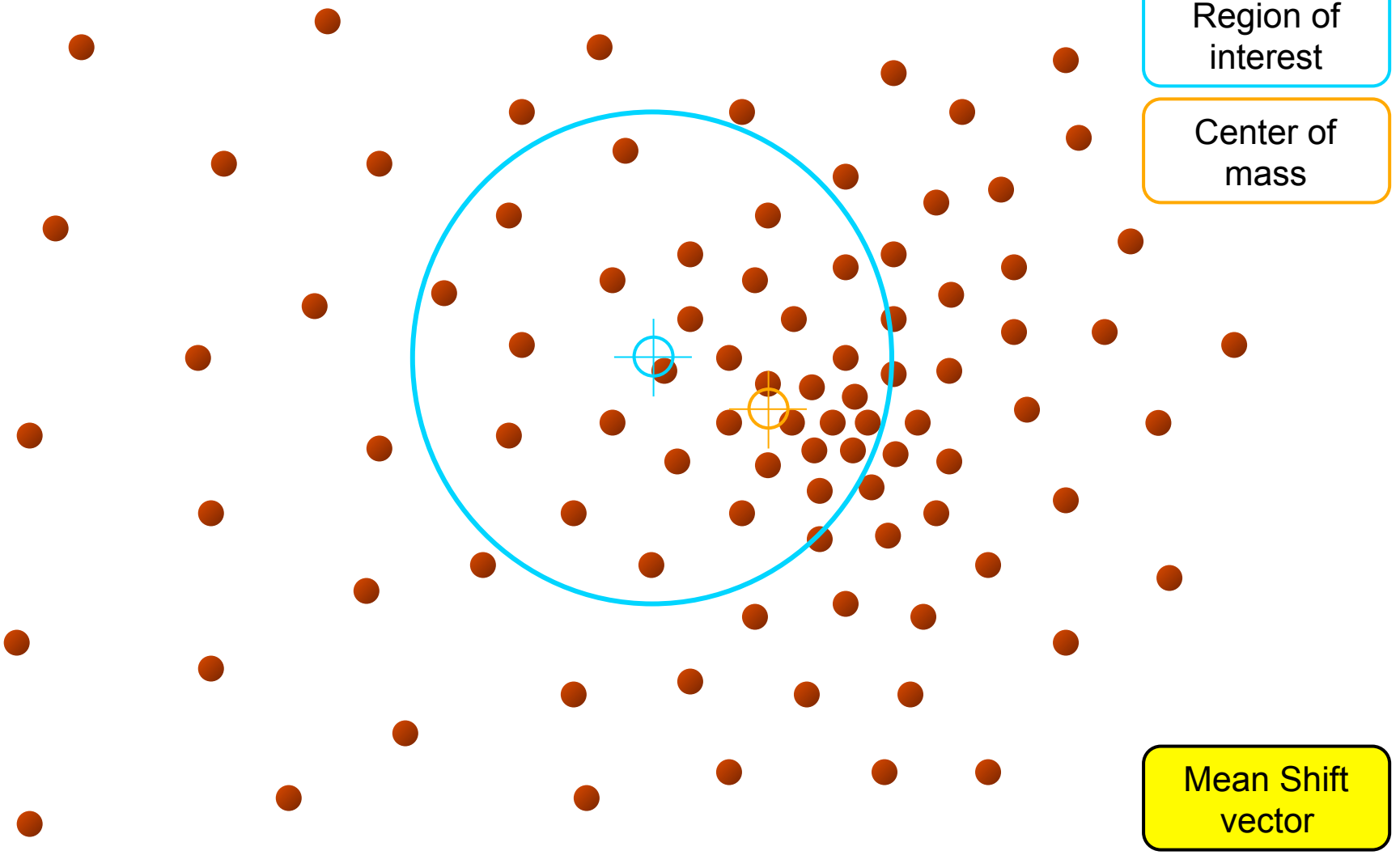
Slide courtesy: Ulkrainitz & Sarel

Mean Shift



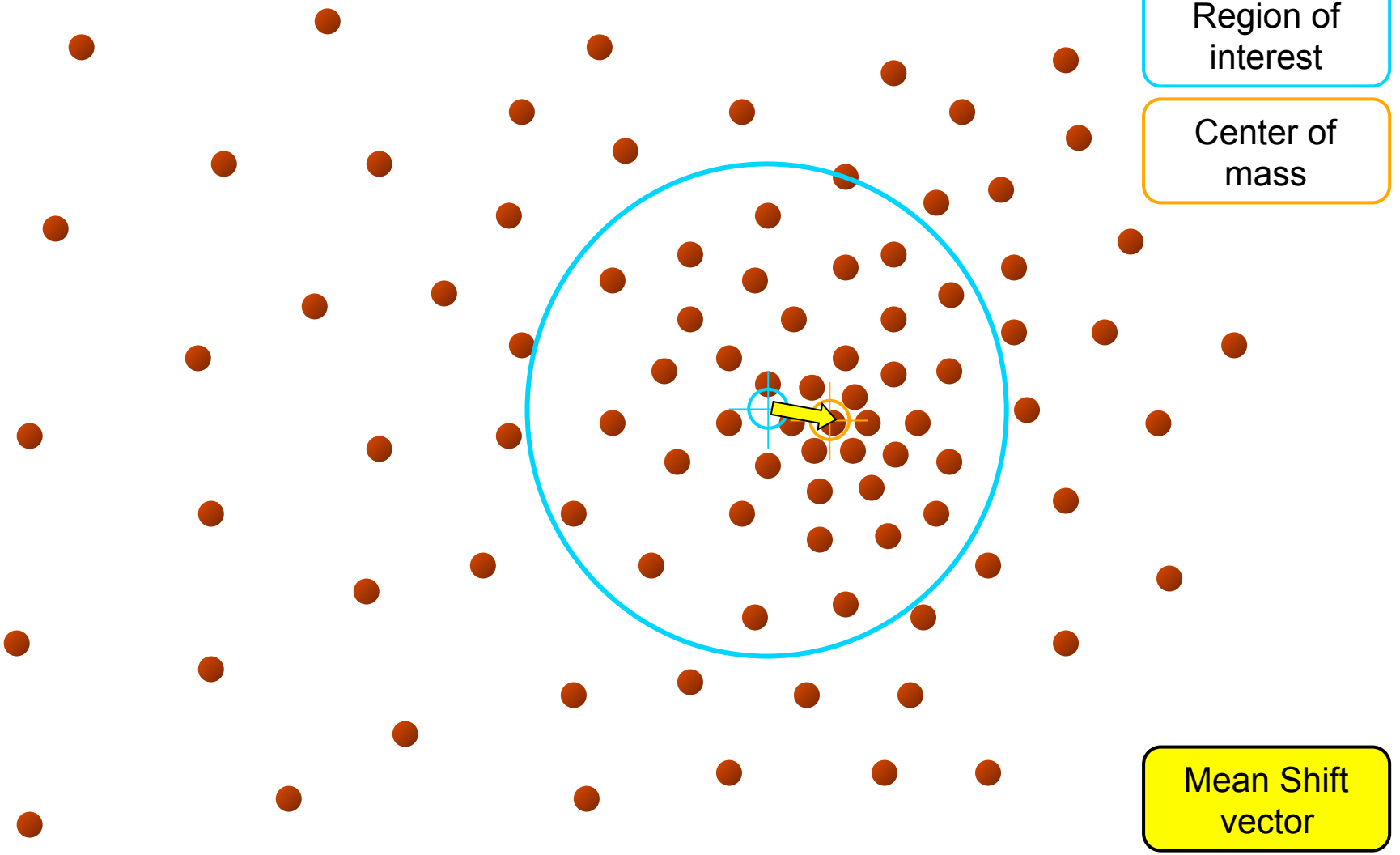
Slide courtesy: Ulkrainitz & Sarel

Mean Shift



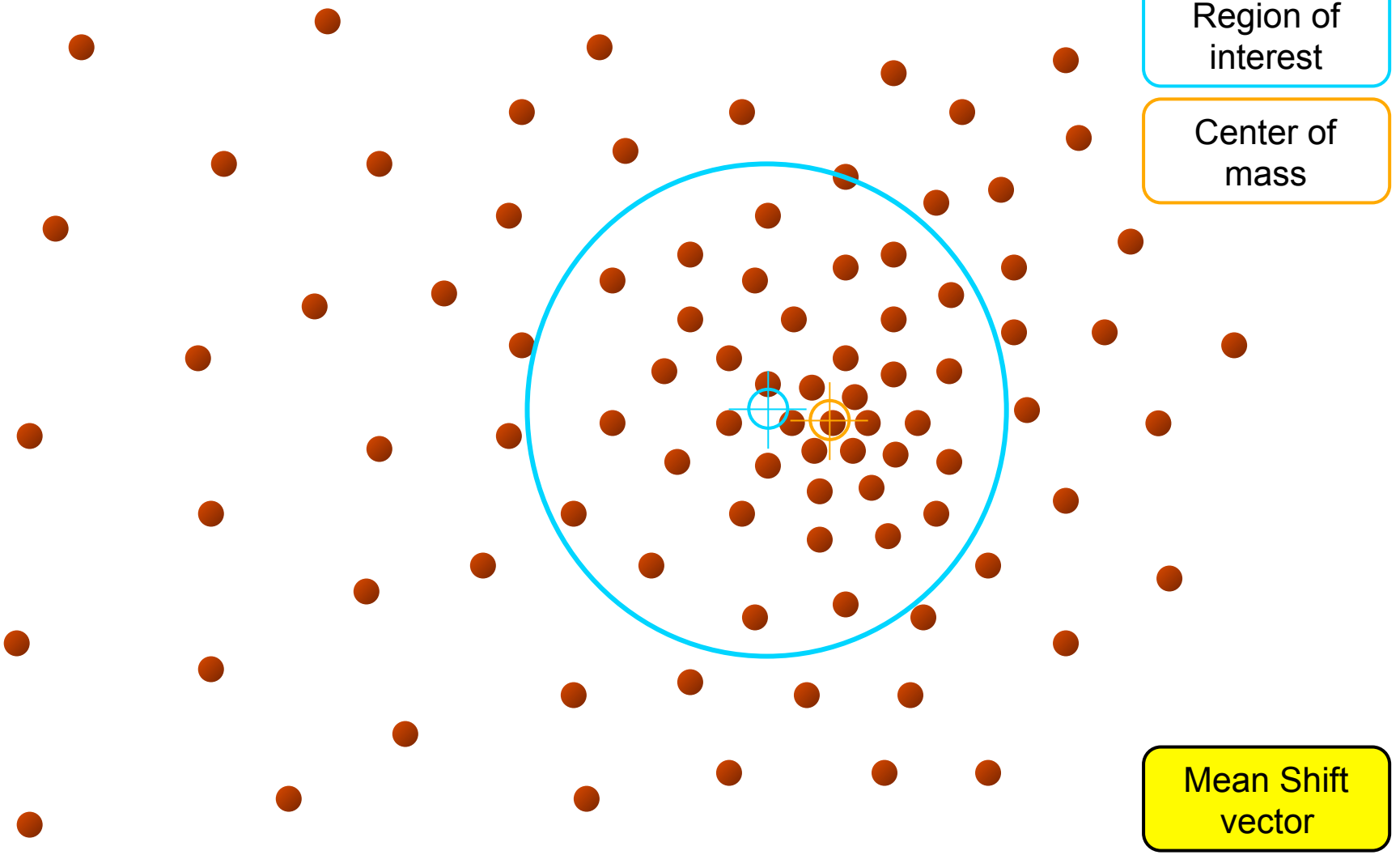
Slide courtesy: Ulkrainitz & Sarel

Mean Shift



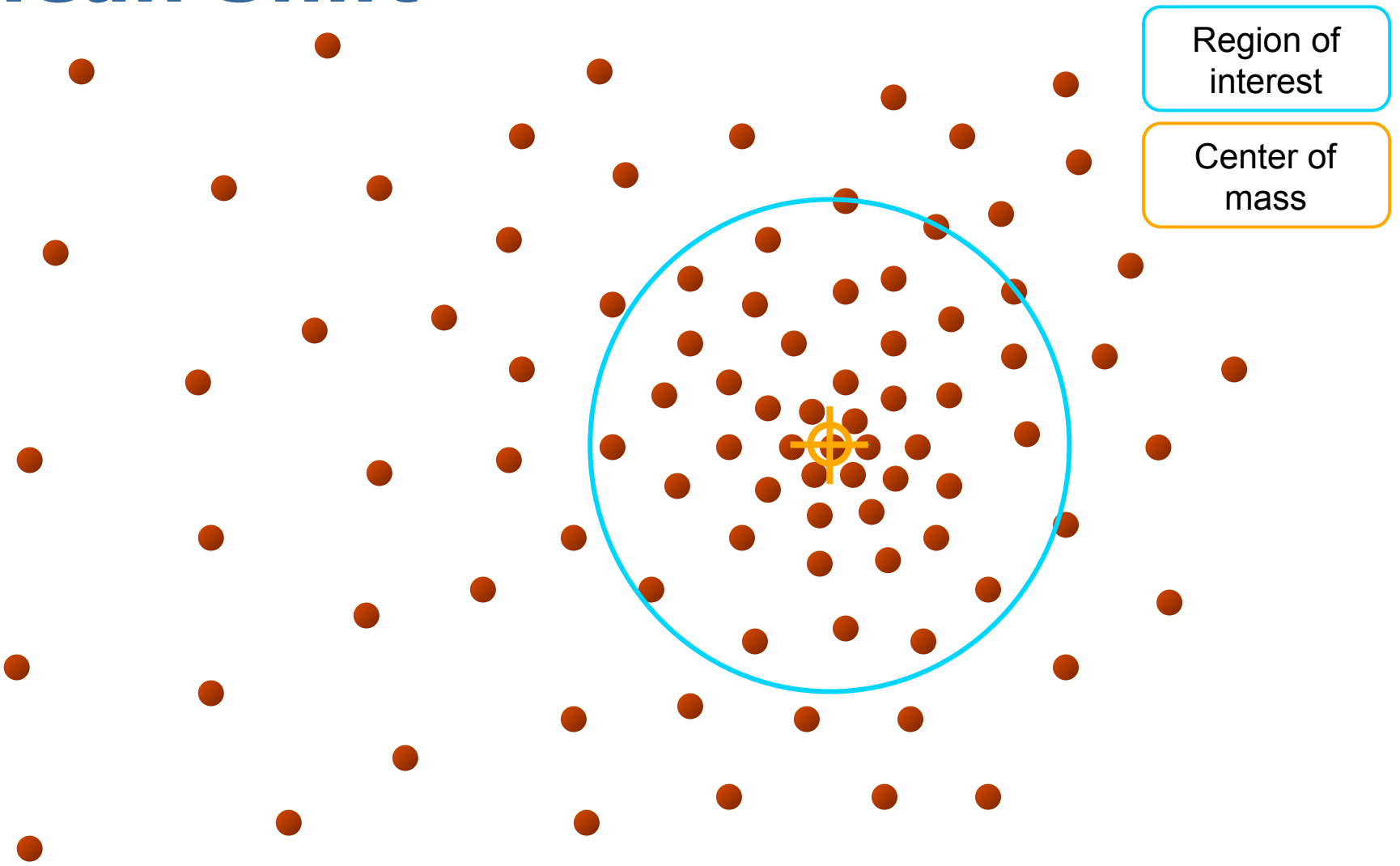
Slide courtesy: Ulkrainitz & Sarel

Mean Shift



Slide courtesy: Ulkrainitz & Sarel

Mean Shift



Slide courtesy: Ulkrainitz & Sarel

Computing the Mean Shift

Simple mean shift procedure:

- Compute mean shift vector
- Translate the Kernel window

$$\hat{\boldsymbol{x}} = \frac{\sum_m \boldsymbol{x}_m \exp\left(-\frac{1}{2}\left\|\frac{\boldsymbol{x}-\boldsymbol{x}_m}{h}\right\|^2\right)}{\sum_m \exp\left(-\frac{1}{2}\left\|\frac{\boldsymbol{x}-\boldsymbol{x}_m}{h}\right\|^2\right)} - \boldsymbol{x}$$

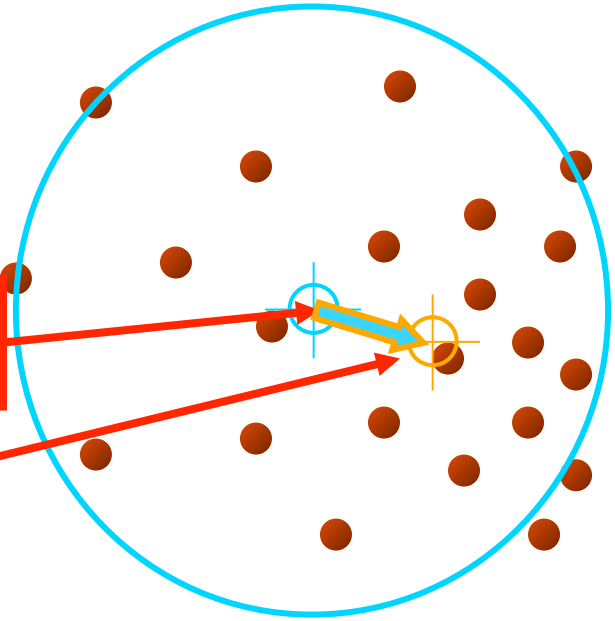
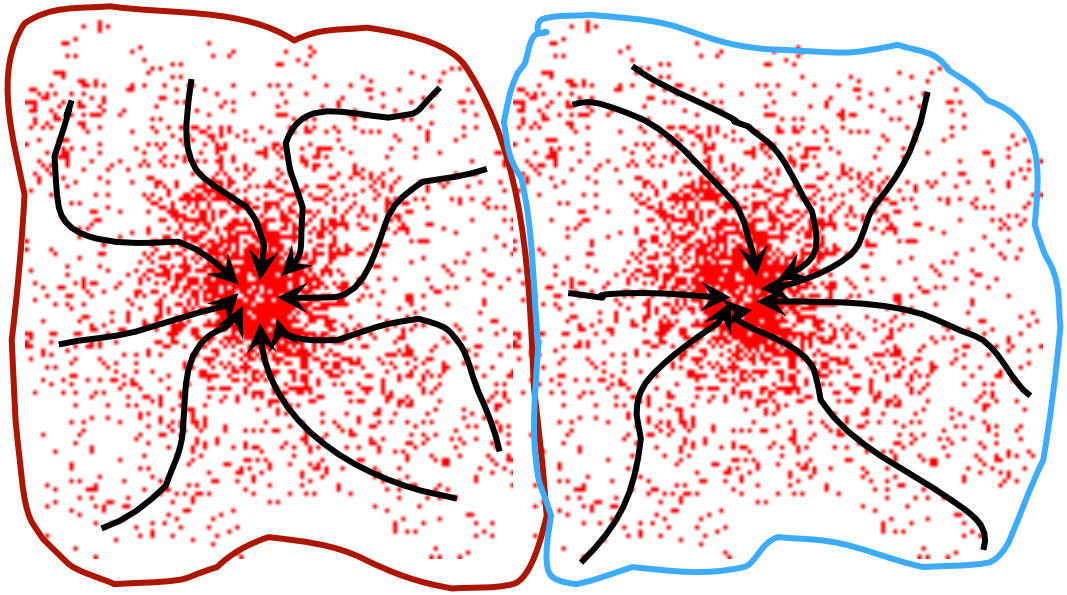


Image courtesy: Ulkrainitz & Sarel

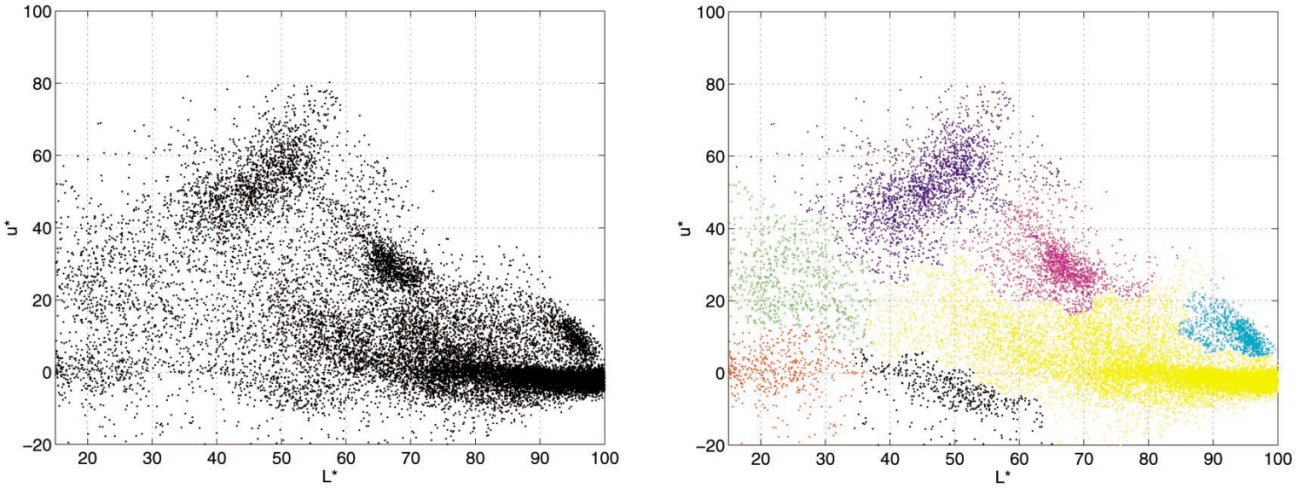
Attraction Basin

- **Attraction basin:** the region for which all trajectories lead to the same mode
- **Cluster:** all data points in the attraction basin of a mode



Slide courtesy: Ulkrainitz & Sarel

Attraction Basin



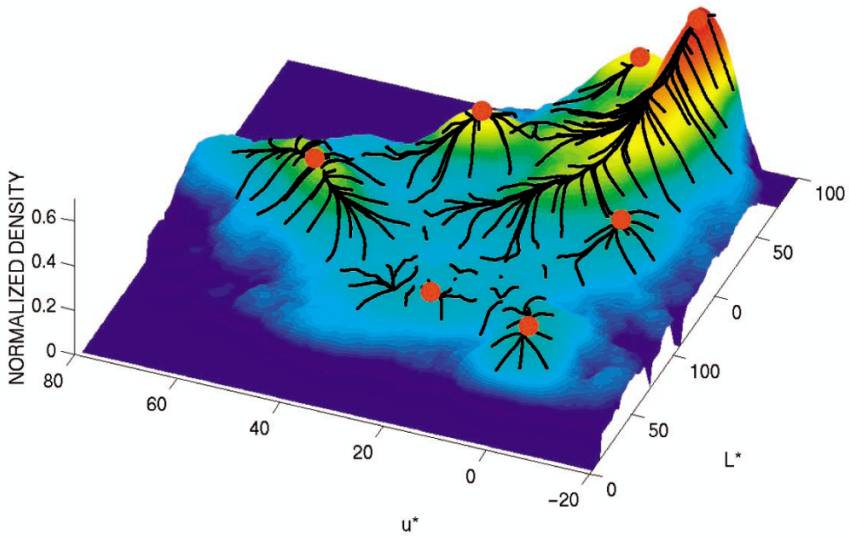


Image courtesy: Comaniciu and Meer

Mean Shift Algorithm

The mean shift algorithm seeks *modes* of the given set of points

1. Choose kernel and bandwidth
2. For each point:
   a) Center a window on that point
   b) Compute the mean of the data in the search window
   c) Center the search window at the new mean location
   d) Repeat (b,c) until convergence
3. Assign points that lead to nearby modes to the same cluster

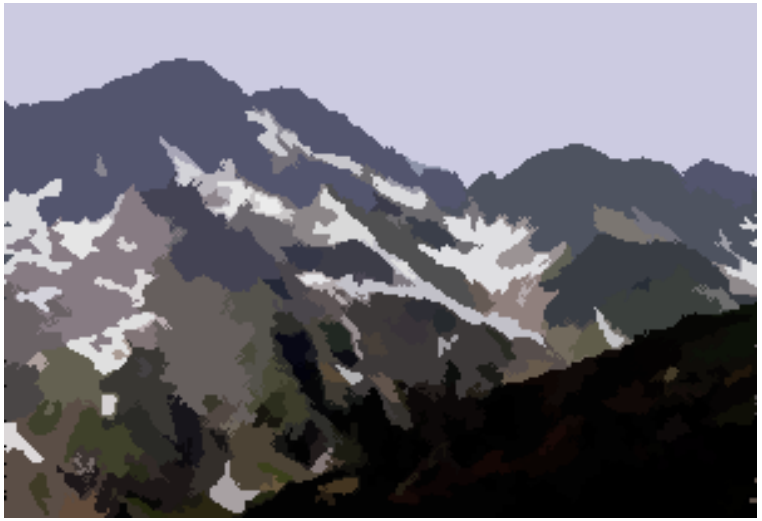
Segmentation by Mean Shift

- Compute features for each pixel (color, gradients, texture, etc.)
- Set kernel size for features K_f and position K_s
- Initialize windows at individual pixel locations
- Perform mean shift for each window until convergence
- Merge windows that are within width of K_f and K_s

Slide courtesy: Hoiem

Mean Shift Segmentation



http://www.caip.rutgers.edu/~comanici/MSPAMI/msPamiResults.html

Image courtesy: Comaniciu and Meer

Mean Shift Segmentation

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Mean Shift Pros and Cons

Pros

- Good general-practice segmentation
- Flexible in number and shape of regions
- Robust to outliers

Cons

- Have to choose kernel size in advance
- Not well suited for high-dimensional features

Summary

- Clustering = “group similar things”
- Unsupervised image segmentation is a clustering problem
- Mean shift is a popular technique for image-based segmentation
- Several other clustering approaches:
  - Agglomerative clustering
  - k-means
  - GMM estimation
  - …

Literature

- D. Comniciu and P. Meer: Mean Shift: A Robust Approach toward Feature Space Analysis, PAMI 2002.
- Szeliski, Computer Vision: Algorithms and Applications, Chapter 5