KECE471 Computer Vision

EM Algorithm and Mean Shift

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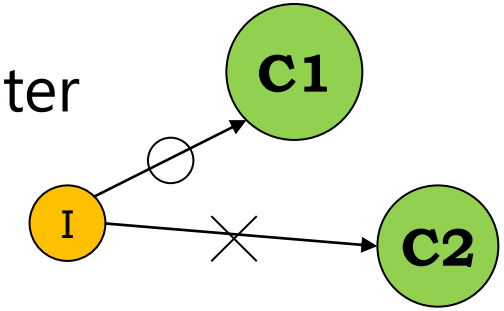
Chapter 14, Computer Vision by Forsyth and Ponce
Chapter 5, Computer Vision by Richard Szeliski
Note: Dr. Forsyth's notes are partly used.
The contents on meanshift part are copied from the ppt file of
Yaron Ukrainitz & Bernard Sarel

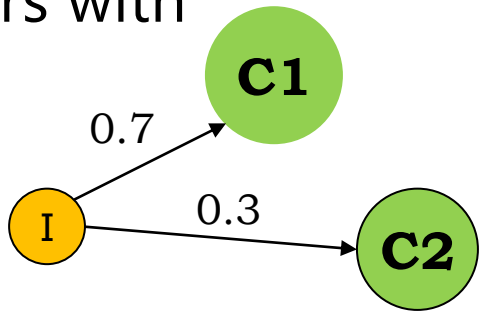
EM - EXPECTATION MAXIMIZATION

K-means and EM algorithm

- K-Means
  - Hard Clustering
    - An instance belongs to only one cluster

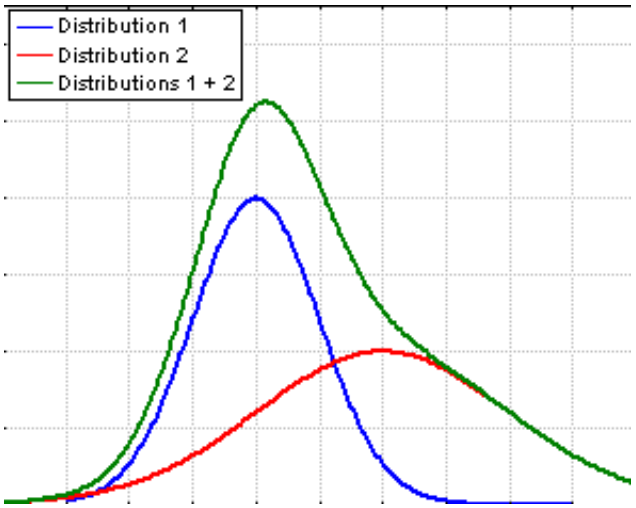


- EM
  - Soft Clustering.
    - An instance belongs to several clusters with membership probability



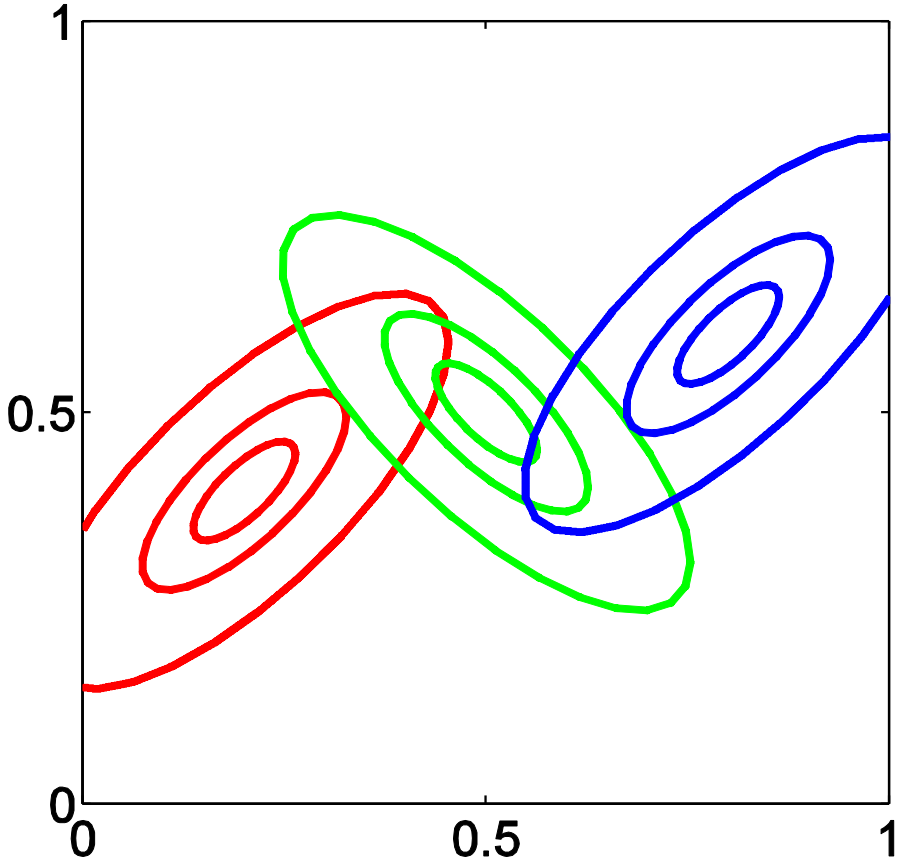
Clustering - EM algorithm

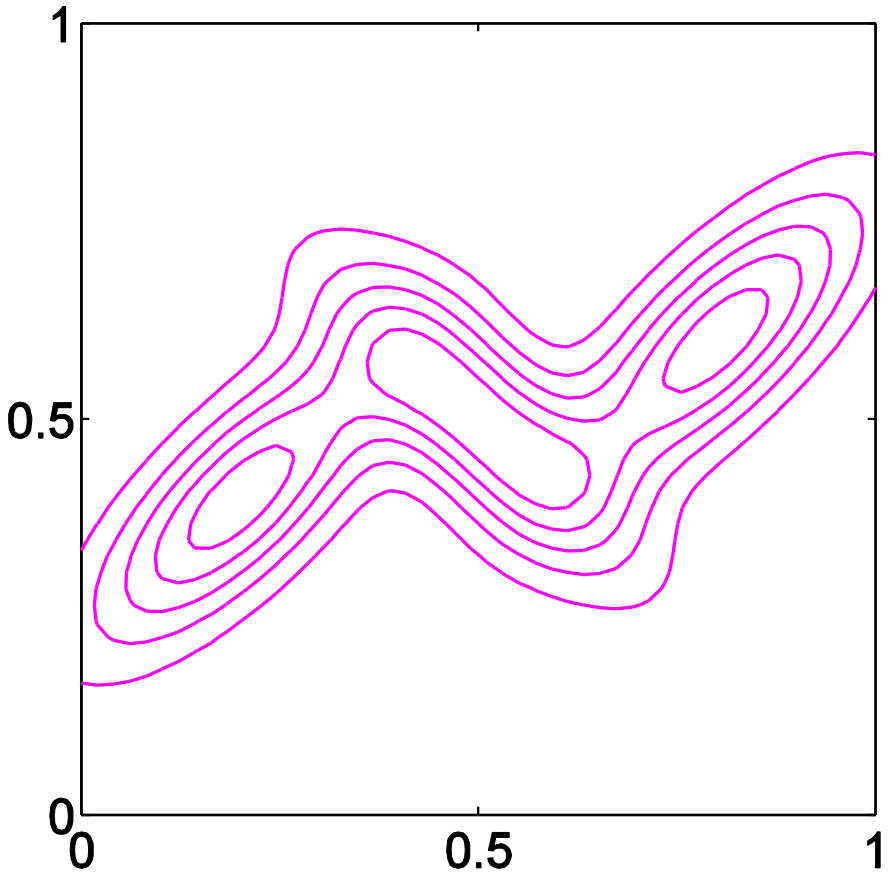
- Gaussian mixture model
  - A mixture is a set of *k* Gaussian distributions, representing *k* clusters.
  - Each Gaussian distribution is represented by mean and variance.
  - The mixture model combines several Gaussian distributions.



Clustering - EM algorithm

- Example : Mixture of 3 Gaussians



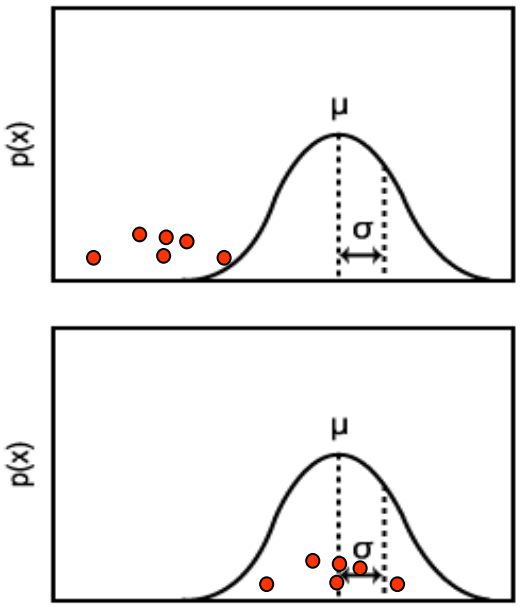


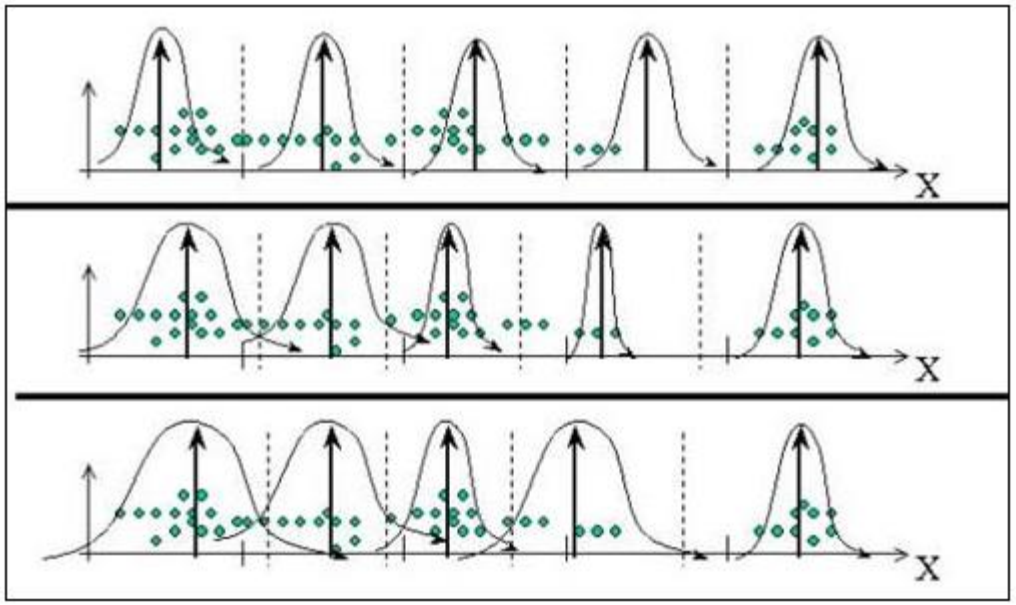
Fitting a Gaussian Mixture

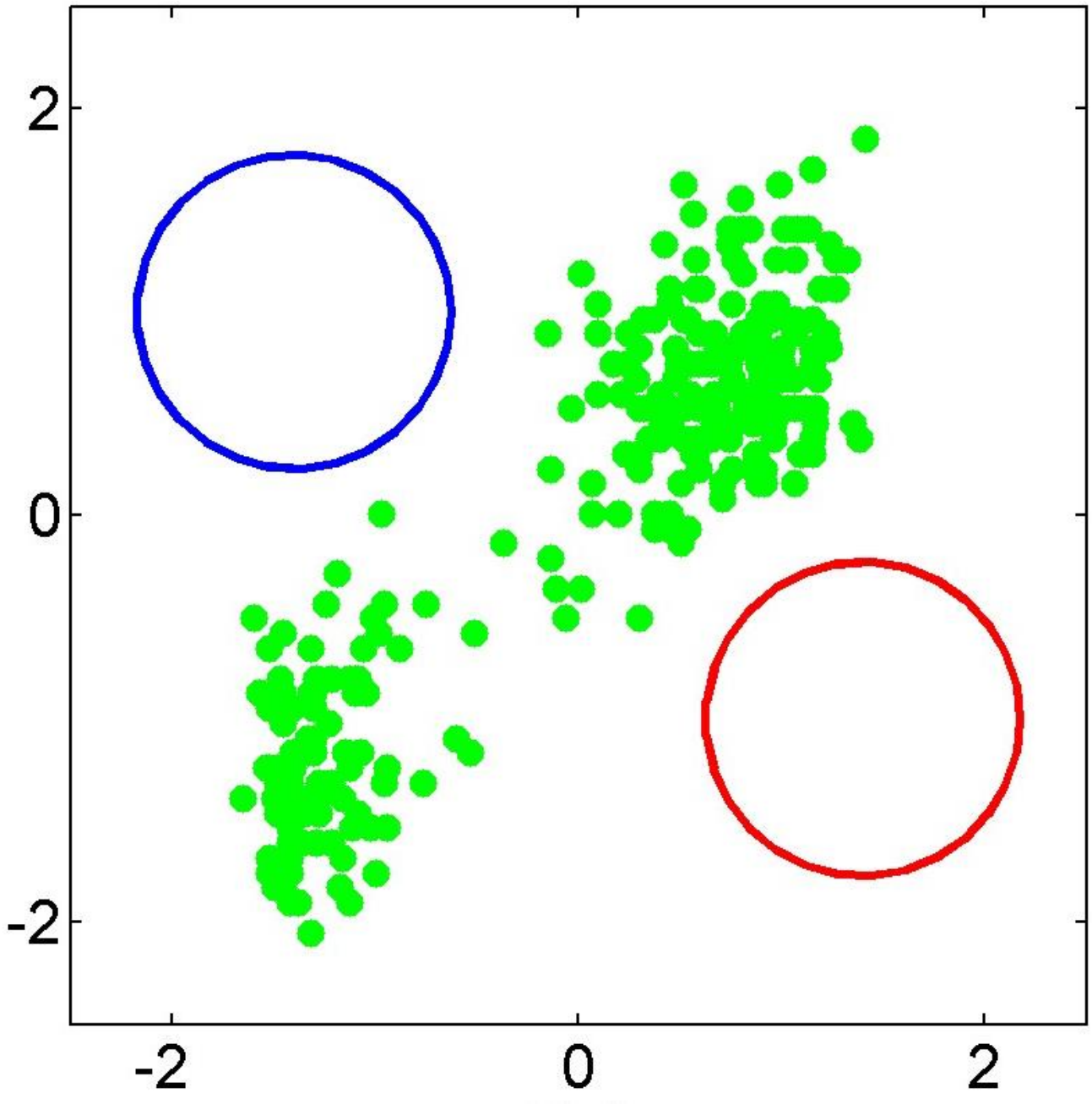
- Given the data set, estimate the parameters:
  - Mixing coefficients
  - Means
  - Variances
- If we know which cluster generates each data point, the estimation is very easy
- But the information is unknown

Informal derivation

- Iterative scheme
  - Make initial guesses for the parameters
  - Alternate between the following two stages:
    1. E-step: evaluate responsibilities
    2. M-step: update parameters using ML results



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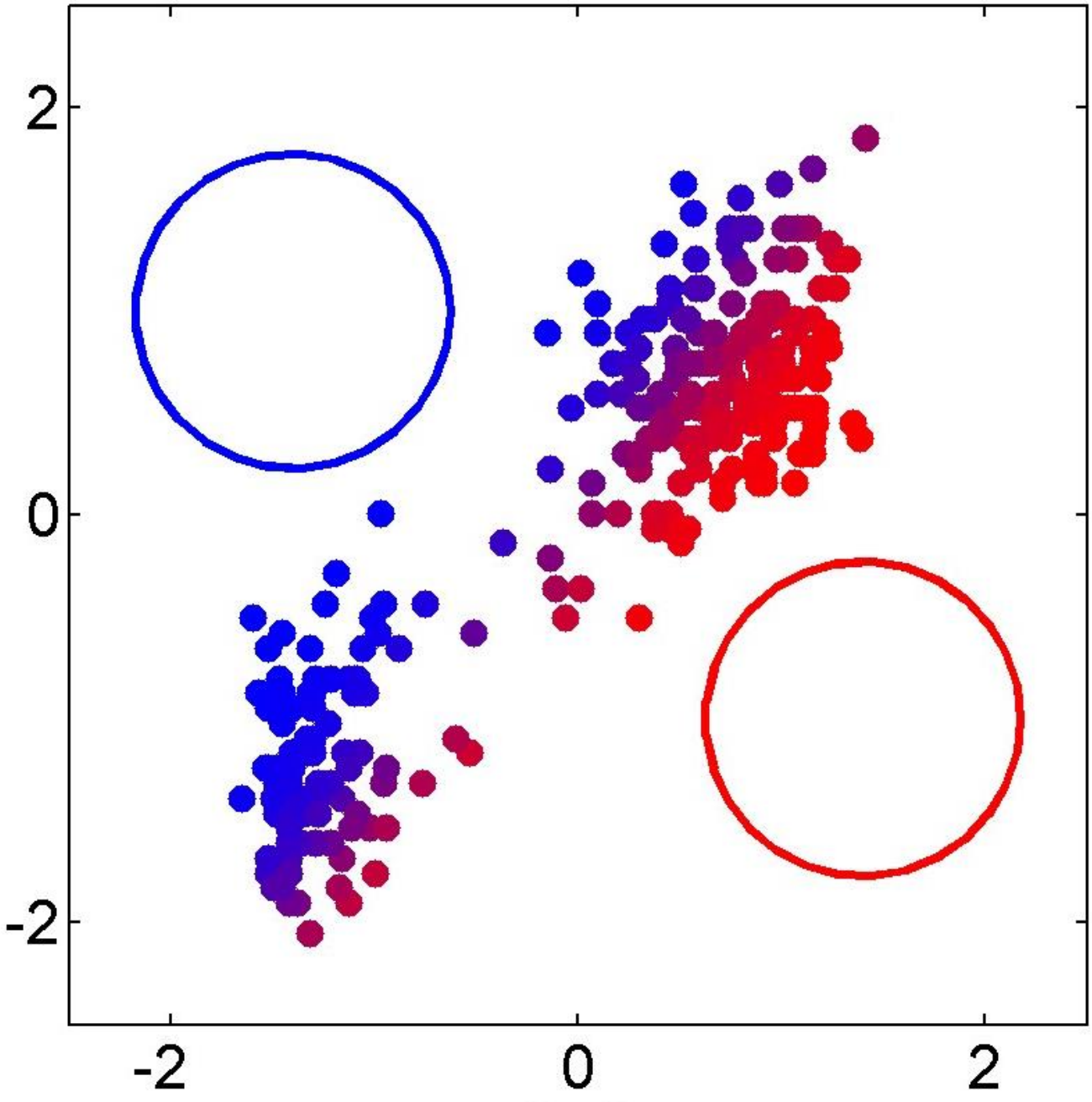
-2
-2
0
2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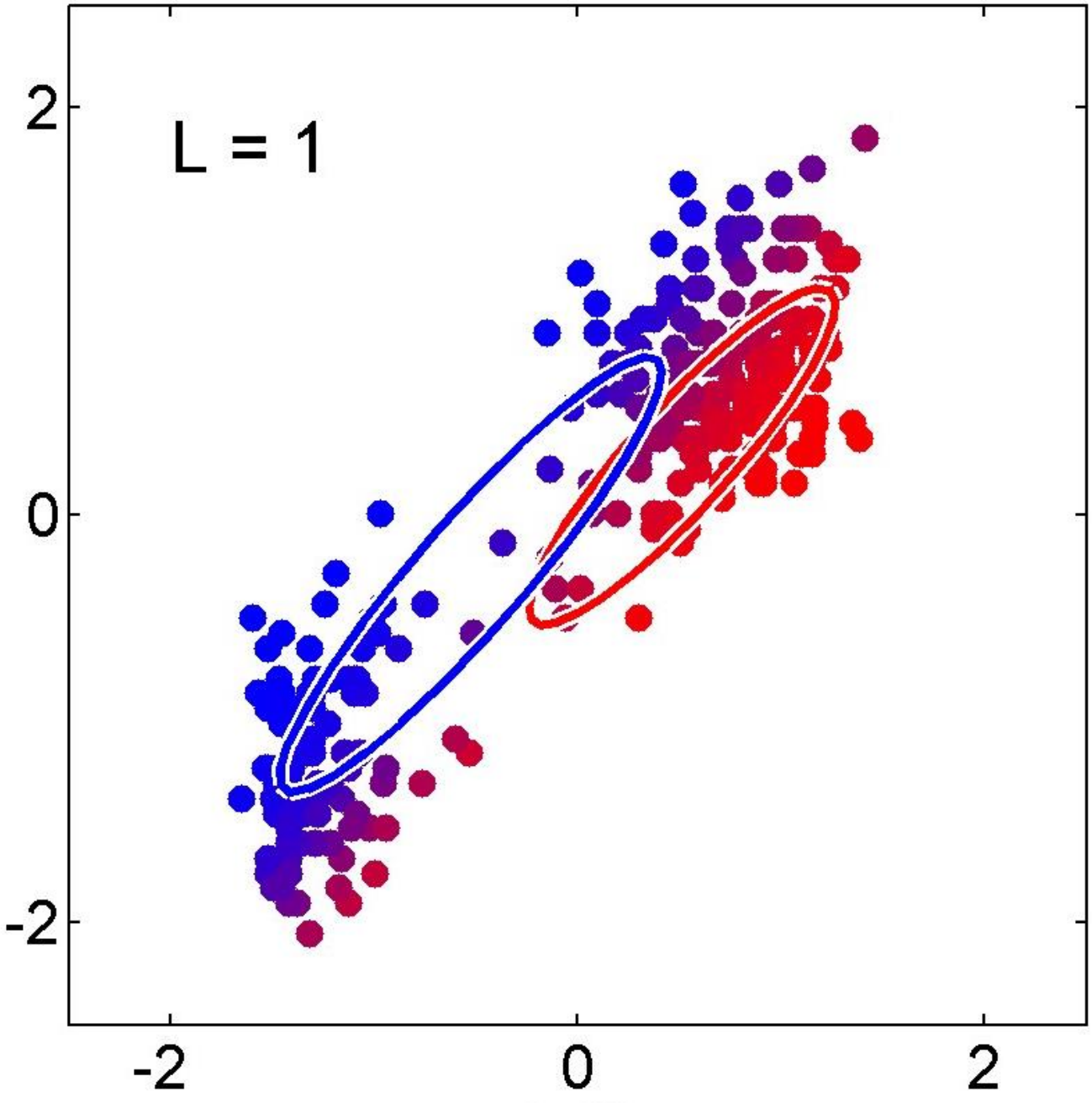
0
-2
-2
0
2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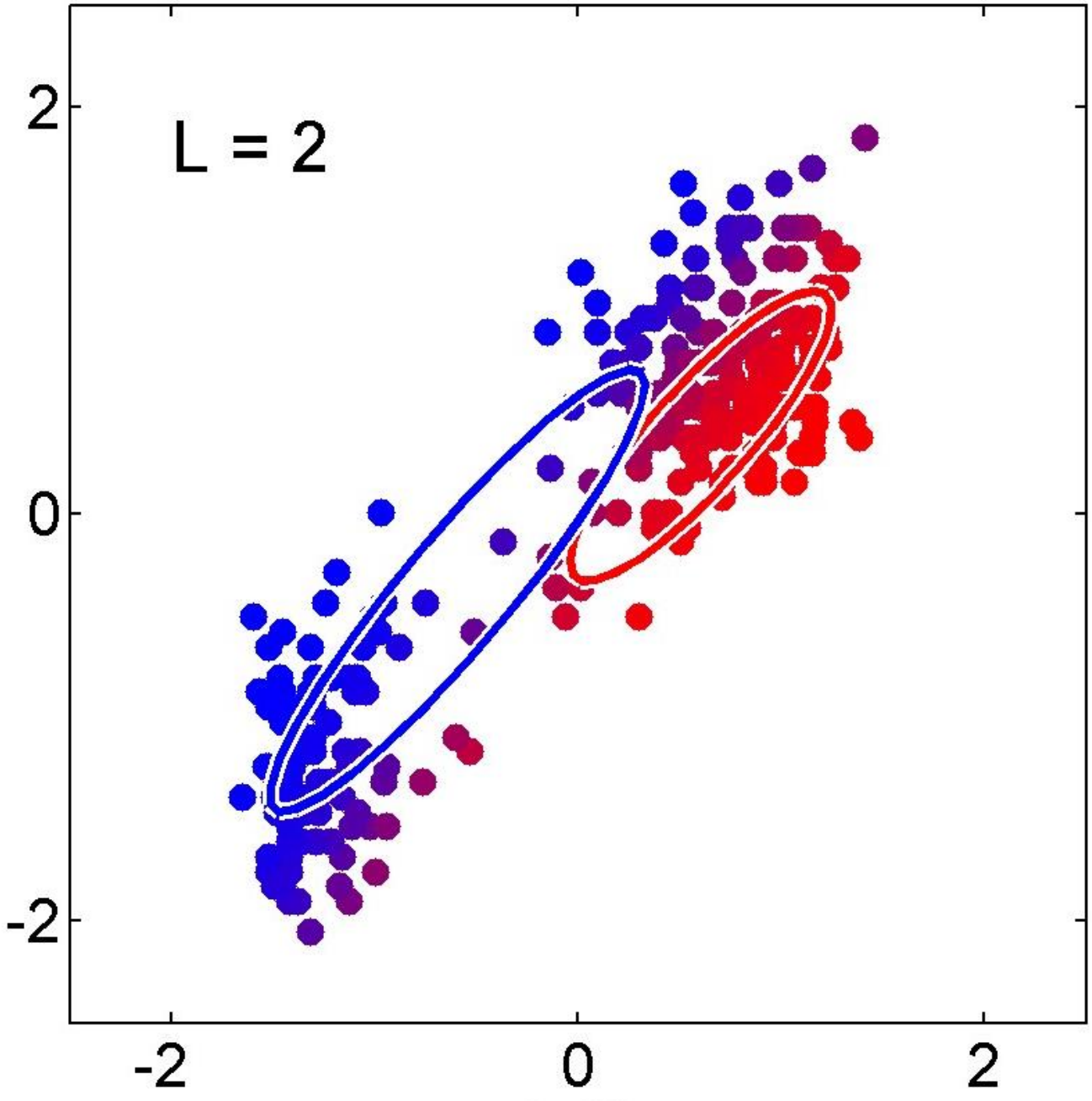
-2
-2
0
2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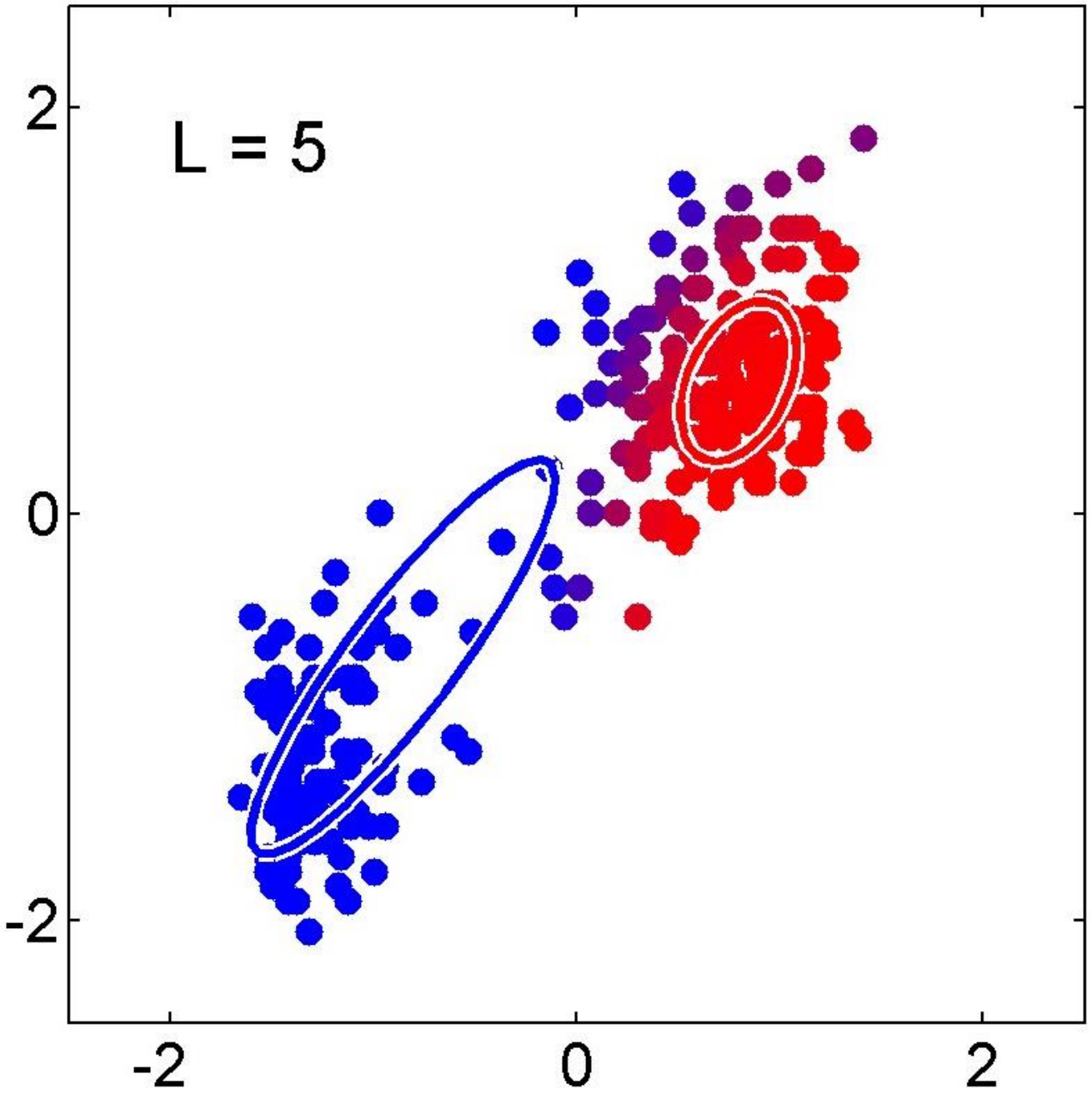
-2
-2
0
2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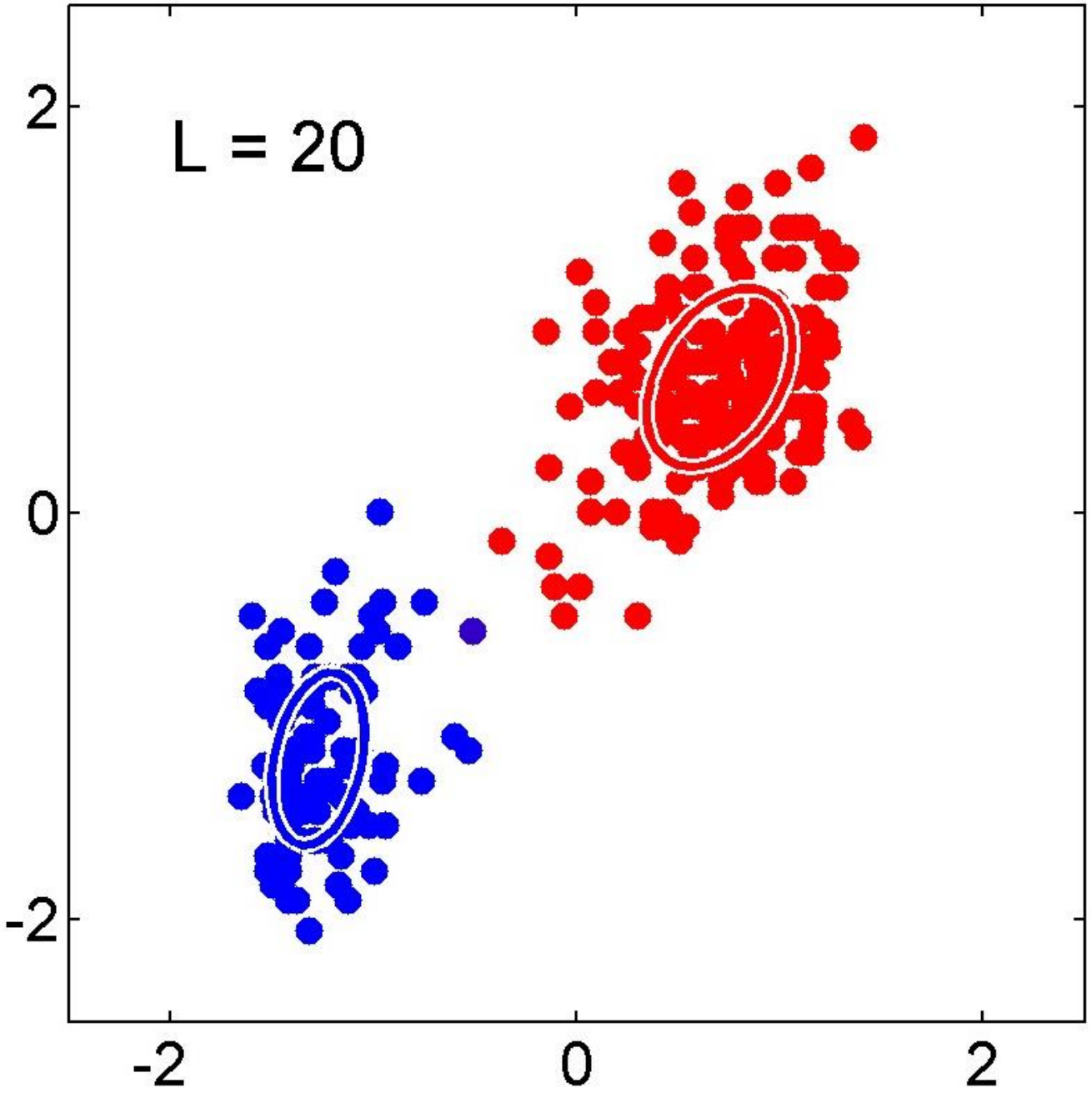
-2
-2
0
2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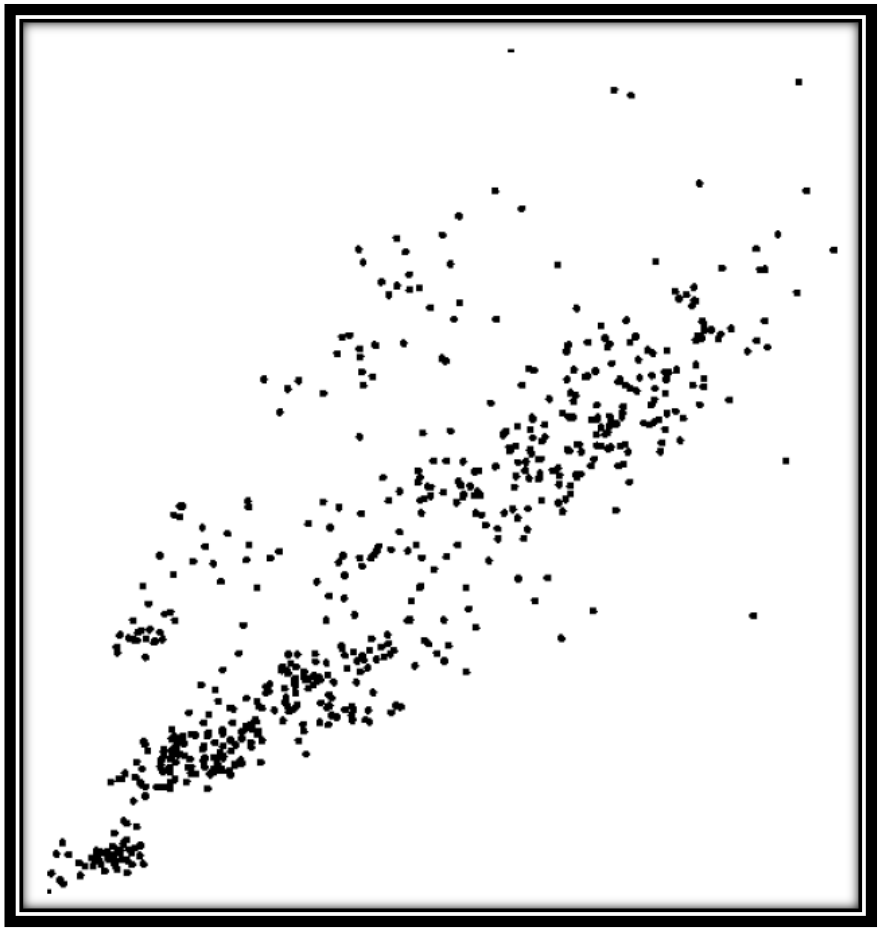
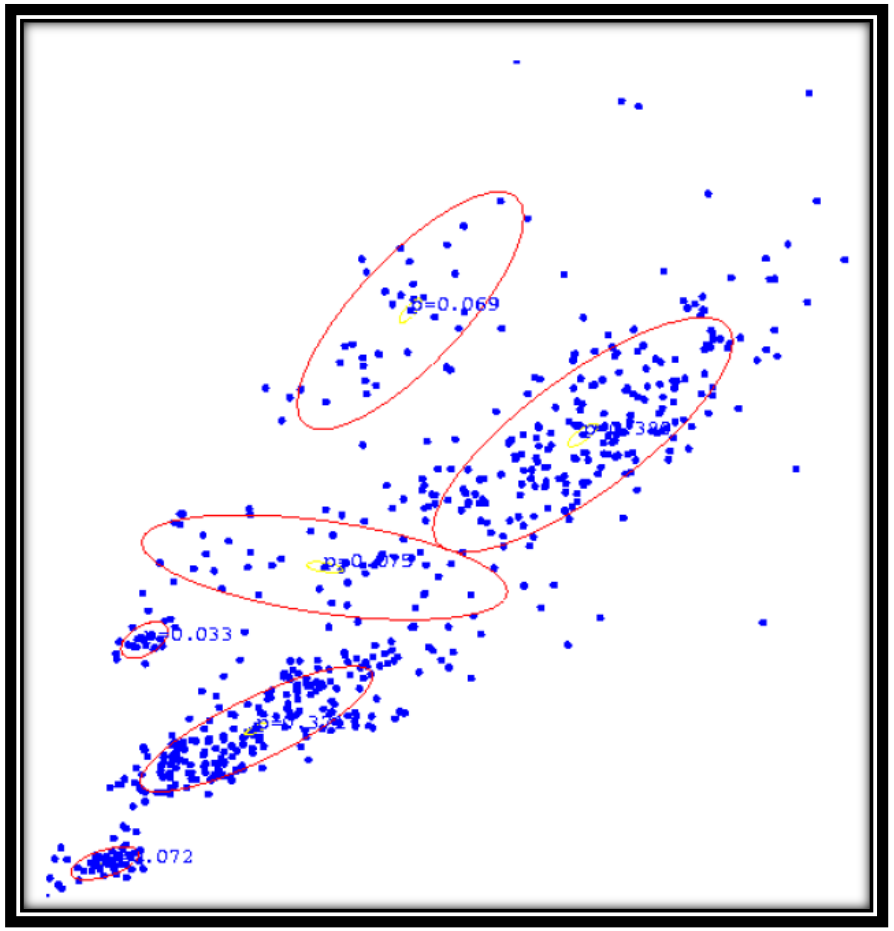
-2
0
2

Another Example

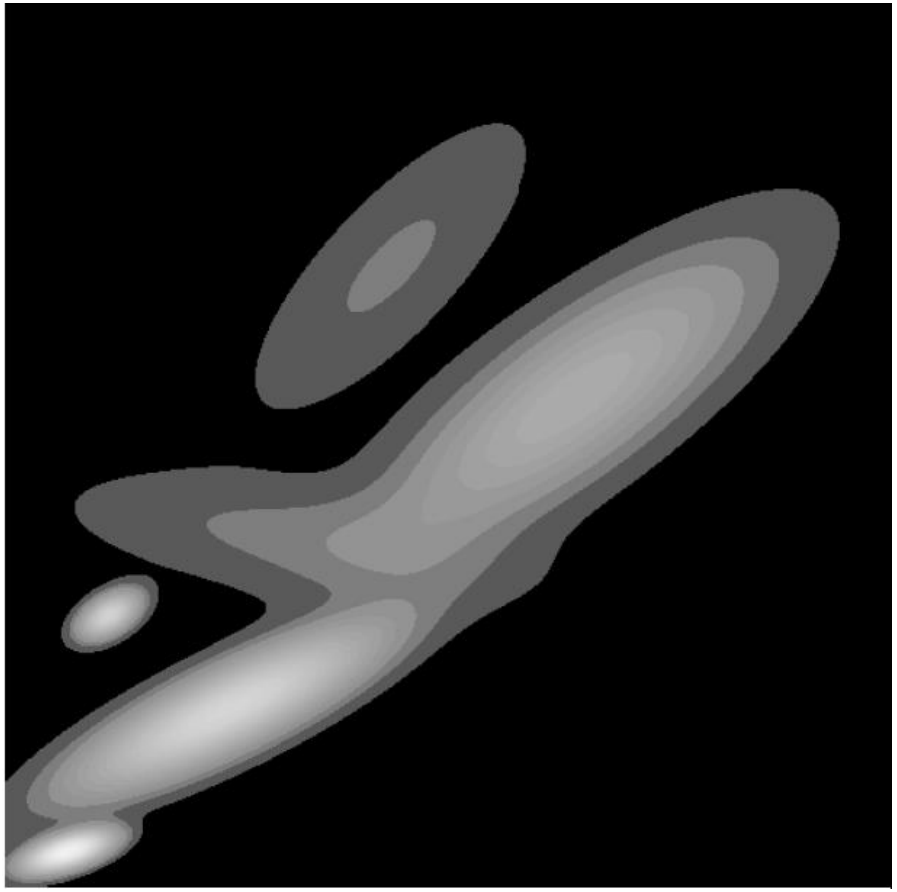
- Data set – 6 clusters





Fitting the Gaussian Mixture

- Resulting density estimation



Another Example

Original image

2 clusters

5 clusters

10 clusters

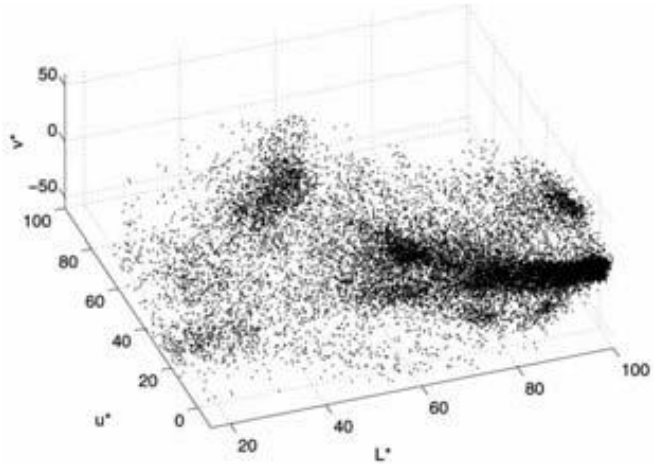
20 clusters

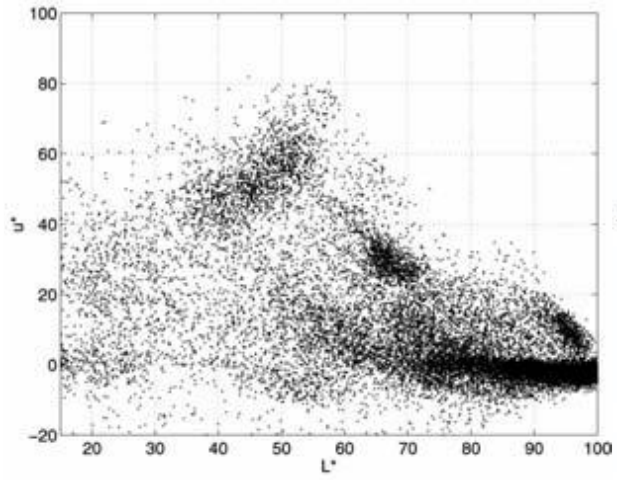
50 clusters

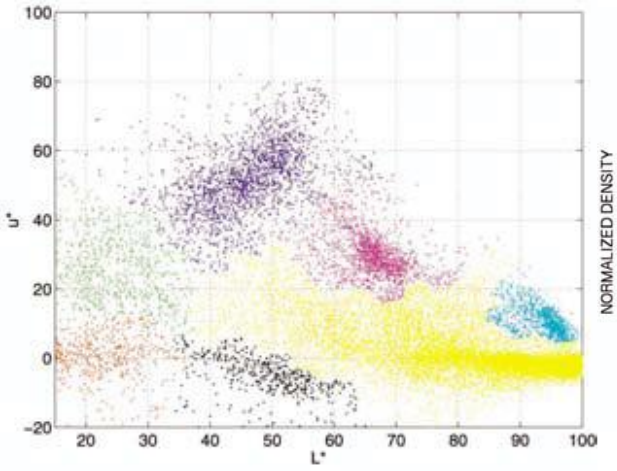
MEAN SHIFT AND MODE FINDING

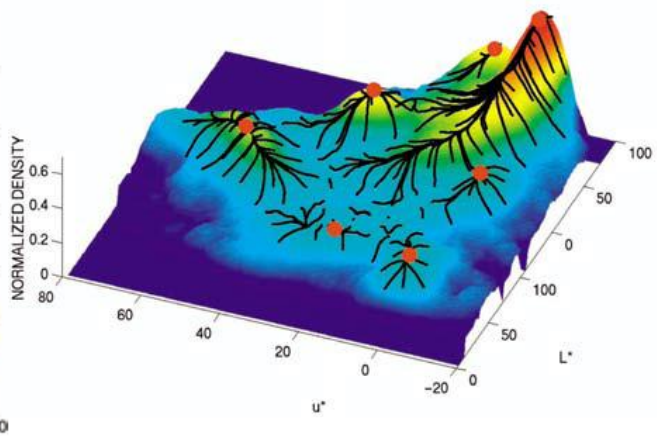
- D. Comaniciu and P. Meer, “Mean shift: A robust approach toward feature space analysis,” IEEE Trans. PAMI, vol. 24, no. 5, pp. 603-619, 2002.
- Slides are excerpted from those of Yaron Ukrainitz & Bernard Sarel

Mean shift and Mode Finding

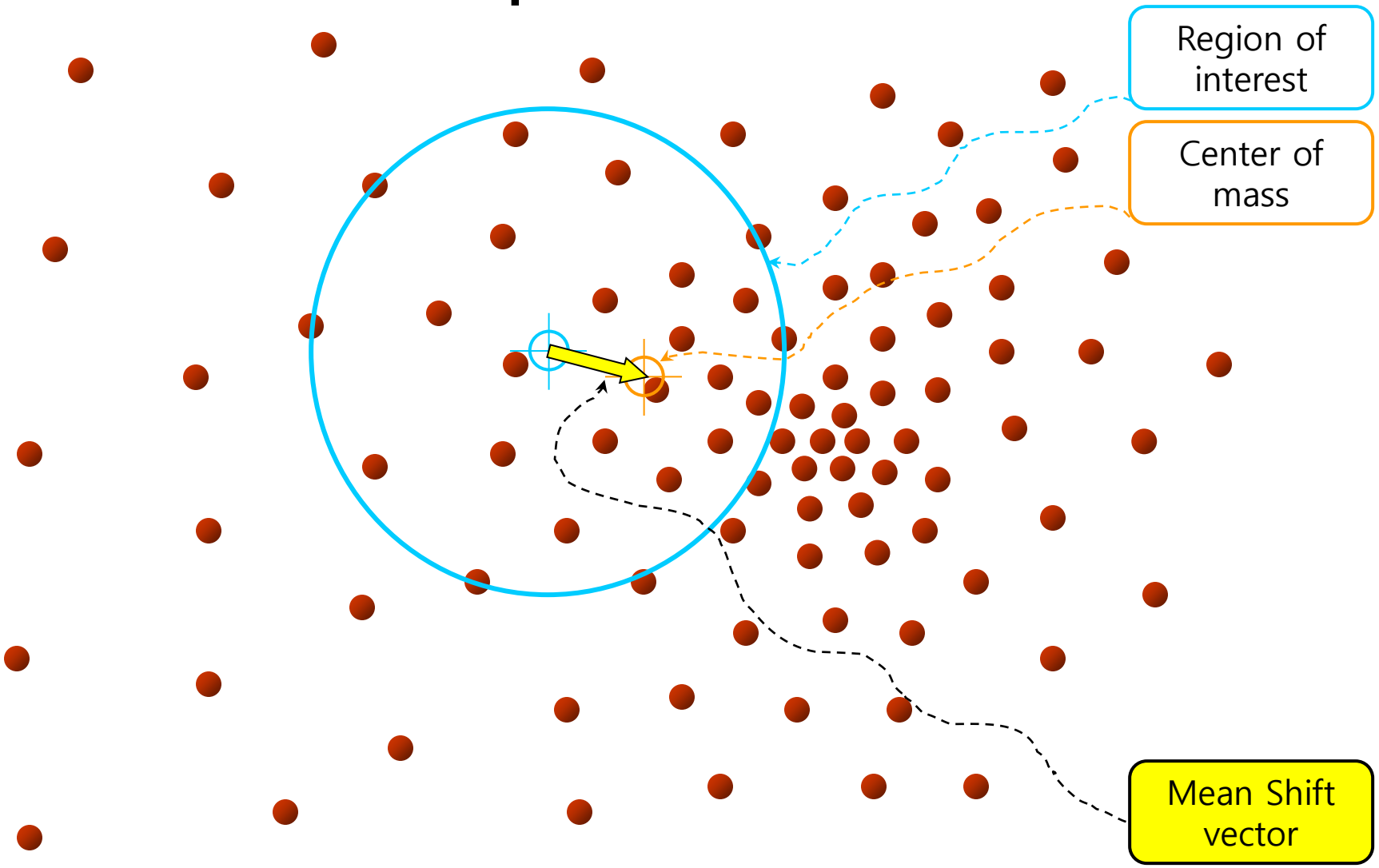






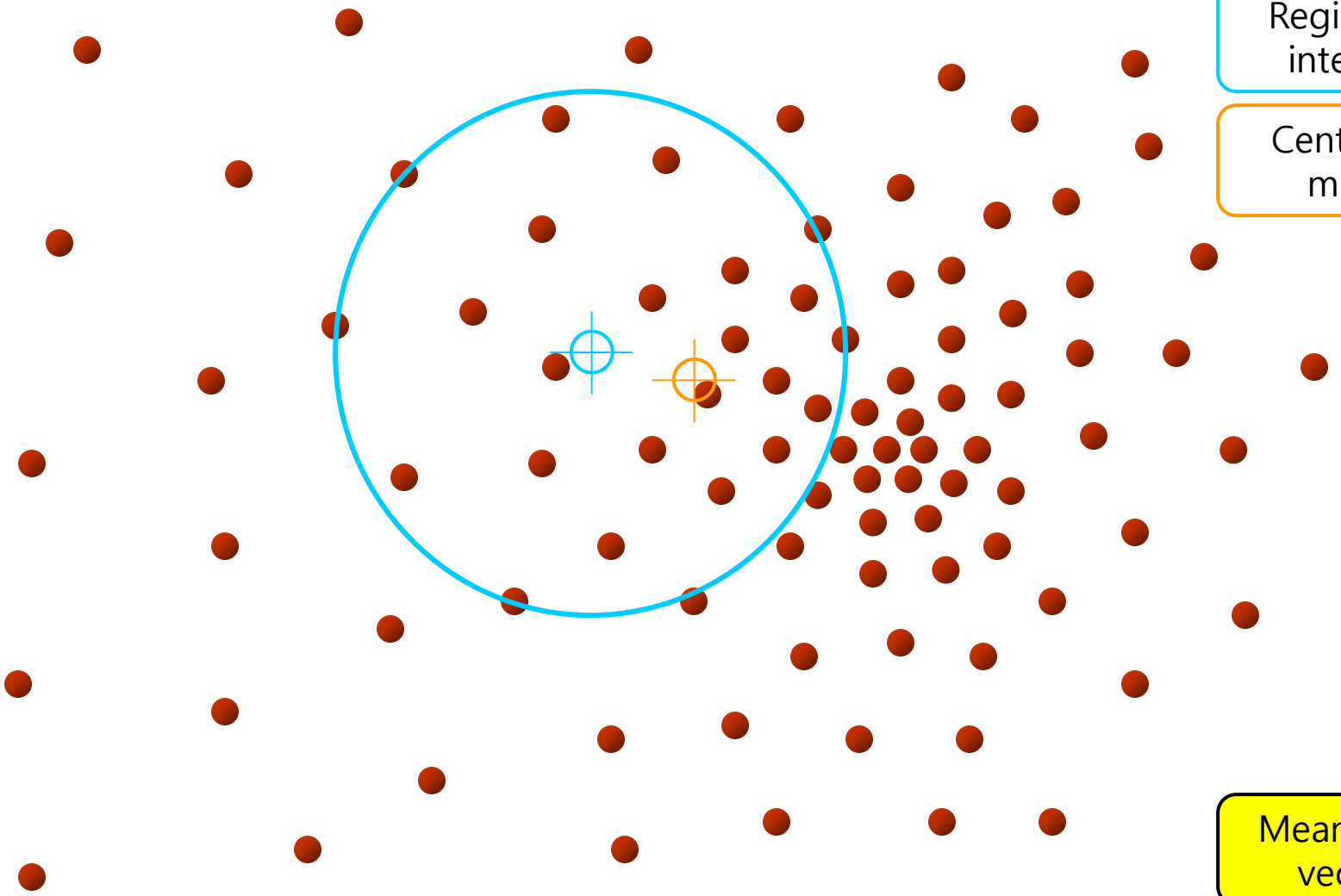


Intuitive Description



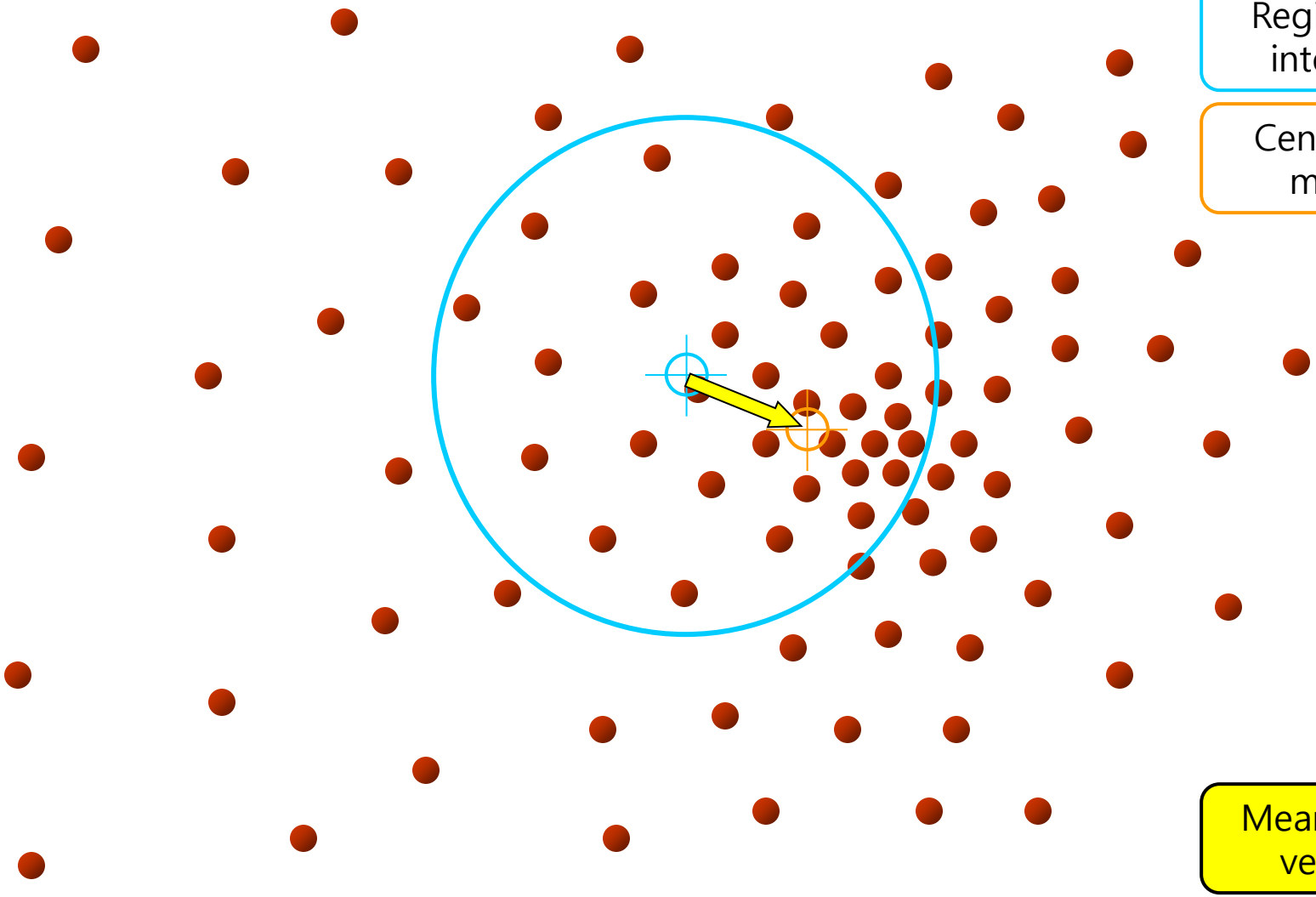
Objective : Find the densest region

Intuitive Description



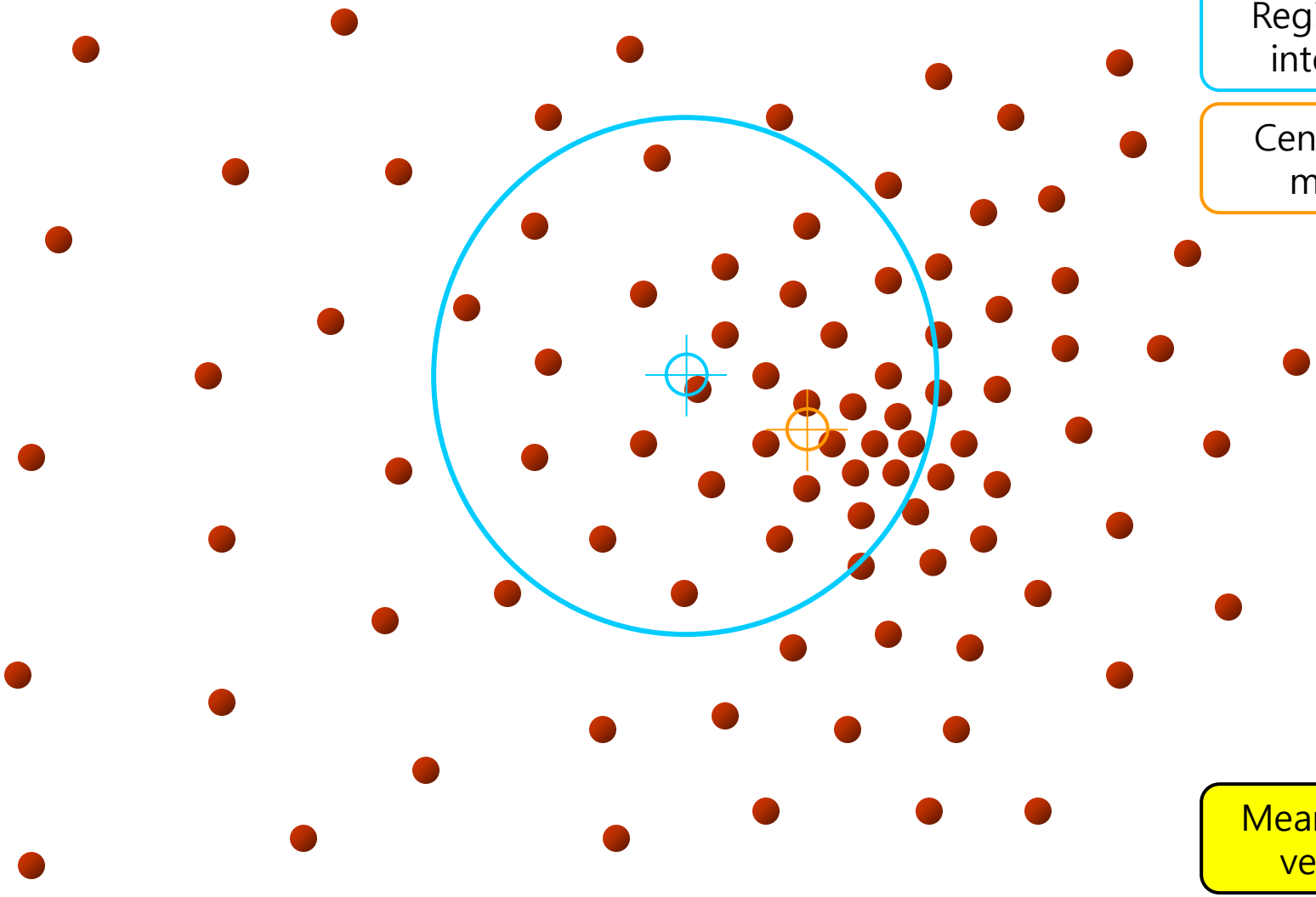
Objective : Find the densest region

Intuitive Description



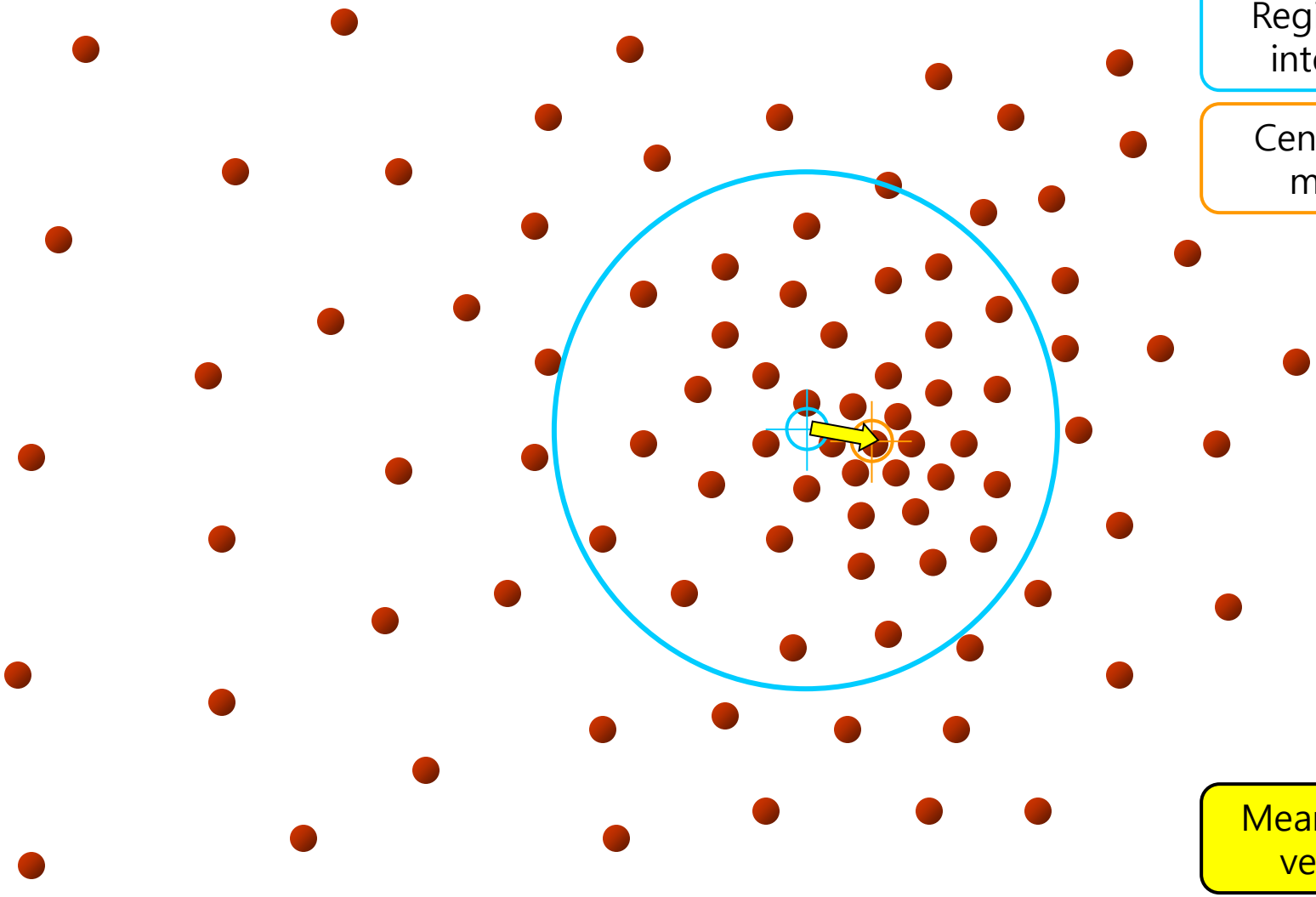
Objective : Find the densest region

Intuitive Description



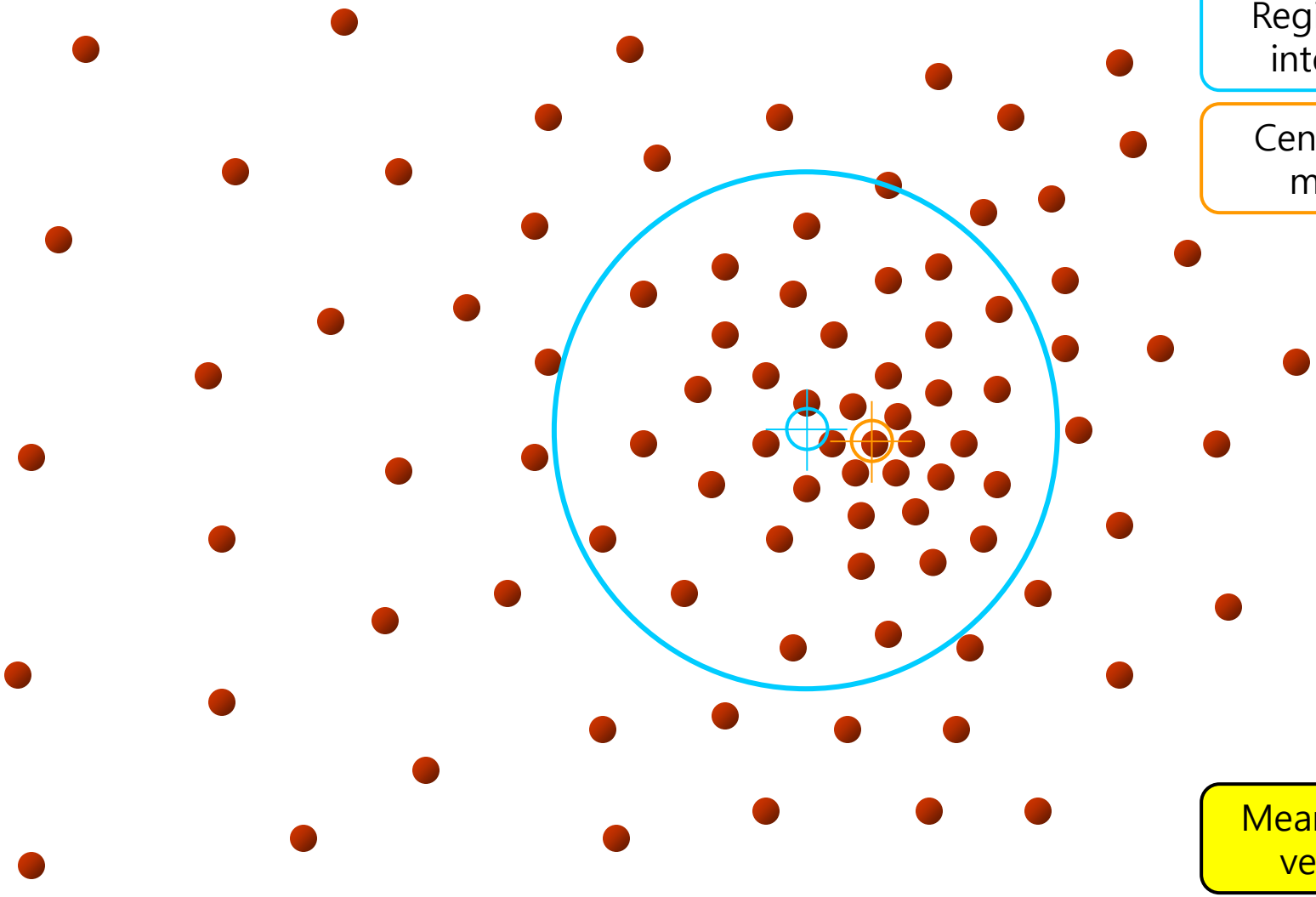
Objective : Find the densest region

Intuitive Description



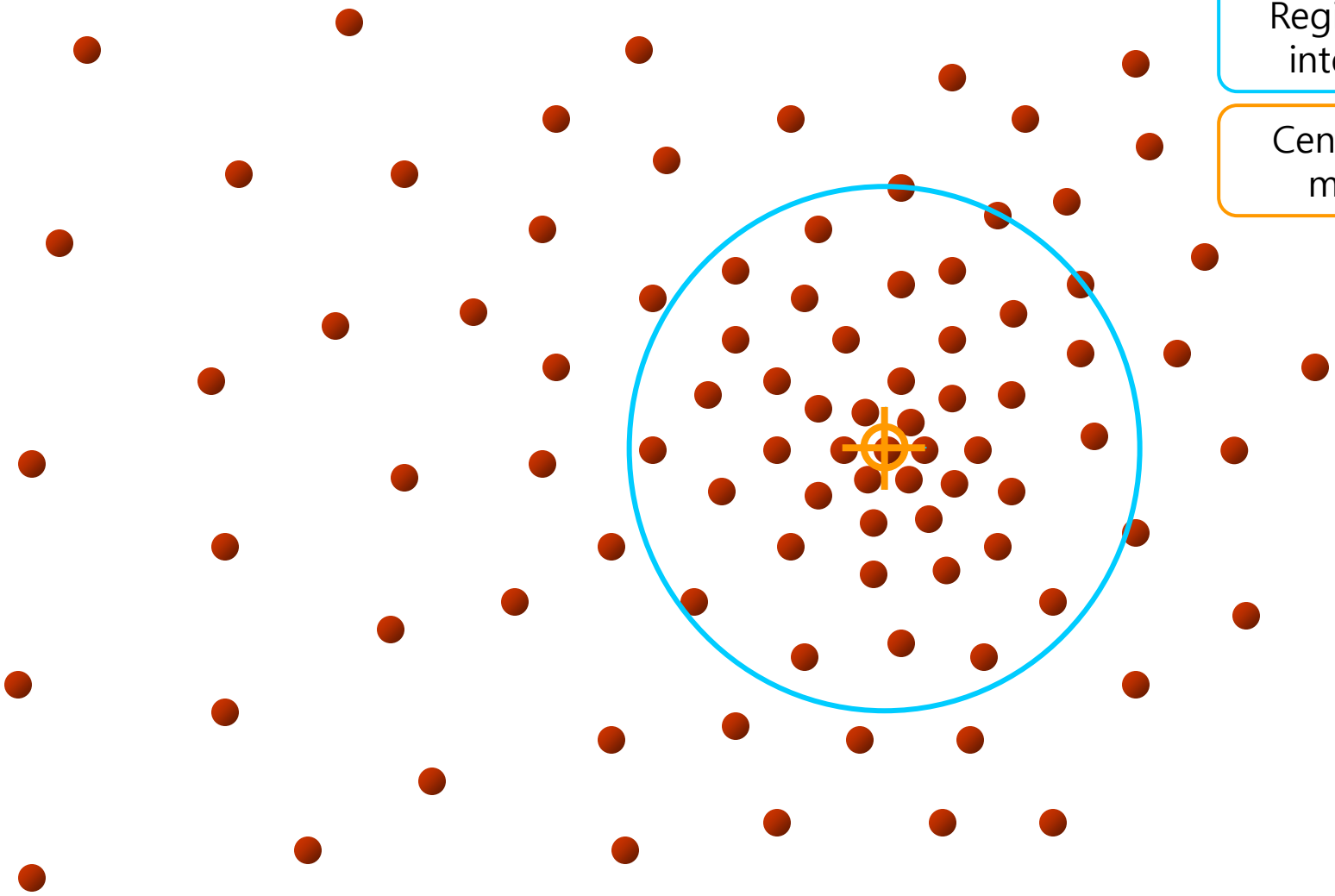
Objective : Find the densest region

Intuitive Description



Objective : Find the densest region

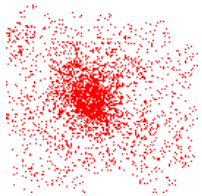
Intuitive Description



Objective : Find the densest region

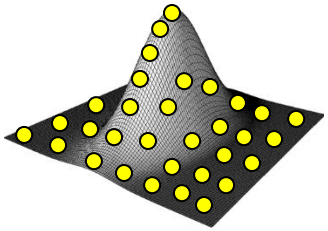
What is Mean Shift ?

A tool for:
Finding modes in a set of data samples, representing an underlying probability density function (PDF) in R^N



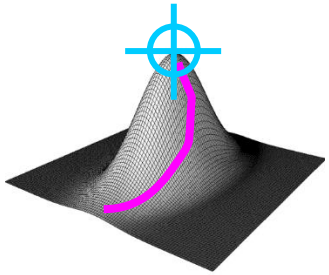
Data

Non-parametric
Density Estimation



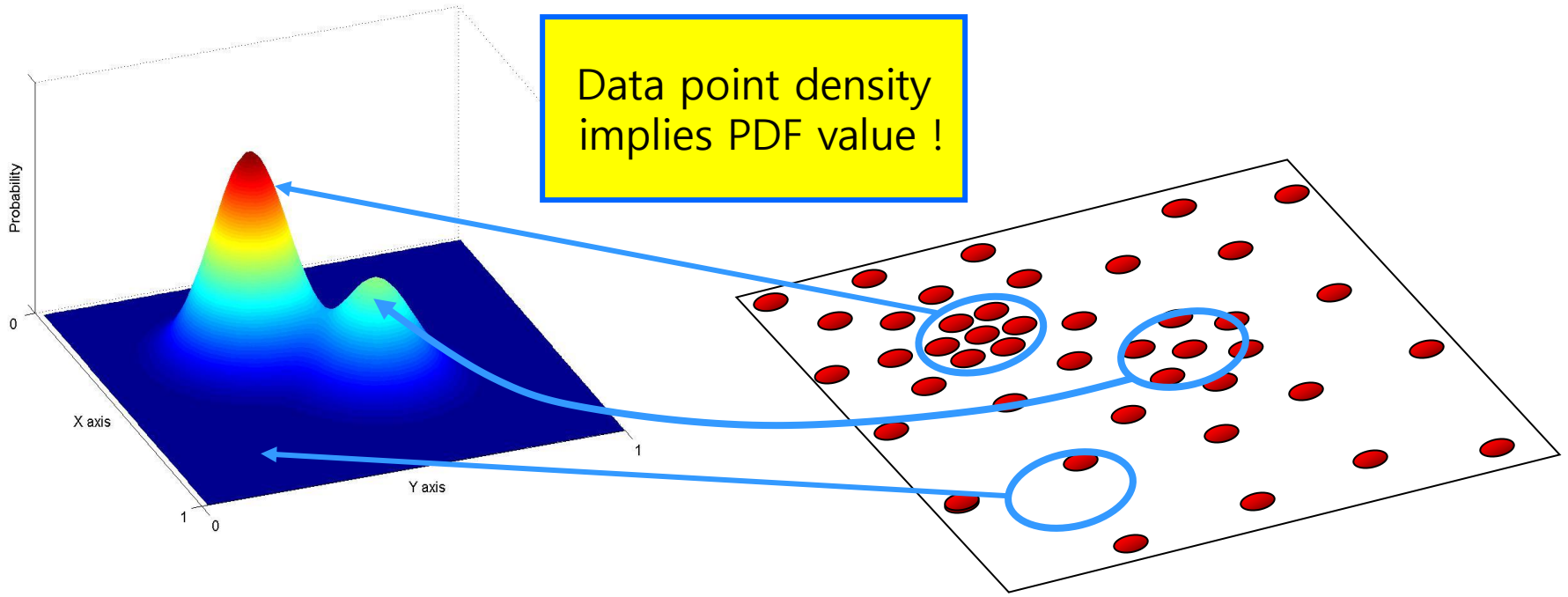
Discrete PDF Representation

Non-parametric
Density **GRADIENT** Estimation
(Mean Shift)



PDF Analysis

Density Estimation



Underlying PDF

Real Data Samples

Density Estimation

- Parametric density estimation

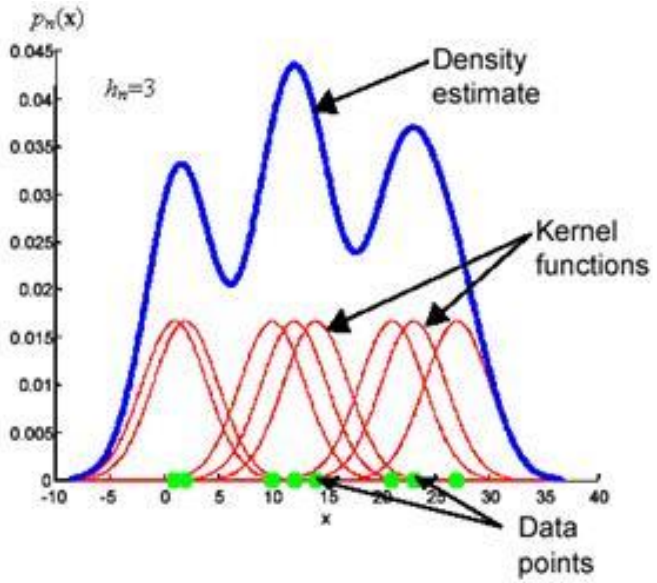
$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-m)^2}{2\sigma^2}\right)$$

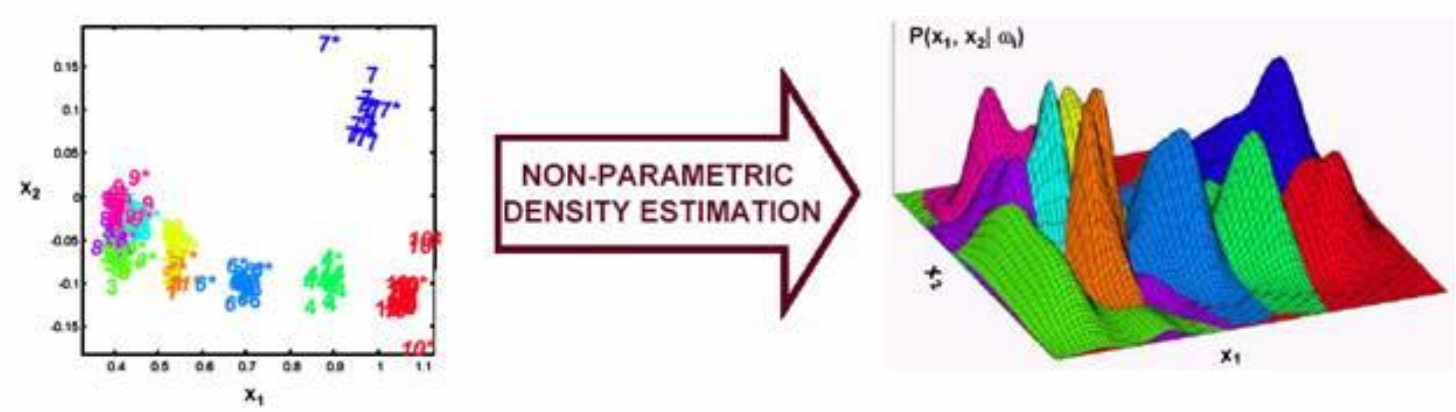
- Nonparametric density estimation

$$f(x) = \sum_i k(x - x_i)$$

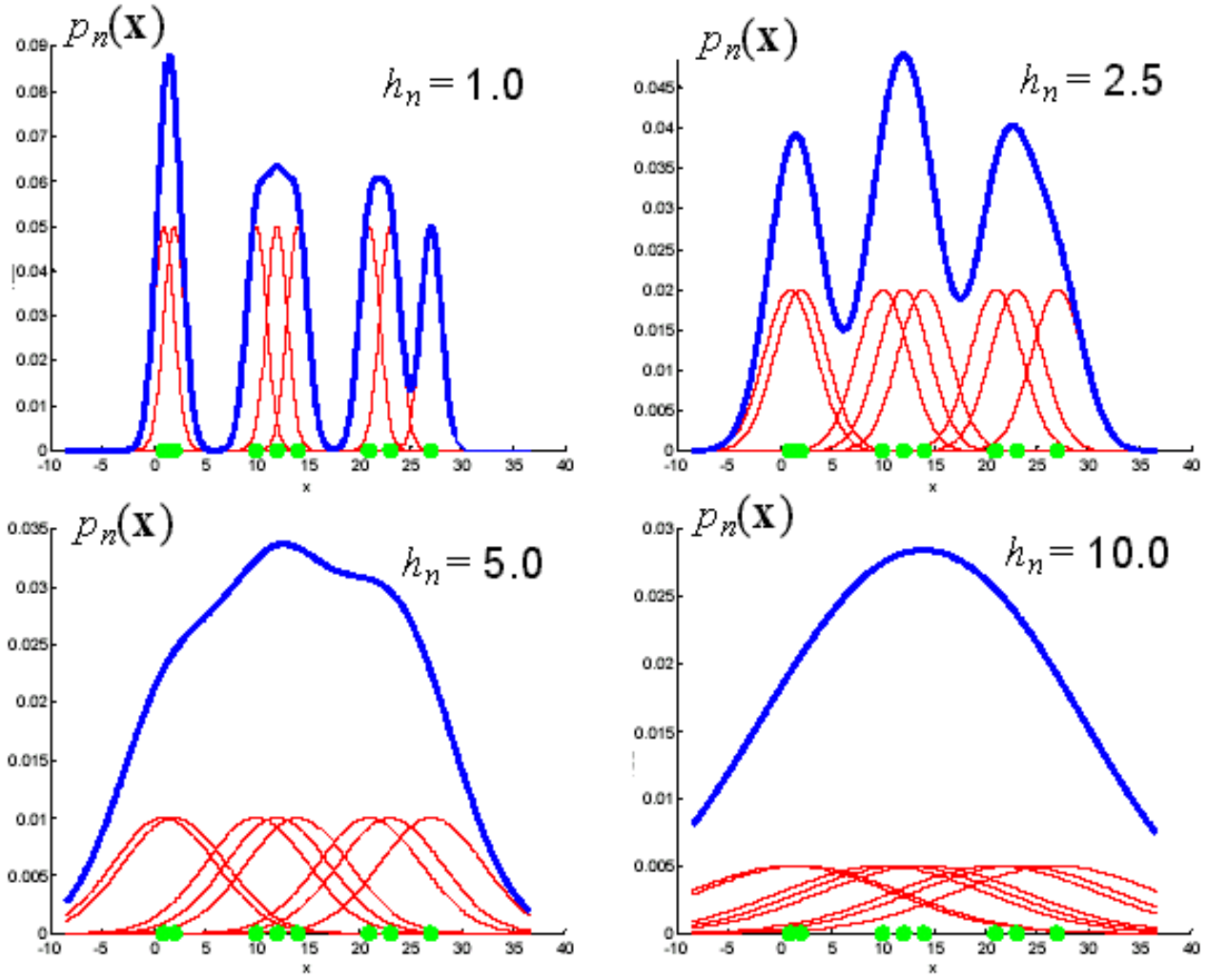
  - Kernel density estimation
  - Parzen window technique

Non-Parametric Density Estimation





Non-Parametric Density Estimation



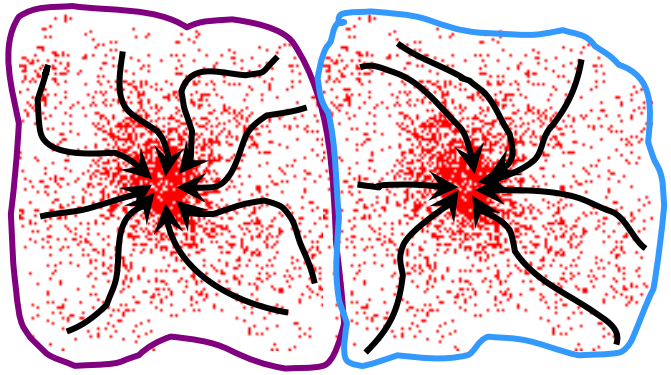
Mean Shift Operation

- In the mean shift procedure, we obtain not the density $f(x)$, but its gradient $\nabla f(x)$
- Clustering
  - Record the moving trajectory of each point
  - All points leading to a mode form a cluster
- A faster approach
  - Randomly subsample input points
  - Keep track of the temporal evolution of each point.
  - Classify the remaining points based on the nearest evolution path

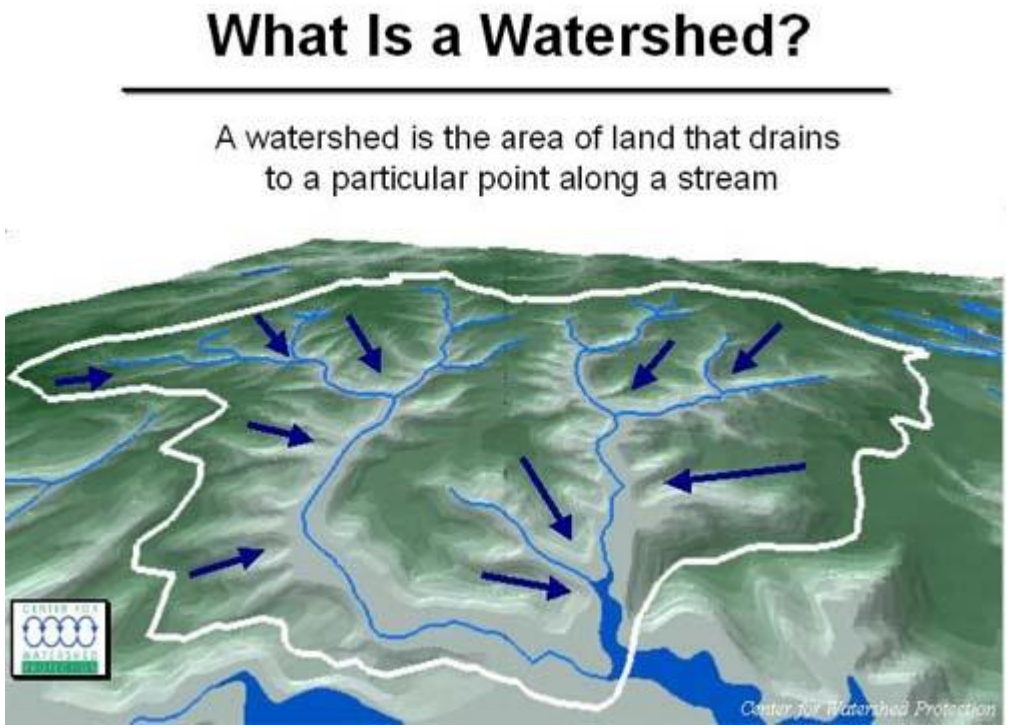
Clustering

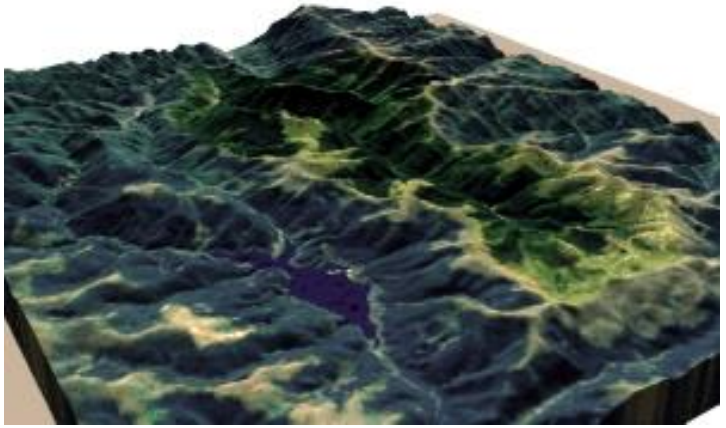
Cluster : All data points in the ***attraction basin*** of a mode

Attraction basin : the region for which all trajectories lead to the same mode



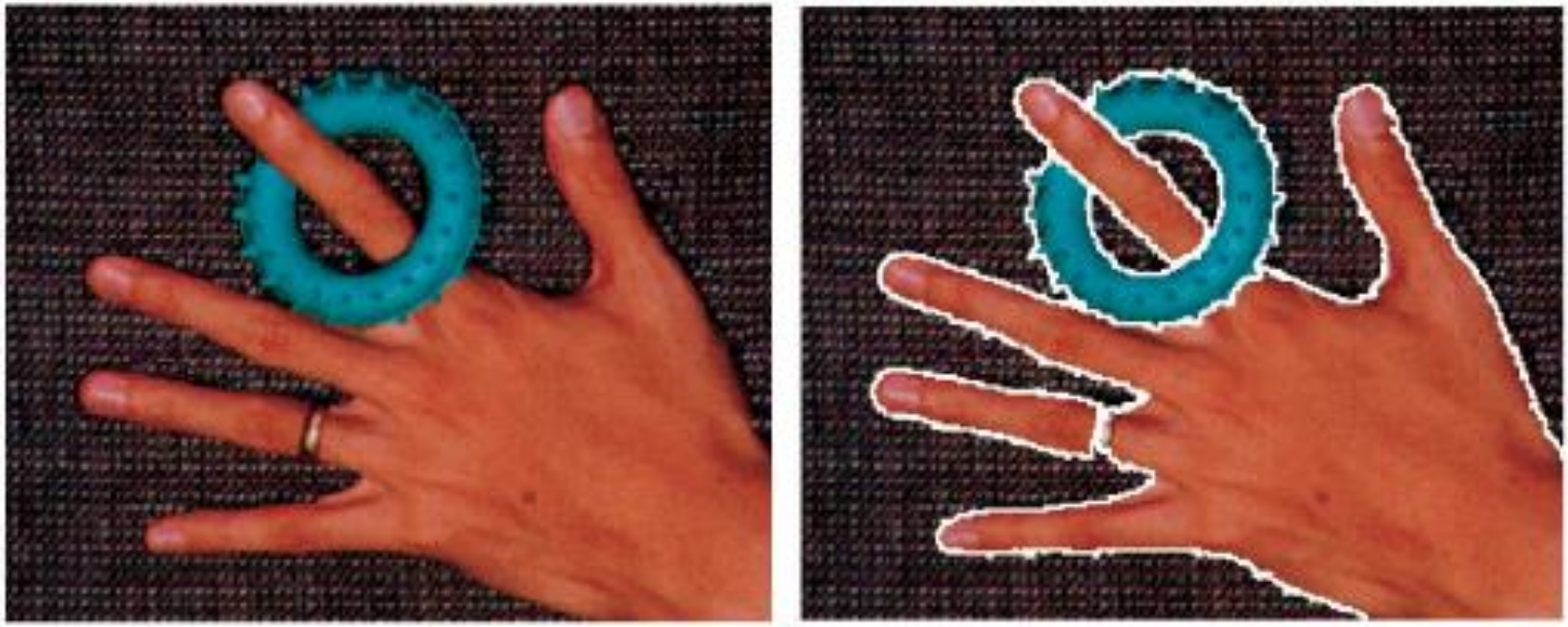
Drainage Basin (Watershed)





Segmentation

Example



Segmentation

Example

Supplemental Materials

Sequential Clique Optimization for Video Object Segmentation

Anonymous ECCV Submission
Paper ID 2253