



Lecture-9



Target Tracking Using Mean Shift


Alper YILMAZ
Computer Vision Lab.
University of Central Florida

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Problem

- Given a target (object) in the first frame track it through all other frames.




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Key Concepts

- Mean
- Mean shift
- Probability Density Functions (PDFs)
- Kernel Density
- Gradient of Kernel Density
- Bhattacharya coefficient

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Mean Shift Vector

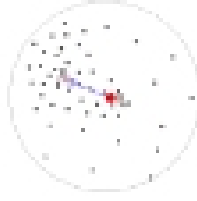
Given:
Data points and approximate location of the mean of this data.

Task:
Estimate the exact location of the mean of the data by determining the shift vector from initial mean.

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Mean Shift Vector Example


$$\mathcal{M}_k(\mathbf{y}) = \left[\frac{1}{n_k} \sum_{i=1}^{n_k} (\mathbf{x}_i - \mathbf{y}_0) \right]$$

n_k : number of points
 \mathbf{y}_0 : initial mean location
 \mathbf{x}_i : data points

Mean shift vector always points towards the direction of the maximum increase in the density.

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Modified Mean Shift (weighted)

$$M_h(y_0) = \left[\frac{\sum_{i=1}^{n_h} w_i(y_0) x_i}{\sum_{i=1}^{n_h} w_i(y_0)} \right] - y_0$$

n_h : number of points in the kernel
 y_0 : initial mean location
 x_i : data points
 h : kernel radius

Weights are determined using kernels (masks):
 Uniform, Gaussian or Epanechnikov

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Properties of Mean Shift

- Mean shift vector has the direction of the gradient of the density estimate.
- It is computed iteratively for obtaining the maximum density in the local neighborhood.

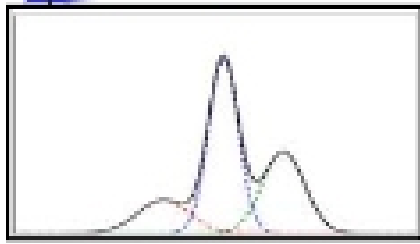
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Probability Density Functions (PDFs)

- Parametric models
 - Uniform
 - Gaussian
 - Exponential
 - ...
- Some PDFs can not be modeled by parametric models

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Probability Density Functions (PDFs)

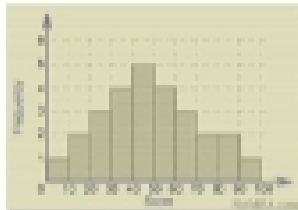


Mixture of Gaussians

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Histogram

- The histogram records the count of data points falling in different ranges, called bins.
- It captures the frequency distribution of the data.



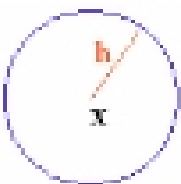
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Kernel Density Estimation

- Kernel Density estimate can be used to represent any non-parametric pdf. (general)
- All data points are saved. (large storage)
- The probability of any given value is calculated by using all the data points.

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Kernel Density Estimate

$$\hat{f}(x) = \frac{1}{nh^d} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right)$$


n : number of points in the kernel
 h : window radius
 x : mean vector
 d : number of dimensions
 K : Kernel density function


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Possible Kernels

- Uniform kernel
- Normal kernel (convex, monotonic decreasing)


$$K_{\sigma} = (2\pi)^{-d/2} e^{-\|x\|^2 / 2\sigma^2}$$

d : number of dimensions


- Epanechnikov kernel (convex, monotonic decreasing)

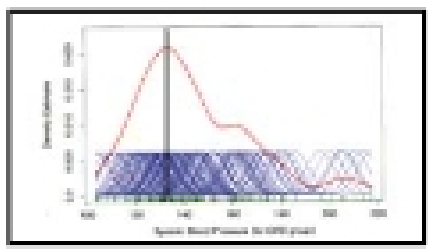
$$K_{\sigma}(x) = \begin{cases} \frac{1}{2} c_d^{-1} (d+2) (1 - \|x\|^2) & \text{if } \|x\| < 1 \\ 0 & \text{otherwise} \end{cases}$$

c_d : volume of unit d-dim sphere
 d : number of dimensions



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Kernel Density Estimation

$$\hat{f}(x) = \frac{1}{nh^d} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right)$$


Kernel Density

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Estimate of Density Gradient

density estimate: $\hat{f}(x) = \frac{1}{nh^d} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right)$

gradient of density estimate: $\hat{\nabla}f(x) \equiv \nabla\hat{f}(x) = \frac{1}{nh^d} \sum_{i=1}^n \nabla K\left(\frac{x-x_i}{h}\right)$

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Mean Shift Vector in Terms of Epanechnikov Kernel

$$\hat{\nabla}f(x) \equiv \nabla\hat{f}(x) = \frac{1}{nh^d} \sum_{i=1}^n \nabla K\left(\frac{x-x_i}{h}\right)$$

Using Epanechnikov kernel: $K_{\sigma}(x) = \frac{1}{2} c_d^{-1} (d+2) (1 - \|x\|^2)$

$$\hat{\nabla}f(x) = \frac{d+2}{nh^{d+2} c_d} n \left(\frac{1}{n} \sum_{i=1}^n [x_i - x] \right) = \frac{d+2}{h^{d+2} c_d} M_s(x)$$

Homework

mean shift vector

n : number of points in unit d-dimensional sphere

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Target Model for Tracking

- Features used for tracking includes:
 - Gray level
- Feature probability distribution are calculated by using weighted histograms.
- The weights are derived from Epanechnikov kernel.

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