Mean Shift Segmentation

Proseminar "Aufgabenstellungen der Bildanalyse und Mustererkennung„

1

Thu Huong Nguyen
Fakultät Informatik – TU Dresden

Contents

1. Overview about Mean Shift Segmentation
2. Mean Shift algorithm
   - Kernel density estimation
   - Kernel
3. Mean shift segmentation
4. Applications of Mean Shift
   - Clustering
   - Filtering
   - Visual tracking
5. Conclusions

Overview about Mean shift Segmentation

- What is Mean Shift ?
  - For each data point, mean shift defines a window around it and computes the mean of data point. Then it shifts the center of window to the mean and repeats the algorithm till it convergens
  - Mean shift is a nonparametric iterative algorithm or a nonparametric density gradient estimation using a generalized kernel approach
  - Mean shift is the most powerful clustering technique
  - Mean shift is used for image segmentation, clustering, visual tracking, space analysis, mode seeking ...

- Mean shift segmentation is an advanced and vertisale technique for clustering based segmentation

Mean Shift algorithm

- Kernel density estimation
  - Kernel density estimation is a non parametric way to estimate the density function of a random variable. It is a popular method for estimating probability density.
  - This is usually called as the Parzen window technique.
  - *K(x)* : kernel, h: bandwidth parameter (radius), n data point x_i , i=1..n in d-dimension space R^d
  - Kernel density estimator for a given set of d-dimensional points is

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

Mean Shift algorithm

- The estimate of the density gradient is defined as the gradient of the kernel density estimate

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

Setting it to 0 and define
g(x) = -K'(x) we have

$$m(x) = \frac{\sum_{i=1}^{n} g\left(\frac{x-x_i}{h}\right) x_i}{\sum_{i=1}^{n} g\left(\frac{x-x_i}{h}\right)} - x$$

is called Mean shift vector (or sample mean shift)

MEAN SHIFT ALGORITHM

- The mean shift vector computed with kernel G is proportional to the normalized density gradient estimate obtained with the kernel K
- The mean shift algorithm seeks a *mode* or local maximum of density of a given distribution
- Mean shift can be sumed up like this
  - For each point x_i
  - Choose a search window
  - Compute the mean shift vector $m(x_i^t)$
  - Repeat till convergence

Mean Shift algorithm

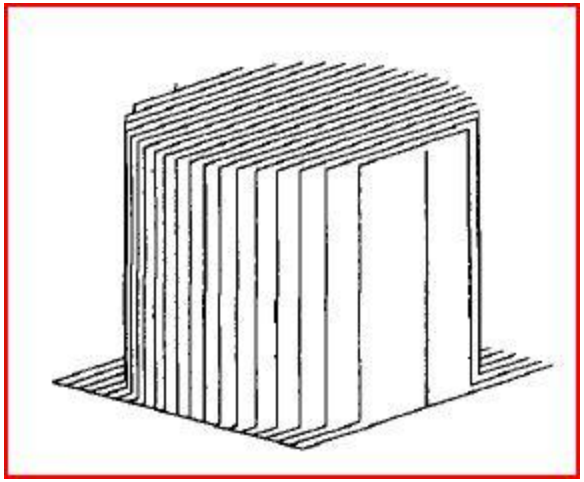
Mean Shift algorithm

- Kernel K is a fuction of $\|\mathbf{x}\|^2$

$$K(\mathbf{x}) = k(\|\mathbf{x}\|^2)$$

- k is called the profile of K
- The simplest kernel is the flat kernel

$$F(x) = \begin{cases} 1 & \text{if } \|x\| \le 1 \\ 0 & \text{if } \|x\| > 1 \end{cases}$$



Mean Shift algorithm

Shadow of the Kernel K is kernel H if

$$\boxed{m(x) - x = \frac{\sum_{s \in S} K(s-x)w(s)s}{\sum_{s \in S} K(s-x)w(s)} - x,}$$

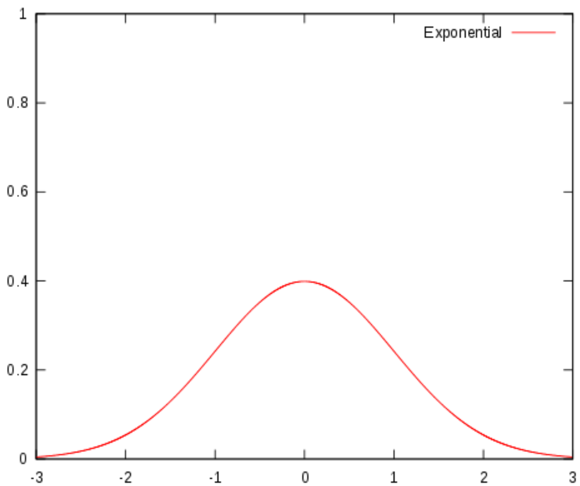
is in the gradient direction at x of the density estimate using H

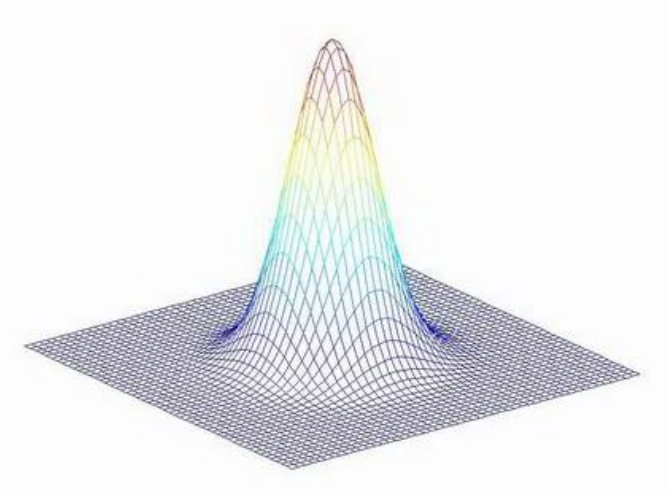
$$\boxed{q(x) = \sum_{s \in S} H(s-x)w(s).}$$

Mean Shift algorithm

- The most popularly kernel is Gaussian kernel

$$K(\mathbf{x}) = \exp(-\|\mathbf{x}\|^2)$$

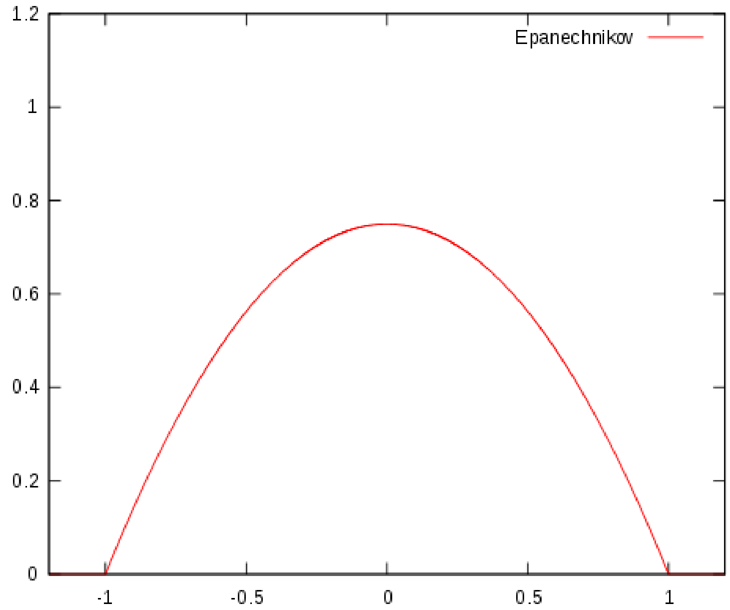




- And their shadows *SK(x) = K(x)*

MEAN SHIFT ALGORITHM

- Epanechikov kernel
  - $E(x) = \frac{3}{4}\,(1 - x^2)$ *if* $|x| \leq 1$
    0 *else*
- and its shadow SE(x) = E(x)



Mean Shift Segmentation

- An advanced and versatile technique for clustering-based segmentation
- Let $\{x_i\}_{i=1\ldots n}$ be the original image points, $\{z_i\}_{i=1\ldots n}$ the points of convergence, and $\{L_i\}_{i=1\ldots n}$ a set of labels

Mean Shift Segmentation

- For each $i = 1\ldots n$ run the mean shift procedure for x_i and store the convergence point in z_i .
- Identify clusters $\{C_p\}_{p=1\ldots m}$ of convergence points by linking together all z_i which are closer than 0,5 from each other in the joint domain.
- For each $i = 1\ldots n$ assign $L_i = \{p \mid z_i \epsilon C_p\}$.
- Optional: Eliminate spatial regions smaller than
- M pixels.

Mean Shift Segmentation

- Parameter of mean shift segmentation
  - h_s : *Spatial resolution parameter*

    Affects the smoothing, connectivity of segments

    Chosen depending on the size of the image, objects
  - h_r : *Range resolution parameter*

    Affects the number of segments

    Should be kept low if contrast is low
  - M : *Size of smallest segment*

    Should be chosen based on size of noisy patches

Samples of mean shift segmentation

original

$(h_s, h_r) = (8,4)$

$(h_s, h_r) = (8,7)$

Samples of mean shift segmentation

original

$(h_s, h_r) = (8,8)$

$(h_s, h_r) = (8,7)$

Samples of mean shift segmentation

$(h_s, h_r) = (8,4)$

$(h_s, h_r) = (16,4)$

$(h_s, h_r) = (16,16)$