Fast Prototyping Exercise 2

Exercises, 8, 9, 10
CSC872
Pattern Analysis and Machine Intelligence

https://bidal.sfsu.edu/~kazokada/csc872/
Segmentation_Data.zip

Download this!

Fast Prototyping Exercise

- Fast Prototyping
  - Learn how to do a quick proof of concept by building a prototype
  - Correctness matters (no sloppy algorithm!)
  - Speed matters (no beautification!)
  - No perfect SE necessary
  - No copying of codes online.
  - Parameterization/Visualization/Experimentation
    - Find out what are **free parameters** in your algorithm whose value must be hand-picked by you
    - Learn how to view internal variable's current values
    - Learn how to visualize your prototype's results in plots/images etc
    - Tweak the parameter values and study your prototype's behavior to understand the how algorithm works
- Group Work
  - You are encouraged to freely exchange ideas and codes
  - Contributions to others are as valuable as making your own work

Fast Prototyping Exercise

- **Please upload your matlab codes thru iLearn forum for my grading and your playing!**
  - **First two exercises: Due on midnight of the day (just what you did during the exercise)**
  - **Third last exercise: Due on midnight next day (complete version with some doc/screen shots of running the code)**
- **Your grade on FP exercise will be partly based on these submitted codes and what I observe during the in-class exercises.**
- **If received helps from others and/or used codes from others, please credit the person who helped you.**

Platforms

- MATLAB
  - MathWorks: http://www.mathworks.com/
  - http://en.wikipedia.org/wiki/MATLAB
- MATLAB @ SFSU
  - https://at.sfsu.edu/at-mathworks-matlab
- Various tutorials available online
  - https://matlabacademy.mathworks.com/?s_tid=acb_tut

Public Libraries

- OpenCV (Computer Vision)
  - http://www.intel.com/technology/computing/opencv/overview.htm
- ITK (Medical Imaging)
  - http://www.itk.org/
- WEKA (Machine Learning)
  - http://www.cs.waikato.ac.nz/~ml/weka/index.html

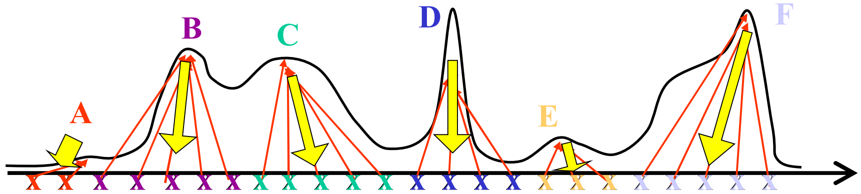
Segmentation

- Image Segmentation
  - Label pixels according to the image intensity such that pixels with similar intensity have same label

  1) Intensity-based Features: use only proximity in intensities
     - Pixels placed far away can be grouped together due to similar value
  2) Spatio-intensity-based: Features use both space and intensity proximity
     - Segment a connected-components with similar intensity values!

Segmentation cond.

- Segmentation is a labeling process
- Edge-preserved smoothing
- Density-based smoothing



- Grouping of Modes

Paper 2

- **D. Comaniciu, P. Meer,**
- ***Mean Shift: A Robust Approach toward Feature Space Analysis*, IEEE Trans. Pattern Analysis Machine Intelligence, 24(5):603-619 (2002)**
- http://comaniciu.net

Data

- I provide a set of nine test images
- **https://bidal.sfsu.edu/~kazokada/csc872/Segmentation_Data.zip**
- 3 Color images (r, g, b) (x, y)
  - Baboon, Lena, Pepper (r, g, b, x, y)
  - A set of pixels with a 3D 8bit (0-255) RGB feature
  - Feature space is a 3D histogram of RBG colors (Color space) or 5D RBG-Space feature
- 6 Grayscale images (i) (x, y) (i, x, y)
  - Baboon, Lena, Pepper, Barbara, Cameraman, Goldhill
  - A set of pixels with a 1D 8bit (0-255) feature
  - Feature space is a 1D histogram of intensity values or 3D intensity-Space feature

Mean shift

- "Conceptual" Steps
  1) Do ~~KDE on~~ ~~$\boldsymbol{x}_1,..,\boldsymbol{x}_N$~~ ~~for~~ $\boldsymbol{p(x)}$
  2) Do Clustering of $\boldsymbol{x}_1,..,\boldsymbol{x}_N$ according to the ~~estimated~~ ~~$\boldsymbol{p(x)}$~~
  3) Re-label each $\boldsymbol{x}_i$ by its cluster center value
- Mean Shift
  - Adaptive step-size gradient-ascent in a feature space $\boldsymbol{x}$
  - Convergent to nearest mode/peak $\boldsymbol{x}^{mle}$
  - **No need for explicitly computing a density estimate!!!**
  - ~~Bandwidth parameter must be hand-picked though~~

Algorithm

Vector Norm: $\|\boldsymbol{x}\| = \sqrt{x_1^2 + \cdots + x_d^2}$

- Suppose we are given ***N*** samples $\boldsymbol{x_1,..,x_n,..,x_N}$
- And we model ***p(x)*** by KDE with bandwidth ***h***
- **Mean Shift Vector** defined at arbitrary location ***x***
  - Compute arithmetic mean of the samples with a weight function g
-

$$\boldsymbol{m}(\boldsymbol{x}; h) = \frac{\sum_{n=1}^{N} \boldsymbol{x}_n g\left(\left\|\frac{\boldsymbol{x}-\boldsymbol{x}_n}{h}\right\|^2\right)}{\sum_{n=1}^{N} g\left(\left\|\frac{\boldsymbol{x}-\boldsymbol{x}_n}{h}\right\|^2\right)} - \boldsymbol{x}$$

- With Epanechnikov Kernel, you get
  - We can simplify the above MS because you get a constant weight function

$$g\left(\left\|\frac{\boldsymbol{x}-\boldsymbol{x}_n}{h}\right\|^2\right) = \begin{cases} C & \|x - x_n\| \le h \\ 0 & \text{otherwise} \end{cases}$$

- With (isotropic) Gaussian Kernel
  - We have smooth KDE ***p(x)*** so we expect better behavior

$$g\left(\left\|\frac{\boldsymbol{x}-\boldsymbol{x}_n}{h}\right\|^2\right) = \exp\left(-\frac{\|\boldsymbol{x}-\boldsymbol{x}_n\|^2}{h^2}\right)$$

Algorithm Cond.

- Mean Shift Procedure
  - Given ***N*** samples $\boldsymbol{x_1,..,x_i,..,x_N}$
  - Iteratively compute $\boldsymbol{y_1,\ldots,y_k,\ldots,y_K} \rightarrow \boldsymbol{y_{mle}}$ (until convergence)

$\boldsymbol{y_1} \leftarrow \boldsymbol{x_{init}}$ This loops at each pixel

$loop\ over\ \ k$

$$\boldsymbol{y_{k+1}} = \boldsymbol{m}(\boldsymbol{y_k}, h) + \boldsymbol{y_k} = \frac{\sum_{n=1}^{N} \boldsymbol{x}_n g\left(\left\|\frac{\boldsymbol{y}_k-\boldsymbol{x}_n}{h}\right\|^2\right)}{\sum_{n=1}^{N} g\left(\left\|\frac{\boldsymbol{y}_k-\boldsymbol{x}_n}{h}\right\|^2\right)}$$

$\boldsymbol{y_k} \leftarrow \boldsymbol{y_{k+1}}$

This sums over the sample set

- Stopping Criteria

$$\left\|\frac{\boldsymbol{m}(\boldsymbol{x};h)}{h}\right\|^2 \le TH^2$$

Hints

- First try grayscale image then color image next if you can
- Try small image size like 64 by 64 (should take about 1min)
- How to make an output image by doing MS clustering?
  - Define a new image ***J*** whose size is the same as the input ***I***
  - For each pixel of the input image ***I(x,y),***
    - Initialize the iterator variable ***y*** by the intensity of the pixel $y_1 = x_{init} = I(x,y)$
    - Do the mean shift procedure shown in the previous slide $y_1 \rightarrow y^{mle}_k$
    - Set the corresponding intensity value of the output image $J(x,y) = y^{mle}_k$
  - This is known as **Mean Shift Filtering**
- Free parameters to be hand-picked
  - Bandwidth ***h***
  - Stop threshold ***TH***
  - Max iteration ***K***
- Think of how to group the convergence points?
- Think how to visualize the density and each mean shift step
- Think how to extend to color image

Speed up?

13

Useful MATLAB Codes

For Mean Shift

- vec = Matrix(:) colon operator to vectorize a matrix
- val = exp(), exponential function
- M = double(M), casting the data type to dobule
- figure, display a figure window
- Imagesc(IMG), display a matrix as an image (scaling the values to 8bit range)

14