Project 3: The Mean Shift Algorithm

In this project you will implement the mean shift algorithm for clustering, image filtering and segmentation, following Comaniciu and Meer, 2002. Along with a written report, you should turn in all source code that you write.

Methods:

1. Implement the mean shift algorithm for finding the modes of the kernel density estimate from vector-valued data.

2. Create a function that will perform image filtering using the mean shift algorithm. The feature vectors should include both pixel position and pixel value. The filtered image should retain the original pixel positions but replace the pixel values with the output of the mean shift algorithm.

3. Use the mean shift algorithm to perform image segmentation. This is similar to the filtering procedure, with an additional step at the end that clusters the resulting modes in feature space that are close to each other and assigns each cluster a label.

Experiments:

1. Generate several (3-5) clusters of 2D data points. Each cluster should be simulated from a multivariate Gaussian distribution. Vary the means and covariances of the distributions, as well as the number of points in each cluster. Now run your mean shift implementation on your synthetic data. How effective is mean shift at finding the cluster centers?

2. Try out your mean shift filtering algorithm on the images provided here: 
   http://www.sci.utah.edu/~fletcher/CS7960/hw3-data.zip
   Also, give the cc0.png corpus callosum image a shot. Use intensity plus position as your features for the grayscale images, and RGB values plus position for the color images.

3. Apply your mean shift image segmentation algorithm on the images above.

4. For each of the three experiments above, try the algorithm with both a Gaussian and a Epanechnikov kernel. What difference do you notice in the algorithm results?

5. For each of the three experiments above, try varying the bandwidth of your kernel. What effect does this have? What kernel width do you think gives the best results (could be different for each experiment)?

Report: You should submit a report (either as html or pdf) describing your work. Be sure to include the following:
• Describe your implementation. You do not need to recount the theory and equations behind all of the methods, just a brief description of how you implemented them and the issues you faced.

• Describe your results for all of the experiments listed above. Be sure to list all of the parameter values that you ended up using. For the synthetic data, plot the generated data points and also the modes that you found. For the images display the initial input images and also the filtered/segmented images.

• Be sure to show your results of different bandwidths and kernels, and discuss the effects of varying these parameters.

**Extra Stuff:** If you have extra time to kill (not required):

• Look up and try out one or more methods for automatic bandwidth selection.

• Try a different color space, where distances are closer to human visual perception, e.g., $L^*u^*v^*$ or $L^*a^*b^*$. If you are using R, see the command `convertColor`.