CSE166 – Image Processing – Homework #4
Instructor: Prof. Serge Belongie
`http://www-cse.ucsd.edu/classes/fa11/cse166-a`
Due (in class) 12:00pm Friday Nov. 4, 2011.

Reading

- GW Second and Third Edition 6.0-6.2.

General Homework Guidelines

- Use the Cover Sheet provided.
- Please attach all code that you use. Attach code at end of submission.
- In general try to keep your answers concise. Use as many words as you need and no more. Also work on your presentation skills. This means organize your plots and displays. Always use titles and add captions when appropriate. *Points will be awarded for clarity and presentation.*

Written exercises

1. GW Second and Third Edition, Problem 6.4.
2. GW Second and Third Edition, Problem 6.5.
3. GW Second and Third Edition, Problem 6.6.
4. GW Second and Third Edition, Problem 6.7.
5. GW Second and Third Edition, Problem 6.12.

Matlab exercises

1. Gabor Functions

   In 1D, the Gabor function of width σ and spatial frequency u_o is given by the following complex-valued function:
   $$h(x) = e^{-x^2/2\sigma^2} e^{j2\pi u_o x}$$
   In 2D, the corresponding expression is
   $$h(\mathbf{x}) = e^{-\|\mathbf{x}\|^2/2\sigma^2} e^{j2\pi \mathbf{u}_o \cdot \mathbf{x}}$$
   where $\mathbf{x} = (x, y)$ and $\mathbf{u}_o = (u_o, v_o)$, and it serves as an oriented bandpass filter. The even and odd Gabor functions are equal to the real and imaginary parts of h, respectively.

   (a) Compute eight examples of even and/or odd 1D Gabor functions on the interval $x \in [-16, 15]$ using parameters chosen in the following ranges: $\sigma \in [1, 3]$ and $u_o \in [0, 0.3]$. For each example, plot the function and its Fourier transform magnitude.

   (b) Compute eight examples of even and/or odd 2D Gabor functions on the interval $\mathbf{x} \in [-16, 15] \times [-16, 15]$ using parameters chosen in the following ranges: $\sigma \in [1, 3]$ and $\mathbf{u}_o \in [0, 0.3] \times [0, 0.3]$. For each example, display the function (either as an image or a surface plot) and its Fourier transform magnitude.

(c) Load in the fingerprint image of Figure 10.29(a) (Second Edition) or Figure 10.38(a) (Third Edition) and visually inspect it to determine the approximate spacing between the ridges. Choose two 2D Gabor functions, one even and one odd, with $\|\mathbf{u}_o\|$ approximately equal to the ridge frequency. Display the raw fingerprint image, the even filter, and the odd filter along with the magnitudes of their respective Fourier transforms. Note: zero-pad the filters to the size of the image before transforming them, and use the logarithmic transformation to display the transform magnitude. Now filter the fingerprint image with each Gabor function and display the results. Explain what you observe.

Things to turn in:

- Printouts of plots for steps 1a and 1b.
- Printouts and written response for step 1c.

2. Gaussian derivatives vs. Gabor functions

(a) Evaluate the 1D Gaussian function $e^{-x^2/2\sigma^2}$ on the interval $x \in [-16, 15]$ using $\sigma = 3$. Compute its approximate third derivative by repeated application of the centered first difference kernel. Plot the resulting function and its DFT magnitude.

(b) Experimentally find parameter values for an even or odd 1D Gabor function that closely matches the Gaussian 3rd derivative. Note: you may also need to apply an amplitude scaling factor. Once you have found a good match, make plots showing the quality of the match in both the spatial domain and the frequency domain.

Things to turn in:

- Printout of plots in steps 2a and 2b.

3. Color Histograms

(a) Make a function in Matlab that computes the RGB color histogram for a user-selected rectangular region in an arbitrary color image. Use 32 bins for each color channel, spaced equally between 0 and 255. Concatenate the three histograms together to make a combined histogram of length $3 \times 32 = 96$. Once you have computed the combined histogram, normalize it so that it sums to 1.

(b) Using the above function, compute and display the color histogram for each of five different rectangular regions of your choice for Figure 6.30(a) (a bowl of strawberries). Use `bar` to plot each histogram, and clearly mark the x-axis to indicate the division between the R, G, and B intervals. Annotate your plot (use `gtext` or just mark it by hand) to explain the significance of the various peaks you observe. Along with each histogram, display the corresponding region of the image used to compute it.

(c) Implement a function to compute the χ^2 distance between a pair of normalized histograms $h_i(k)$ and $h_j(k)$, which is defined as:

$$\chi^2\left(h_i(k), h_j(k)\right) = \frac{1}{2}\sum_{k=1}^{K} \frac{[h_i(k) - h_j(k)]^2}{h_i(k) + h_j(k)}$$

Use this function to compare all pairs of the five histograms you computed in the previous step. Output the values in a 5 by 5 matrix; because of symmetry, only the upper triangular portion of this matrix is needed. Choose at least three representative entries in this matrix and explain their values in terms of the color distributions you compared to obtain them.

Things to turn in:

- Code listings for steps 3a and 3c.
- Written answers for steps 3b and 3c.
- Printouts for steps 3b and 3c.