CSE 166: Image Processing, Fall 2017 – Assignment 3
Instructor: Ben Ochoa
Due: Monday, October 30, 2017, 11:59 PM

Instructions

- Review the academic integrity and collaboration policies on the course website.
- This assignment contains both math and programming problems.
- Programming aspects of this assignment must be completed using MATLAB.
- Unless specified below, you may not use MATLAB functions contained in toolboxes, including the image processing toolbox. Use the MATLAB `which` command to determine which toolbox a function is contained in. If you are unsure about using a specific function, then ask the instructor for clarification.
- You must prepare a report containing your solutions and results.
- Your report will be a pdf file named `CSE_166_hw3_lastname_studentid.pdf`, where `lastname` is your last name and `studentid` is your student ID number.
- All of your MATLAB source code must be included as a listing in the appendix of your report.
- Submit your report on Gradescope.
- Additionally, you must create a zip file named `CSE_166_hw3_lastname_studentid.zip`, where `lastname` and `studentid` is your last name and student ID number, respectively. This zip file will contain the pdf file and a directory named `code` that contains all of your MATLAB source code.
- Submit your completed assignment by email to `rkollipa@eng.ucsd.edu` **and** `asrikant@ucsd.edu`. The subject of the email message must be `CSE 166 Assignment 3`. Attach the zip file to the message.
- It is highly recommended that you begin working on this assignment early to ensure that you have sufficient time to correctly implement the algorithms and prepare a report.

Problems

1. **Textbook problems (11 points)**
   (a) Problem 4.3 (1 point)
   (b) Problem 4.4 (1 point)
   (c) Problem 4.9 (2 points)
   (d) Problem 4.27 (1 point)

(e) Problem 4.33 (2 points)

(f) Problem 4.40 (3 points)

(g) Problem 4.45 (1 point)

2. **Programming: The Fourier transform and filtering in the frequency domain (35 points)**

   (a) **The Fourier transform pair (5 points)**

   Develop a MATLAB script called `hw3_dft_ift.m` that reads the input image `cameraman.tif` (included with MATLAB), computes the discrete Fourier transform (DFT) $F(u,v)$ (shifted such that the zero-frequency component $F(0,0)$ is centered) of the input image $f(x,y)$, calculates the magnitude $|F(u,v)|$ and phase $\phi(u,v)$ of $F(u,v)$, calculates the DFT $G(u,v) = |F(u,v)|e^{j\phi(u,v)}$, computes the inverse discrete Fourier transform (IDFT) $g(x,y)$ of $G(u,v)$ (after inverting the centering shift), and writes the real part of $g(x,y)$ to the output image `cameraman_dft_ift.png`. Use the function `imread` to read the input image in MATLAB. Use `imwrite` to write the output image in MATLAB. You may use MATLAB built-in functions to perform the intermediate steps.

   Include in your report the input image and output image. Additionally, include figures of $\log|F(u,v)|$ and $\phi(u,v)$, both with colorbars to show the scale. Include a title with each figure. What are the row and column indices of the $F(0,0)$ component before and after the centering shift?

   (b) **The convolution theorem (20 points)**

   The objective of this problem is to show that the ouput image

$$g(x,y) = f(x,y) \bigstar h(x,y) = \mathfrak{F}^{-1}\{F(u,v)H(u,v)\}$$

   where $F(u,v)$ and $H(u,v)$ are the DFTs of the input image $f(x,y)$ and kernel $h(x,y)$, respectively.

   Develop a MATLAB function called `filterInFrequencyDomain` that applies a filter to an image in the frequency domain. The function inputs are a grayscale image and a kernel, and the function output is the filtered (double precision) image corresponding to the input image. The inputs and output are in the spatial domain. Zero padding must be used to mitigate wraparound error. The calculated output image must be the same size as the input image.

   Develop a MATLAB script called `hw3_convtheorem.m` that reads the input image `moon.tif` (included with MATLAB) and applies the Laplacian kernel

$$h(x,y) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

   to the input image $f(x,y)$ in spatial domain and in the frequency domain. Use the function `imread` to read the input image in MATLAB. The script must call the function `filterInFrequencyDomain` to apply the filter in the frequency domain. You may use the function `imfilter` to apply the filter in the spatial domain.

Include in your report the input image. Additionally, include figures of both resulting filtered images (with colorbars to show the scale). Include a title with each figure. Comment on the resulting filtered images. (Optional: subtract a filtered image from the input image to yield a sharpened image.)

(c) **Ideal lowpass filter (10 points)**

Develop a MATLAB script called `hw3_ilpf.m` that reads the input image `testpat1.png` (included with MATLAB), applies an ideal lowpass filter in the frequency domain, and writes the ouput image to `testpat1_ilpf.png`. The ideal lowpass filter must have radius $D_0 = 50$. Use the function `imread` to read the input image in MATLAB. Use `imwrite` to write the output image in MATLAB.

Include in your report the input and output images. Comment on the resulting output image. Try at least one smaller radius and one larger radius ideal low pass filter and comment on the differing results.