بسم الله الرحمن الرحیم

University of Tehran
College of Engineering

Digital Image Processing

Instructor: Dr. Hamid Soltanian-Zadeh

Homework Assignment 3:

Filtering in the Frequency Domain

Due date: 1403/12/26

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Spring 2025

Contents

1 Instructions

Please answer the following questions based on Chapter 4 (*Filtering in the Frequency Domain*) of the textbook by Gonzalez and Woods. Submit your solutions by the due date. Read the following carefully and follow these instructions when submitting your answers:

Requirement	Description	Consideration
Standard Due Date	1403/12/26- 23:59	
Elearn HW Upload	**Only**	Only use ELearn to submit your homeworks.
Email Address	zahranakhaei1999@yahoo.com	Feel free to say hello!
Submit format	Read Note 4	Extremely important
Late Submit	Penalty	$5 - 10\%$ penalty per day

Note 1: *This request is not intended to impose any hardship on you, but to help with better management of the class. Your cooperation is greatly appreciated in making the process more efficient. Thank you!*

Note 2: *We will also have a Telegram group for Q&A. The link (clickable) is provided here:* [open the link]

Note 3: *Use camera scanners if you wish to submit your handwritten answers. While readability is always important, it is especially critical in the DIP course, which focuses on quality enhancement.*

Note 4: *You must send a zip or rar file named* `DIP-HWx-std.no` *where x is the number of the homework (e.g.* `DIP-HW3-810199034`*). Inside the zipped file will be a folder for each question containing its code and output images. There should also be a single pdf file in the root folder as your main report.*

Academic Integrity: *Plagiarism, cheating, or using unauthorized external resources (including AI tools, solution manuals, or copying from peers) is strictly prohibited. All assignments will be checked for originality, and any violations will result in academic penalties. Please submit only your own work.* ***It's easy to detect whether your answers are generated by AI or are truly your own work, so be sure to submit original solutions.***

2 Fourier Transform

Question background

In this problem, we want to be acquainted with Fourier transform.

(a) First, load the images q2/`woman.tif` and q2/`parrot.tif` and compute their Discrete Fourier Transform (DFT) using the **`fft2`** command. Next, calculate the magnitude and phase angle of the computed DFTs. Finally, plot the results for each image.

(b) Compute the phase angle of q2/`parrot.tif` using the given equation. Then, compare the result with the phase angle obtained in the previous part. Do you observe any differences?

$$\phi(u,v) = tan^{-1}(\frac{I(u,v)}{R(u,v)})$$

(c) Now, attempt to reconstruct q2/`woman.tif` using the following properties and determine which component contains the most significant information in the images:

(a) Only the phase angle

(b) The frequency spectrum and phase angle of q2/`parrot.tif`

(c) The phase angle combined with the frequency spectrum of q2/`parrot.tif`

(d) Scale q2/`parrot.tif` to 1.5x of its size. Explain the impact on the Fourier domain representation of an image and provide examples.

Note:

Zero-padding is required since your scaled image's size is changed and in order to be able to compare results in a meaningful way, it is simpler to have the same DFT size.

(e) This time, shift the image in spatial domain by 5% in X, Y and both X-Y directions and discuss the effect on the Fourier transform for each shifted direction.

Note:

Since the shifted image content will get outside the image box, there are strategies to overcome this issue, such as zero-padding, circular method, etc. Choose one and discuss based on your preferenece.

(f) Carefully, replace the lower-half frequency components of `q2/woman.tif` with those of `q2/parrot.tif`. Analyze and visualize the results.

3 Exploring filter type

Question background

In this problem, you will create a custom MATLAB function called **`filter_function`** for image filtering. This function will enable you to apply different types of filters, including Low-Pass (LPF) and High-Pass (HPF), while providing various filter options for processing images.

```
[img_filtered,freq_response] = filter_function(img,'LPF','Butterworth',parameters);
```

This function should have the following inputs:

- Image
- Filter Type(High Pass Filter / Low Pass Filter)
- Kernel type (Ideal/Butterworth/Gaussian)
- Specific parameters of each filter

And these outputs:

- Filtered image
- Frequency response of the filter

Now load `q3/char.tif` image. Use your function and apply low-pass and high-pass ideal filters with $D0$ parameter set at values 15, 30, 50, 150 and 400 to filter the image, then, compare each one with the original image in a single figure. Additionally, create a single figure that displays a comparison of the filter frequency responses with varying parameters. Then, repeat the same process using a Butterworth filter (order $= 2$) and a Gaussian filter.

Note:

You may not use any kind of MATLAB built-in functions that are directly used for filtering. Try to show each group of images in a single figure.

4 High Frequency Emphasis Filtering

Question background

X-rays cannot be focused in the same manner that optical lenses are focused, and the resulting images generally tend to be slightly blurred. The objective of this problem is to enhance the image using high-frequency emphasis filtering.

(a) Load `q4/chest.tif` image and enhance it using high-frequency emphasis filtering.

(b) The resulting image has intensity levels concentrated in a narrow range of the grayscale. Explain how this issue can be improved, then apply your suggested method to enhance the image further. Finally, display the results.

Note:

You may not use built-in functions that are specifically designed for this kind of filtering.

5 Moiré Pattern

Question background

A moiré pattern is an undesirable visual artifact that occurs when two regular patterns overlap, creating wavy or beating distortions that reduce image quality. In this assignment, the objective is to remove moiré patterns from an image and enhance its clarity.

(a) Load `q5/carmoire.tif` image and display it alongside its frequency spectrum to understand how moiré affects the image information.

(b) Design and apply a notch filter in the frequency domain to remove the moiré pattern selectively.

(c) Display the filtered image and its corresponding frequency spectrum. Analyze the effectiveness of the filter in removing the moiré pattern while preserving image details.

Note:

You may not use MATLAB built-in functions.

6 Laplacian Filtering

(a) Load `q6/bld.tif` and apply the following Laplacian kernel in the spatial domain

-1	-1	-1
-1	8	-1
-1	-1	-1

(b) Plot the frequency spectrum of this filter and discuss its properties.

(c) Apply the same Laplacian filter in the frequency domain.

(d) Compare the results obtained from spatial and frequency domain filtering and discuss the differences.

7 Analytical Questions

Textbook Questions

Please provide the solutions to the questions presented in the 4th chapter of the Image Processing book (Edition3): 15, 26, 33, 39, 42.