BMEN 509 Introduction to Biomedical Imaging

Laboratory 2

Frequency Domain

1 Purpose

The purpose of this laboratory is to become familiar with the frequency domain representation of images. In this exercise, you will demonstrate 1) a basic understanding of the frequency domain, 2) understanding the inverse discrete Fourier transform, and 3) frequency domain filtering.

2 Review Supplementary Material

The following documents have been supplied with the laboratory:

Document	Description
BMEN509-Lab2-Notes.pdf	Notes relevant to laboratory 2
Lab2Ex*.ipynb	Example code references from the laboratory notes
Data/	A directory of image data to be used for the laboratory

Review and use the laboratory notes and code references to guide you.

3 Visualizing the Frequency Domain (/25)

Using the image `knee_ct2.tif`, `knee_xray2.tif`, `mri-pd.tif` and `T1Weighted8.jpg` do the following:

1. Load and display each image
2. Compute the Discrete Fourier Transform (DFT) of each image (i.e. the transform from space to frequency domain)
3. Display the real, imaginary, magnitude, and phase components for each image. Make sure to scale each component into a visible range.

Are the pixels in a DFT image real valued or complex valued? What do the "magnitude" and "phase" components represent? Why do some components need to be scaled?

4 Understanding Phase and Magnitude (/18)

A Magnetic Resonance (MR) scanner produces images by collecting data in k-space, the colloquial name for the frequency domain. An inverse DFT (i.e. the transform from frequency to space) must be applied to reconstruct the original image. To better understand the importance of both the magnitude and phase when calculating the inverse DFT, we will reconstruct each image with only the magnitude or phase component. For the images `knee_ct2.tif`, `knee_xray2.tif`, `mri-pd.tif` and `T1Weighted8.jpg`:

1. Load each image and compute the DFT
2. Reconstruct the image with only the magnitude information

3. Reconstruct the image with only the phase information
4. Compare the original image, the magnitude reconstruction, and the phase reconstruction.

How does phase contribute to image reconstruction? How does magnitude contribute to image reconstruction?

5 Reducing Samples in the Frequency Domain (/20)

A current research topic in MR imaging is reconstructing high quality image with fewer samples in k-space (the frequency domain). Reducing the number of samples in k-space can greatly reduce scan time (i.e. the time that the patient is in the MR scanner).

Here, we are going to explore what happens when we reconstruct our image with fewer samples in the frequency domain.

Using the image `mri_pdf.tif`, do the following:

1. Load the image and display it
2. Calculate the DFT and display the scaled magnitude response
3. Modify the frequency content by removing the smallest 10%, 50%, 90%, 95%, and 99% of the components (by magnitude). This can be accomplished by setting these components to zero
4. Display the magnitude response of the reduced DFT for all five cases
5. Reconstruct images for each of the five DFTs with reduced samples and display the resulting images.

As more samples are removed, what changes in the magnitude response? As more samples are removed, what happens to the reconstructed image? You may have to look closely at the ventricles of the brain.

6 Frequency Domain Filtering (/35)

The image `calcs_grids.tiff` has a periodic artefact that reduces the quality of the image. This is actually a phantom for detecting breast cancer, which is represented by the six dots in the image. Our objective is to produce a frequency domain filter which removes these periodic artifacts. Note that there are six artefacts placed at integer distances from another. If the first artefact appears at frequency $(0, u)$, the remaining artefacts appear at $(0, -u)$, $(0, 2u)$, $(0, -2u)$, $(0, 3u)$ and $(0, -3u)$.

For the image `calcs_grids.tiff`, do the following:

1. Load the image and display it
2. Compute the DFT and display the magnitude response
3. Looking at the magnitude response, indicate the location of the artefacts
4. Design a filter in the frequency domain to remove those artefacts
5. Reconstruct the filtered image using an inverse DFT

Comparing the original image to the artefact removed image, how well did you do at reducing the unwanted responses?

7 Rubric

Please submit a report summarize the results of each part of the lab, including answering the questions at the end of each section. The report should include an objective and conclusion. Please submit your code with your report. Reports without code will receive a zero.

Criterion	Marks
Code is well formatted and commented appropriately	/2
Report is well formatted with name, date, objective and conclusion	/2
Section 3: Image loaded and displayed /5 DFT computed and rescaled properly /10 Questions /10	/25
Section 4: Phase and magnitude reconstruction performed /8 Images compared /5 Questions /5	/18
Section 5: Images displayed /5 Image and magnitude for five reduced samples displayed properly /10 Questions /5	/20
Section 6: Image loaded and displayed /5 DFT and magnitude response performed /10 Artefacts located /5 Filter designed, applied and image after filtering reconstructed /10 Questions /5	/35