Experiment 3
Interference Removal from Digital Images by Filtering

Objective: To use an appropriate FIR digital filter to reduce or remove interferences from digital images

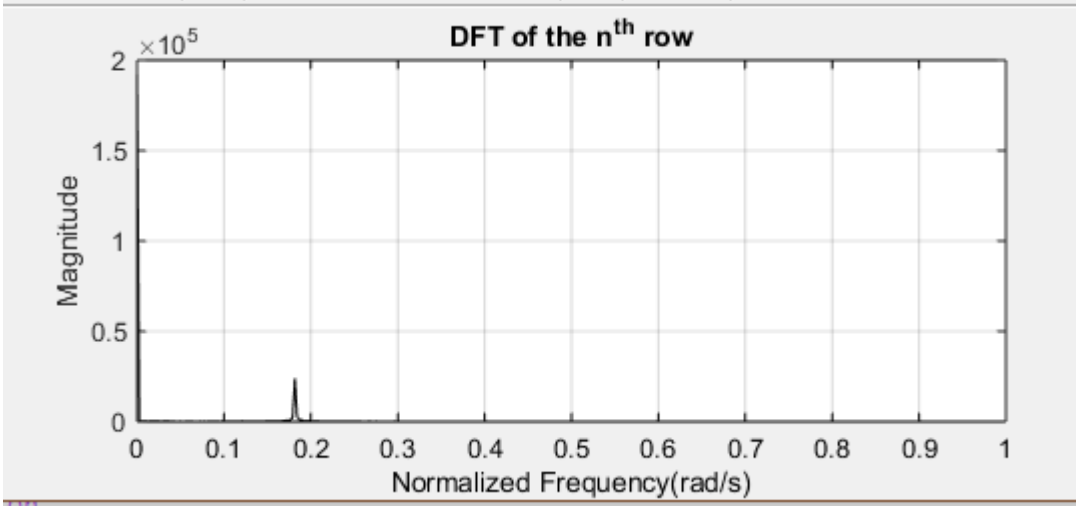
Procedure:

a) Download the following test images from the course website homework_if.mat and homework.mat. The former is an image containing some periodic interference which you will remove using frequency domain filtering while the latter is a clean image which you will use for performance evaluation purpose.

b) Step I : Identifying the interfering frequency interval

You should perform the following in MATLAB

1) Select an appropriate row from the image homework_if.mat
2) Perform spectrum analysis to identify the interfering frequency interval. The spectrum analysis consists of the following steps
   a) Calculate the DFT of the selected row. (Use MATLAB function fft())
   b) Plot the magnitude spectrum of the DFT signal. You should get the following plot.

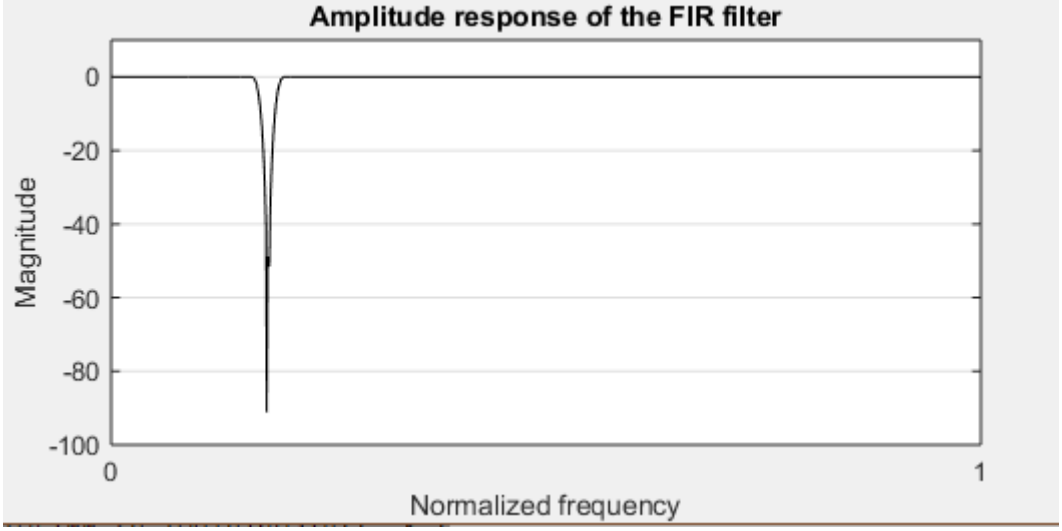


Note: Since the signal is symmetric you can use only half of the DFT signal for plotting. Plot it over normalized frequency (0: N/2 -1)/ (N/2) where N is the length of original fft signal.

   c) Identify the normalized frequency band $[\omega_{c1},\omega_{c2}]$ corresponding to the interference. You need to zoom into the plot and use data cursors to get the values.

c) Step II: Designing a bandstop filter with $[\omega_{c1},\omega_{c2}]$ as the stopband.

1) Download the MATLAB function file win_fourier.m from the course website. You will use this function to design your bandstop filter.
2) Plot the amplitude spectrum of the designed filter to check if it met the desired specifications i.e. if it removes the stop band and leaves rest of the spectrum unchanged. (see freqz, normalize frequency between 0 and 1 to get the desired range. Normalizing is done by dividing the range with the maximum value in the range) An example plot is shown below



d) Step III: Filtering the image
   1) Apply filter on each row of the image homework_if. (Use matlab function conv(…,'same'))
   2) Adjust the pixel value of the filtered image in the range [0 255]. To do this , any pixel value higher than 255 should be made 255 and any pixel value less than 0 should be made 0 while remaining pixels should be as it is . This image should be your homework_f.
   3) Display the homework_f image side by side with homework_if.

e) Step IV: Evaluating the performance
   1) Subjective Evaluation: Visual Inspection of Images before and after filtering.
   2) Objective Evaluation: It is obtained by comparing relative error in frobenius norm before and after filtering.

Before filtering	After filtering
$e_{before} = \frac{\|\text{homework\_if - homework}\|_F}{\|\text{homework}\|_F}$	$e_{after} = \frac{\|\text{homework\_f - homework}\|_F}{\|\text{homework}\|_F}$

Please include the following in your lab report:

- Frequency spectrum of relevant row considered
- Identified frequency band of interference
- Amplitude response of different bandstop filters designed (*for several representative lengths N*)
- Images obtained after filtering with these filters
- Relative error in Frobenius norm for all images
- Comments on which filter length you believe to be optimal (lowest SNR, best visual quality)

Bonus Question:

a) How much percentage reduction in error did you achieve after the filtering? Show your calculations? (0.5)
b) From your observations regarding the periodic noise in the image, what can you conclude about its appearance in frequency domain spectrum? (0.5)

Your lab report should be in the following format.

a) Objective
b) Introduction
c) Implementation , MATLAB code and Results
d) Discussion
e) Conclusion

Note: In section c) first you should describe the MATLAB implementation of your lab.
This should be followed by the MATLAB code and relevant results (including comments) as per the procedure section in the lab manual.