ECE 418 Lab #2 Report   Shuchen Zhang (szhan114)

Introduction:

In Lab2, we compute the 2-D Fourier Transform of an image. Three kinds of operations are performed in Fourier domain, and then the inverse 2-D Fourier Transform is computed. The three operations are: removing the phase of frequency component; eliminating the variation in magnitude of each frequency component; low-pass filtering in Fourier domain.

In Lab Part 1, the phase of each complex frequency sample is removed while the magnitude is preserved. The result image after FFT and Inverse FFT lose the geometric information of the original image. The imaginary part of the image represent the phase shift. The phase in the Fourier domain tells where the frequency component is positioned in the image. The imaginary component of the image is negligible after perform a specific operations in transform domain and taking the inverse 2D DFT because all the pixel values for the input image are real valued. The Fourier Transform of real-valued signal is conjugate symmetric. So the inverse FFT is conjugate symmetric as well. If the phase in frequency domain is ignored, the imaginary part after inverse FFT is almost cancelled out which is the similar to ignoring the imaginary part of the real valued signal.

In Lab Part 2, the magnitude of each complex frequency in Fourier domain is set to 1 while the phase is preserved. The result image preserve the original geometric spatial structure while the brightness of the pixel change and the image is much darker than the original image. By altering the magnitude to 1 but keeping the phase in Fourier domain, the grey value level is scaled to a much lower level. The intensity of each pixel signal which tells the brightness is scaled down. The phase is maintained the same, so the position of frequency component maintains undistorted. Thus, only the brightness of the image change but not its spatial structure. In Part 1, the phase in Fourier domain is removed, which means the position of frequency component is ignored, thus after inverse transform, the position of original spatial signal is messed up and the image is not recognizable. From this experiment, we could see that phase is important when we try to reconstruct the correct image in the spatial domain.

In Lab Part 3, a low pass filter with cutoff frequency ranging from 0 to 0.5 is applied to the image's spectrum, which means the frequency samples outside the passband are set to zero while the rest is unchanged. The result image is blurred after the low pass filtering. As the cutoff frequency decrease, the blurring effect increases. In my subjective opinion after I tune the cutoff frequency value from 0 to 0.5, the smallest size of the low pass filter can be applied to the test image without causing a significant degradation of the image quality is 0.2 as its cutoff frequency value.

From this lab, the information content in Fourier domain is usually represented by complex number which contains the magnitude and phase of the signal. The magnitude tells the intensity of the signal while phase tells the phase shift that is needed for each sinusoid signal in order to recover the original spatial signal by combining the frequency components.

Compared with the averaging method in Lab1, the low-pass filtering method do the similar job in blurring the image. Also, both approaches when assigning new pixel value to get the result image involves taking the values from the neighboring signals into the computation. The difference is that, the pixel values of the result image after the low-pass filter contains small imaginary component while the pixel values of result image after averaging method in Lab1 are all real valued. Also, All the computation in Lab1 happens in spatial domain while the one in Lab2 involves transform the spatial signal to frequency domain signal and inverse transform back to the spatial signal.

There exist linear filter such as low-pass butterworth filter in the Fourier domain that can be used to obtain the same blurring result as the method in Lab1. The butterworth filter is $H(u,v) = 1/[1+[D(u,v)/D_0]^{2n}]$. The cutoff frequency is approximately within 0-0.5.

Conclusion:

In this lab, we learn the basic computation of 2D Fourier Transform and inverse 2D Fourier Transform. We examine the significance of preserving the magnitude and phase in Fourier domain in order to recover image and also learn the low pass filtering technique for image blurring.