Problem 1 Report

Part 1 of the homework creates hybrid images by manipulating the phase and magnitude components of the image. In order to implement a hybrid image, the pictures are first transformed into the frequency domain, manipulated, and then converted back into the spatial domain.

The problem is split into three separate programs focusing completing the task:

I. Hybrid images
    a. Fish magnitude with the motorcycle phase
    b. Motorcycle magnitude with the fish phase
II. Neutralizing the magnitude component
III. Removing the phase component

Each sections code models this technique and is split into four main sections: Image load, Frequency domain, Reconstruction, and Display.

Image load

Image load prepares the images for processing by loading the image into the workspace, resizing it, and then converting the image into grayscale.

Frequency domain

The frequency domain section is responsible for converting the image grayscale matrix into the frequency domain, and then separating the magnitude and phase of each value. To transform the image into the frequency domain the code uses the command fft2 and then shifts the zero-frequency component to center of spectrum using fftshift. From the frequency domain the magnitude and phase can then be calculated from the complex form $z = a + bi$.

The magnitude is calculated by taking the absolute value of the frequency domain and the phase is calculated from the complex portion using the code `exp(1i*Angle(Frequency_Domain)`.

For part ii, to neutralize the magnitude the, the magnitude of the image is set to 1 and in part iii, to remove the phase, the phase the frequency complex portion is set to 0 by the equation `exp(1i*0)`.

Reconstruction

Once the image is split into magnitude and phase the components can be manipulated and then reconstructed back into the spatial domain. To manipulate the data, the magnitude and phase matrices where multiplied together according to the hybrid image instructions. Once the data is properly manipulated the zero-frequency shift is inverted using ifftshift, and then converted back into the spatial domain using ifft2. The data is then converted into a logarithmic scale to better visualize the spatial domain.

Display

The display sections takes the reconverted image and displayed all the required images using subplots in order to visualize the output.

Runtime Analysis

After running timing analysis for each problem, the manipulation and reconstruction portion of the code was found to be consistently the longest. This confirms our initial guess in that the reconstruction section not only has to perform the matrix multiplication for the images in addition to converting the hybrid image back into the spatial domain. This hunch is also confirmed after using the profiler to complete runtime analysis. Both parts ii and ii had the ifft2 command with a longer run time than fft2. The results of fft2 and ifft2 can be seen in the table below.

Command	Part i	Part ii	Part iii
fft2	0.051 s	0.041 s	0.057 s
ifft2	0.050 s	0.071 s	0.061 s

The runtime analysis and timing for the rest of the code can be viewed in the attachments.

Runtime Improvement

In order to improve the critical portion of our code we could implement techniques such as reducing the size of our images or reducing the unnecessary data in the frequency domain similar to wavelets. Since you can cut out large portion of the frequency domain and still retain a good output image, this would allow us to speed up the time of ifft2 and shifting back into the spatial domain.