Maria Shevchuk

Imaging and Image Processing II

Abstract

In the biomedical field, image and movie data are used to diagnose and find treatments for patients, as well as to locate damage or abnormalities in a patient's body. Oftentimes this data needs to be manipulated in order to capture the desired information from it, while removing information that is uninteresting in the given context. Filters can be applied to images in order to either reduce noise or sharpen the image to distinguish certain features. Furthermore, when working with movie data, cross-correlation based image registration can be used in order to stabilize the data. This is vital because the majority of the time in the medical field we need to observe and analyse moving organisms (an MRI is a great example of this) and utilizing image registration can help us combine images to achieve more accurate results.
In this lab, we used the digital cameras in our smartphones to acquire image data, which we then ran through a low-pass and a high-pass filter. In order to apply a low-pass filter to an image, we can take the 2D Fourier transform and attenuate the high frequency pixels, resulting in an overall smoothing/blurring of the image in the spatial domain. The process for applying a high-pass filter to an image is similar, yet this time instead of high frequency pixels, we need to attenuate the pixels with low frequencies, which results in a sharper, more detailed image in the spatial domain. Another way to manipulate images is to register them to each other by taking the cross correlation of the images, which ultimately allows us to stabilize movie data, which we successfully did in this lab.

Results

<u>Examining a real-world image in the spatial and frequency domains</u>

The image data used in this lab was a selfie image acquired using the front camera of an iPhone. The image showed my lab partner Annie's face from shoulders up and had a light uniform background.

<u>Filtering an image in the spatial frequency domain</u>

After acquiring our image data, we first ran the image through a low pass filter by creating a mask that zeroed all frequencies outside of the desired radius. And then through a high pass filter, this time zeroing all frequencies inside the desired radius.
We can better understand the difference between low pass and high pass filters by visualizing the FFT graphs (Figure 1). Looking at the FFT with high frequencies removed, we can see that the frequencies within a certain radius of (0,0) are maintained, while all other frequencies are removed, and the opposite is true for the FFT where the low frequencies are removed. When looking at the spatial domain of the low-pass filtered image we can see that there is a smaller range of pixel values and an overall smoothing of the image which makes it harder to distinguish edges and features. On the other hand, it is evident from the spatial domain of the high-pass filtered image, that the image is sharper and edges are more prominent. When mask size is increased, the blurring effect on the low-pass filter decreases (less blurry), while the sharpening effect on the high-pass filter increases (more sharp). This is because when we increase the mask size, we attenuate fewer high frequencies for the low-pass filter and we remove more low frequencies for the high-pass filter which can be observed in the FFT graphs in Figure 2.

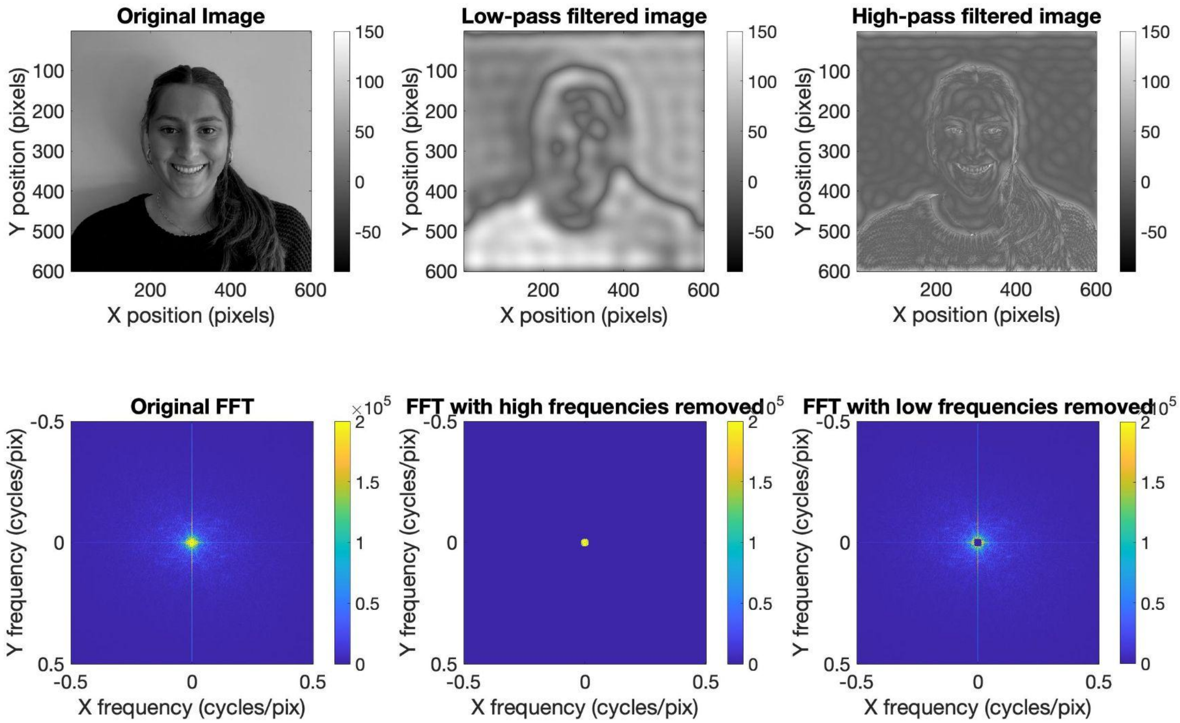

Figure 1: Top row: spatial domain graphs of the original image, low-pass filtered image, and high-pass filtered image. Bottom row: frequency domain graphs of the original image, low-pass filtered image, and high-pass filtered image with color bars representing the intensity of particular frequencies.

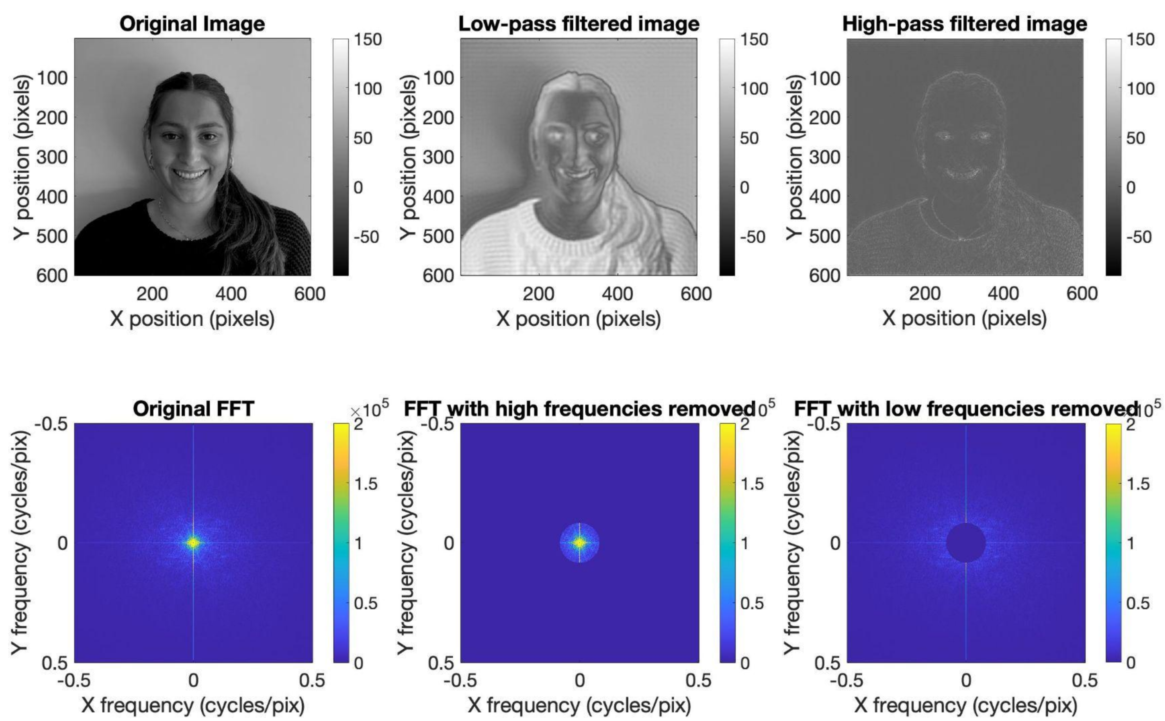

Figure 2: Top row: spatial domain graphs of the original image, low-pass filtered image, and high-pass filtered image with a larger mask radius. Bottom row: frequency domain graphs of the original image, low-pass filtered image, and high-pass filtered image with a larger mask radius and color bars representing the intensity of particular frequencies.

Acquiring and loading movie data

The movie data used in this lab was a movie of the large rock near the Boston University Beach and was acquired using the back camera of my IPhone. While filming the movie, I moved the camera slightly in all directions while keeping the rock in the frame, thus mimicking motion jitter.

Image registration for movie stabilization

The acquired movie was then stabilized. In order to do so, the first frame of the movie was used as a reference and then each frame was cross correlated to the reference frame. We then found the maximum of the cross correlations which indicated how much the frame needed to be shifted relative to the reference frame to achieve the highest possible similarity. In order to calculate how much a frame should be shifted, we calculated the difference between the location of the maximum cross correlation and the dimensions of the frame. If no difference was found, meaning that the location of the maximum cross correlation is the same as the dimensions of the image, then the frame was not shifted. The total displacement was split into displacement across the X and Y axes, which were plotted in Figure 3. This strategy proved to be effective since it successfully detected the shift of frames. When comparing the obtained curves to the original movie, we can see that first, the camera was moved across horizontally, and then moved up and down, which is supported by the graph.

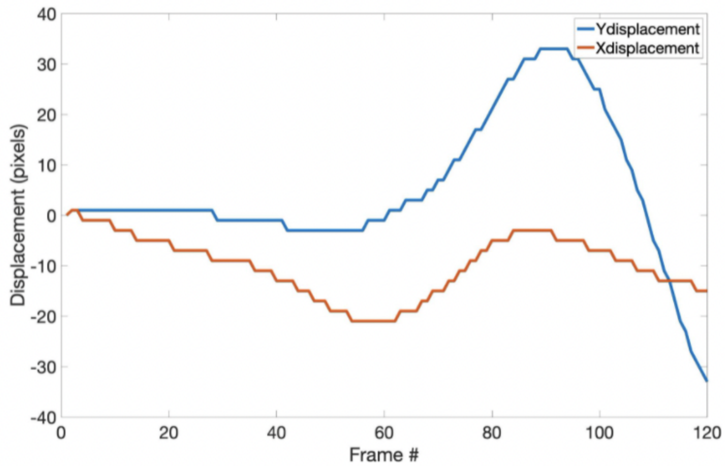

Figure 3: Plot of the X displacement (blue) and Y displacement (red) for each frame compared to the reference frame.

Create stabilized movie

The final stabilized movie has slight motion jitter across the frames however the rock now maintains the center frame position much better than it did in the original movie, meaning that for the most part our code did a good job at stabilizing the movie. This can be seen in Figure 4 which is a still image (last frame) taken from the motion corrected movie.

Figure 4: Still image taken from the motion-corrected movie.

Discussion

Filters have many useful real-world applications. If your desired outcome is a sharper image with increased contrast around edges, you can achieve this by using a high-pass filter. Applying a high pass filter to medical image data can help remove lower frequency variation, removing signals that are uninteresting in the given context. A low pass filter, on the other hand, results in a smoothing/blurring effect by averaging out rapid changes of pixel intensity which can be helpful in medical applications in order to reduce noise. The method used in this lab to apply filters to images by applying masks to the FFT of the images was effective and achieved the desired results.

Image registration is an important tool often used in biomedical imaging in order to establish a correlation between images that may have been acquired at different times or from different perspectives, like in an MRI. This tool can help combine images together to obtain an image with more depth and detail to it. Since biomedical imaging almost always looks at a moving organism, motion correction is extremely important in the field. Motion correction is widely used in MRI scans, since it can be hard for a patient to stay completely still. The method for motion correction using the cross correlation of frames to the reference frame did a decent job at stabilizing the movie in this lab, yet there are still a lot of slight jitter motions. Another issue that arose using this method is the slight resolution decrease, which would certainly be disadvantageous when working with medical movie data. One way we should try to improve this method in the future is to maintain the resolution throughout the motion correction process.