CENG466 - Fundamentals of Image Processing Take Home Exam 2 Report

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***Abstract*—Frequency domain analysis is an important technique used in image processing. Various useful applications can be done using this technique. Multiresolution analysis, noise elimination and edge detection are some of those applications using frequency domain analysis. This document presents the practice of such applications.**

***Index Terms*—image processing, image transformation, frequency domain analysis, fourier transform, wavelet transform, noise reduction, edge detection**

I. Introduction

This document is the presentation for the THE2 (Take Home Exam 2) for the course Fundamentals of Image Processing. Various practices of image transforms were used to achieve the specified goals. Firstly, wavelet transforms of two images are inspected to find the wrongly assembled transformation parts and then restore them. Next, fourier transform of images are used to eliminate the noise in them. Finally, fourier transform is used to detect the edges in the given images.

Some important code snippets that show the procedures which perform the core image processing operations are included.

II. Question 1 - Wavelet Transformations

In this part, two distorted images whose detail parts of wavelet decompositions are mixed up are given. The decomposition is done in 3 levels.

The wavelet decomposition of an image can be obtained as following.

Below are the 3 level decompositions of the images, Fig. 1 and Fig. 2 (There was an error displaying the approximation parts of the images in level 3.).

As seen in Fig. 1 and Fig. 2, some parts of the wavelet decompositions are swapped and those parts should be restored to their correct places.

After assigning the parts to the relevant places, fixed images are obtained by using the decompositions of each image. Below are the outputs, Fig. 3 and Fig. 4.

Fig. 1. 3 Level Haar Transform of A1

III. Question 2 - Noise Elimination

In Question 2 and Question 3, some noisy images are given and the noise should be eliminated. The noise in the images is found to be periodic noise by inspecting the Fourier transforms of the images. Some filters must be applied to mitigate noise and it is also known that in frequency domain, the filter should be applied as element-wise multiplication. The code snippet for creating filter for the Fourier transform of the noisy image is shown below.

The `number` field in the code snippet was decided by inspecting various outputs with various values of the number. This defines the size of the frequency domain filter.

```
% Construct the frequency domain filter
center_x = round(BX_width/2);
center_y = round(BX_height/2);
filterX = ones(BX_height, BX_width);
for x = 1:BX_width
    for y = 1:BX_height
        distance = sqrt((x-center_x)^2 + (y-center_y)^2);
        if((distance > number && distance < number) ||
        (distance > number && distance < number))
```

Fig. 2. 3 Level Haar Transform of A2

Fig. 3. Recovered image, A1

```
            filterX(y, x) = 0;
        end
    end
end
```

A. B1

In this part, there is a picture with periodic noise in the frequency domain as seen in Fig. 5 below.

Two circular shape noise can be seen in the frequincy domain. A filter which only hides two frequency bands with noises can be designed. The required filter can be seen below in Fig. 6.

After element-wise multiplication operation with the filter, we have to use inverse fast fourier transform to get our final image in spatial domain. The result can be seen below in Fig. 7.

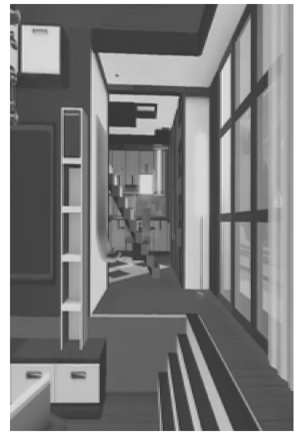

Fig. 4. Recovered image, A2

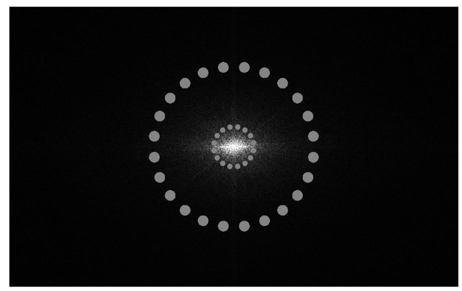

Fig. 5. Fast Fourier Transform of B1

B. B2

In part B2, three nested circular shape noises in the Fourier transform of B2.png can be seen (shown in Fig. 8).

So the same approach in B1 can be used, since the nested circular shape noises are far away from the center. The designed filter for B2 is shown below in Fig. **??**.
After applying the filter, (this image) was obtained.

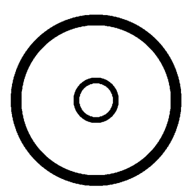

Fig. 6. Filter 1

Fig. 7. Restored image, B1

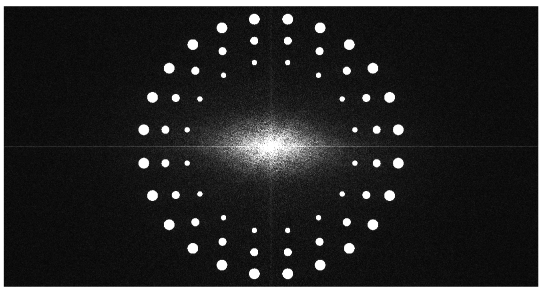

Fig. 8. Fast Fourier Transform of B2

C. B3

In this part, there is a different type of noise in the Fourier transform of B3, as seen in fig. 10. In B1 and B2 circular shape noises are observed but in B3.png the noise is in linear form. However, the same approach can work here.
The linear noise can be handled with a low pass filter. The low-pass filter for B3 can be shown below in Fig. 11.

After the filtering process, our result is shown below.

D. Conclusion

In conclusion, we have learned that most of the noise mitigate problem can be solved with various frequency domain filters.

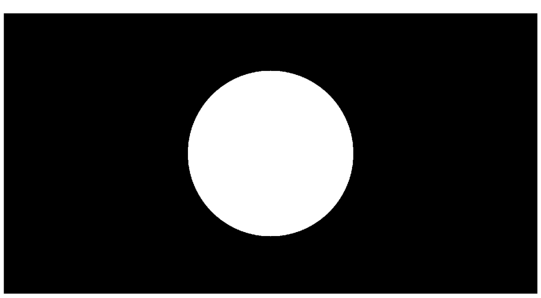

Fig. 9. Filter2

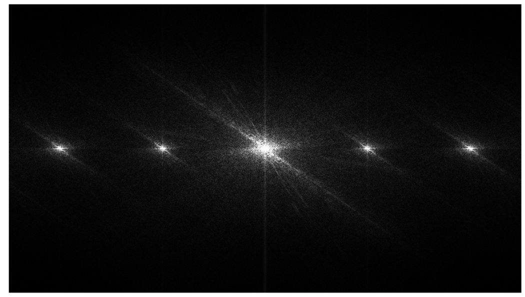

Fig. 10. Fast Fourier Transform of B3

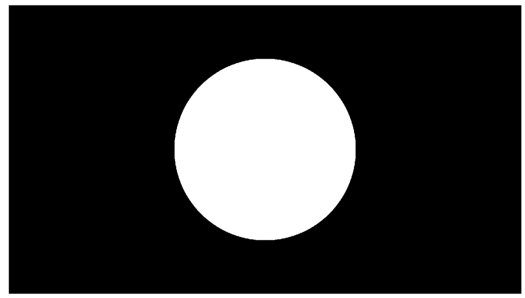

Fig. 11. Filter3

IV. Question 3 - Edge Detection

In section 3, edge detection in frequency domain is practiced by using high-pass filters. The detail part is in low frequency and edge information is in high frequency so if we use high-pass filters we can obtain the edges.

A. C1

In C1, a filter was designed by using the same technique which used in part 2, but the difference is that we use the following code snippet to create the high-pass filter. The Fast Fourier Transform of C1.png is shown in Fig. 12.

```
center_x = round(C1_width/2);
center_y = round(C1_height/2);
filter1 = zeros(C1_height, C1_width);
for x = 1:C1_width
   for y = 1:C1_height
      distance = sqrt((x-center_x)^2 + (y-center_y)^2);
      if((distance > 120)) % Can be adjusted
         filter1(y, x) = 1;
      end
   end
end
```

After applying the filter, the output in Fig. 13 is obtained.

B. C2

In C2, the filter used is quite similar to the one used in C1 as seen in Fig. 14.

After applying the filter, the output in Fig. 15 is obtained.

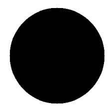

Fig. 12. Filter 1

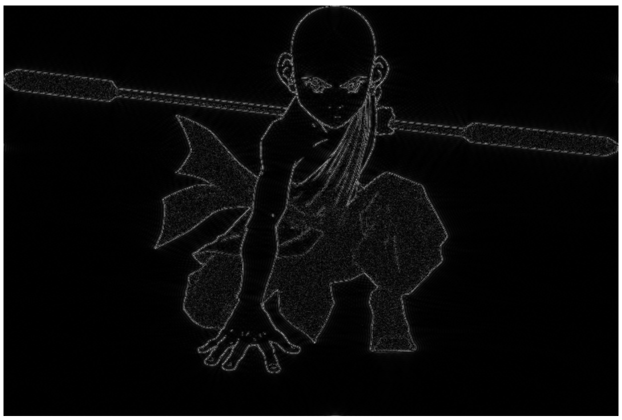

Fig. 13. Edges of C1

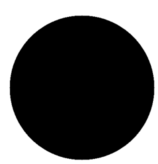

Fig. 14. Filter 2

Fig. 15. Edges of C2

C. Conclusion

Filtering in frequency domain can help finding the edges of an image. By removing the low frequency components in an image, one can easily obtain the edges by using only the high frequency components of the image. However, finding the edges using frequency domain filtering causes some artifacts in the output images such as the ringing effect.

V. Conclusion

In this assignment, the usage of frequency domain image processing techniques were practiced. Frequency domain analysis can be used for multiresolution analysis, noise removal and edge detection. Processing in frequenct domain is required since some operations are impossible to apply in spatial domain such as the removal of periodic noises.