Project #1

Fall 2021
Willie Chang

Abstract

In the course, we have learned about the ideas and algorithms of *Image Denoising.* One of the methods is known as *"Wavelet Image Denoising"*, which applies the subband wavelet transform for decompositions of the image for denoising process.

In this project, we are going to apply the built-in function of Matlab, *"Discrete 2D Wavelet Transform"* to decompose the noisy input image into multiple subbands, and denoise by setting several high frequency subbands, which are the noises, into 0. Then compare each denoising process from each output for better understanding of "*Wavelet Image Denoising"* in digital image processing.

Introduction

Subband/ Wavelet Transform, also known as SWT, is an analysis method to analyze an input signal, which is separated into different subbands by applying both low-pass filter (LPF) and high-pass filter (HPF) to the signal. This allows us to manipulate the signal in different frequencies.

Since we want to denoise the input image, shown in Fig. 1(a), comparing to the clean image, shown in Fig. 1(b), we apply two-dimensional digital wavelet transform for further process.

(a) Noisy image (b) Clean image

Fig. 1. Input image examples for wavelet denoising process

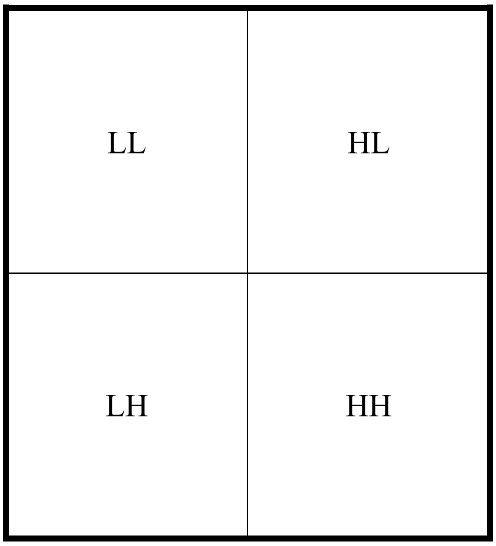
Process

First, we decompose the given image, “lean512noisy.bmp”, into subbands by using:

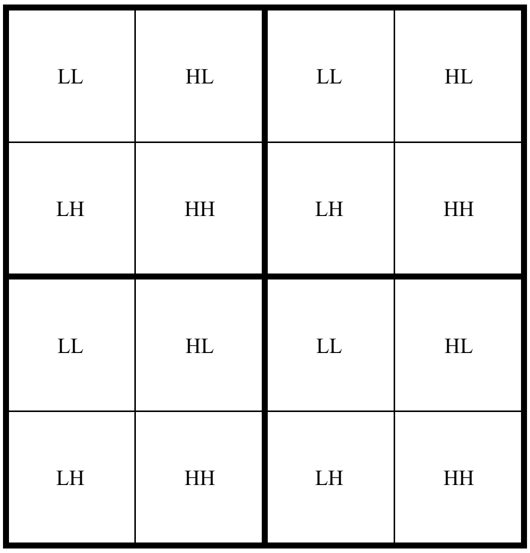
(a) 16-band dyadic decompositions, and

(b) 22-band modified pyramid decompositions.

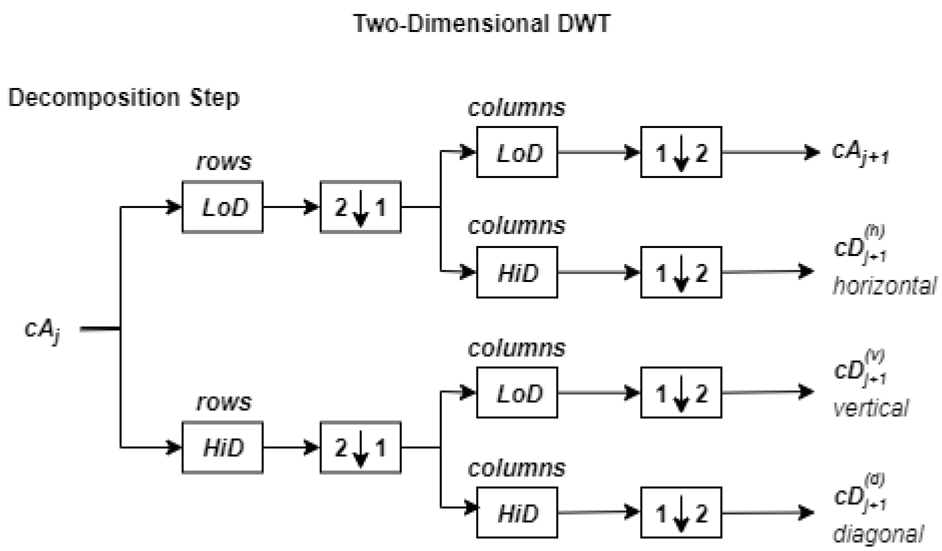
For 16-band decompositions, we apply a decomposition into 4 subbands, LL, LH, HL, and HH. Each L and H represents a LPF and HPF, respectively. We then apply another one-level decomposition to each of the output of previous stage will then give us a 16-band subband/wavelet decomposition. Fig. 2 shows the concept of 16-band decomposition.



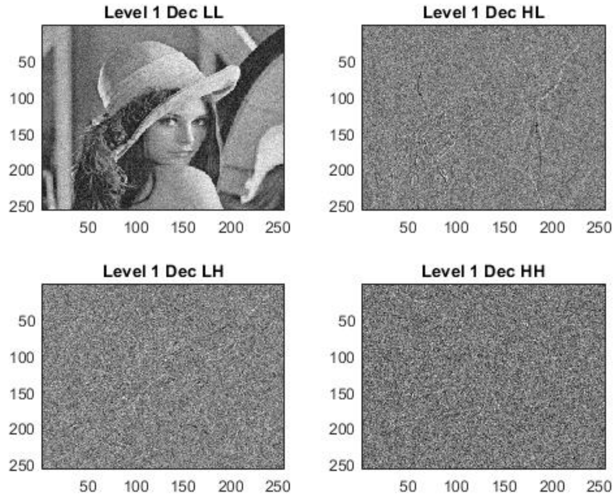
(a) A 4-band decomposition



(b) A 16-band decomposition



(c) Concept of 4-band decomposition from two stages of filters and downsamplings, each applied on rows and columns, respectively, reference from Matlab



(d) A 4-band decomposition using **dwt2()** function in Matlab from the input image

Fig. 2. (a), (b), (c) shows the concept of how to generate a 4-band and 16-band decomposition. Fig. 2. (d) shows the result of a 4-band decomposition applied by Matlab.

Then, we set different higher frequency subbands into zero arrays to mitigate the effects of noise from high frequencies.

For 16-band dyadic decomposition, we set

(a) **one highest-frequency,** *(which is* y_{16}*)*
(b) **three highest-frequency,** *(which are* y_{14}, y_{15}, y_{16}*)*
(c) **six highest-frequency subbands,** *(which are* $y_8, y_{12}, y_{13}, y_{14}, y_{15}, y_{16}$*)* to zero

For 22-band modified pyramid decomposition, we set

(a) three highest-frequency, *(which are* z_{20}, z_{21}, z_{22}*)*
(b) 10 highest-frequency, *(which are* $z_{12}, z_{13}, z_{14}, z_{16}, z_{17}, z_{18}, z_{19}, z_{20}, z_{21}, z_{22}$*)*
(c) 15 highest-frequency, *(which are* $z_8, z_9, z_{10}, z_{11}, z_{12}, z_{13}, z_{14}, z_{15}, z_{16}, z_{17}, z_{18}, z_{19}, z_{20}, z_{21}, z_{22}$*)* to zero

y_1	y_3	y_5	y_7
y_2	y_4	y_6	y_8
y_9	y_{11}	y_{13}	y_{15}
y_{10}	y_{12}	y_{14}	y_{16}

Fig. 3. 16-band dyadic decomposition's compact notation distribution

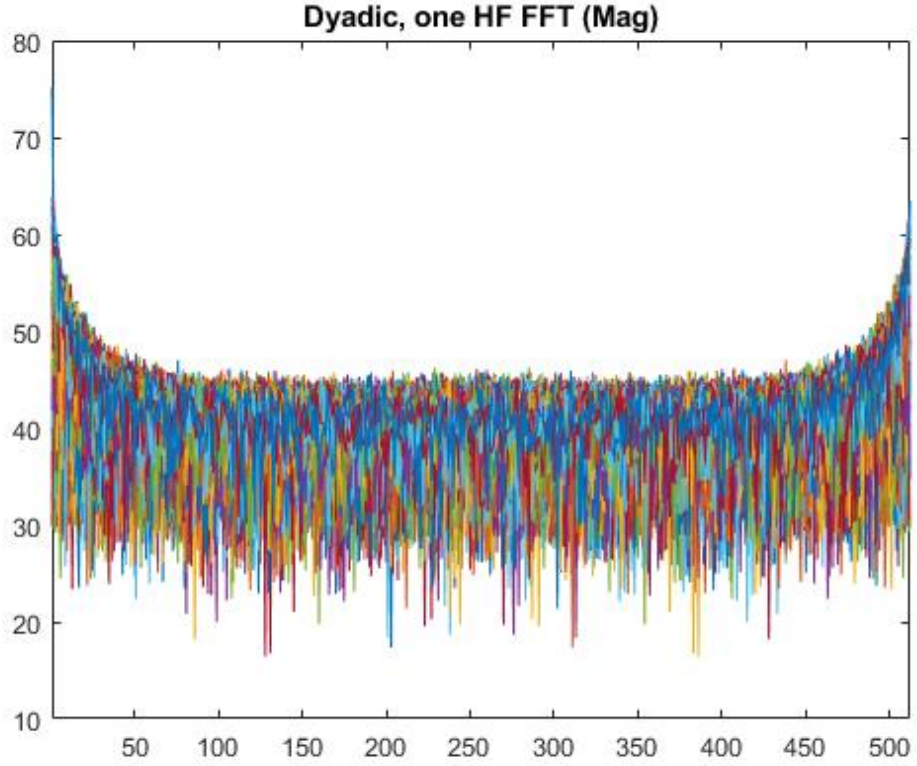
Lastly, by applying inverse subband wavelet transform (ISWT or inverse-SWT), we get the reconstruction images after setting the appropriate coefficients to zero. The following contents show the results of each reconstruction image.

For 16-band dyadic decomposition,

(i) one highest-frequency, *(which is* y_{16}*)*

(a) Original noisy image

(b) Reconstruction image

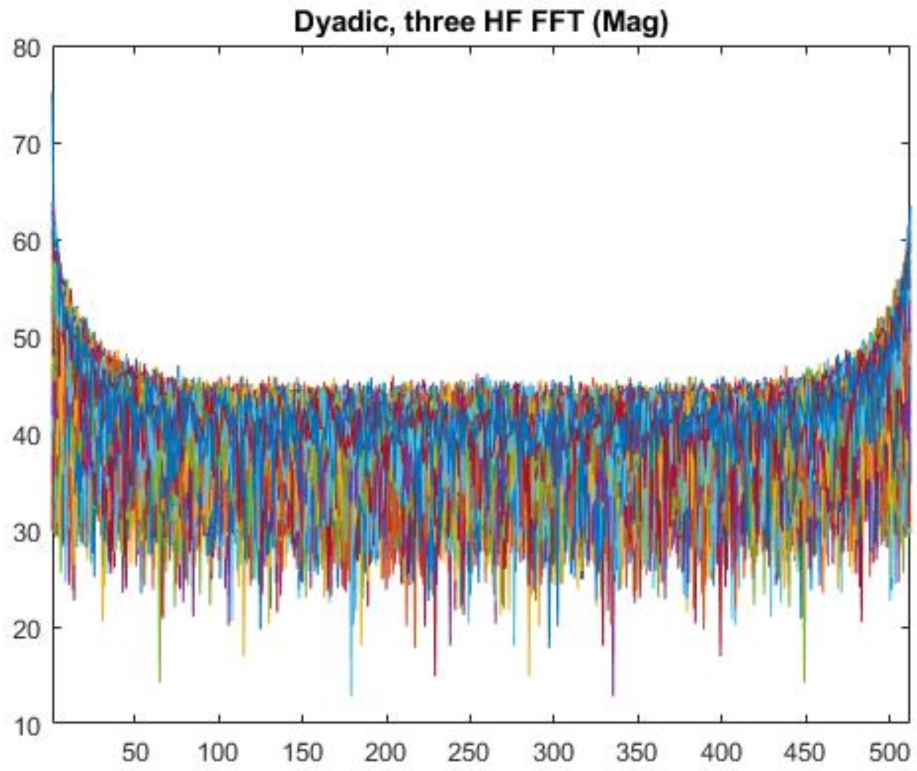


(c) The DFT of the reconstruction image

(ii) three highest-frequency, *(which are* y_{14}, y_{15}, y_{16}*)*

(a) Original noisy image

(b) Reconstruction image

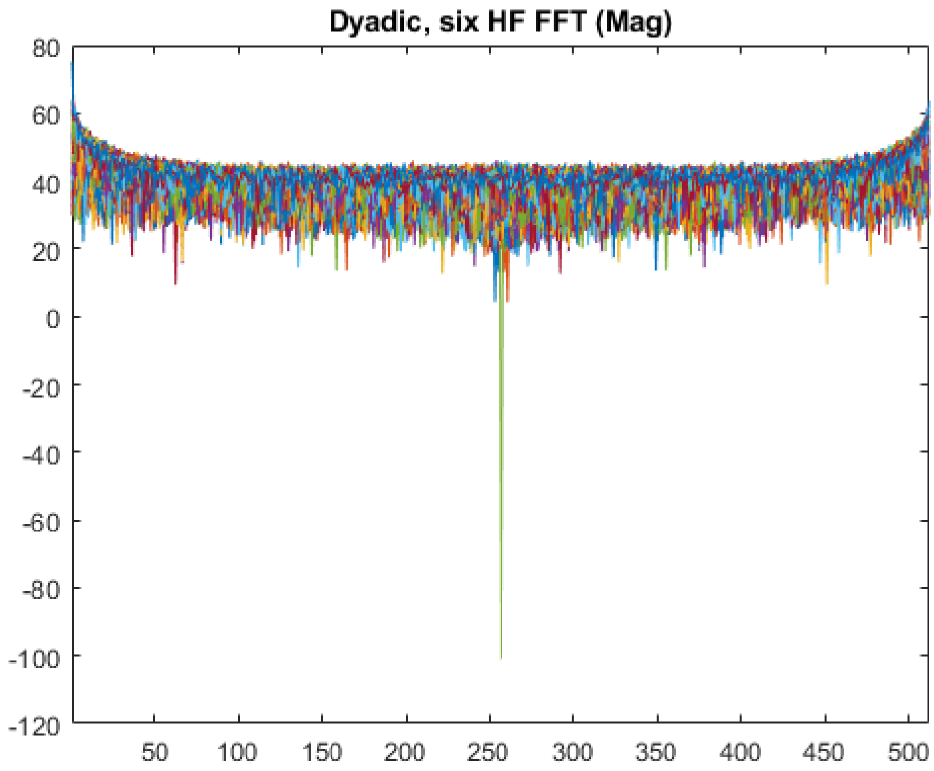


(c) The DFT of the reconstruction image

(iii) six highest-frequency subbands, *(which are* $y_8, y_{12}, y_{13}, y_{14}, y_{15}, y_{16}$*)*

(a) Original noisy image

(b) Reconstruction image



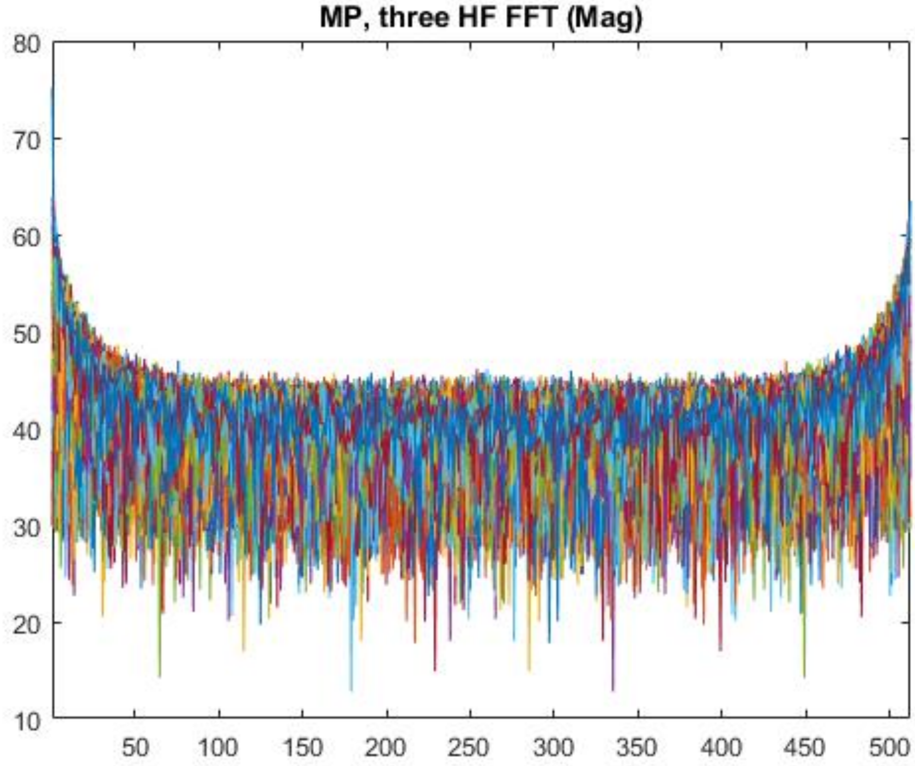
(c) The DFT of the reconstruction image

For 22-band modified pyramid decomposition, we set

(i) three highest-frequency, *(which are* z_{20}, z_{21}, z_{22}*)*

(a) Original noisy image

(b) Reconstruction image

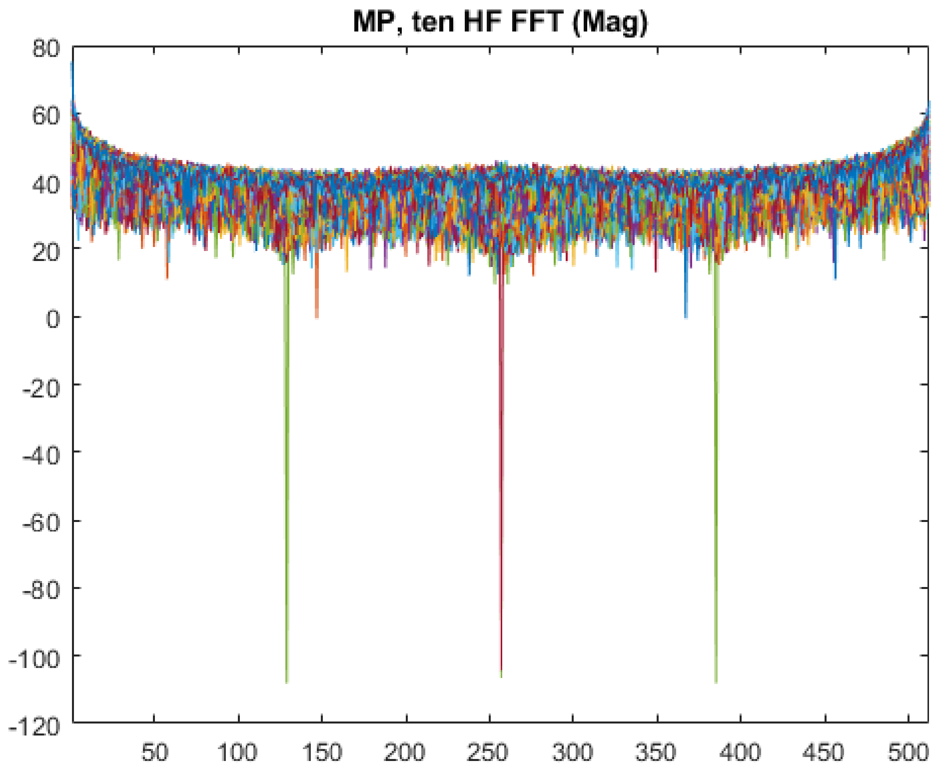


(c) The DFT of the reconstruction image

(ii) 10 highest-frequency, *(which are* $z_{12}, z_{13}, z_{14}, z_{16}, z_{17}, z_{18}, z_{19}, z_{20}, z_{21}, z_{22}$*)*

(a) Original noisy image

(b) Reconstruction image

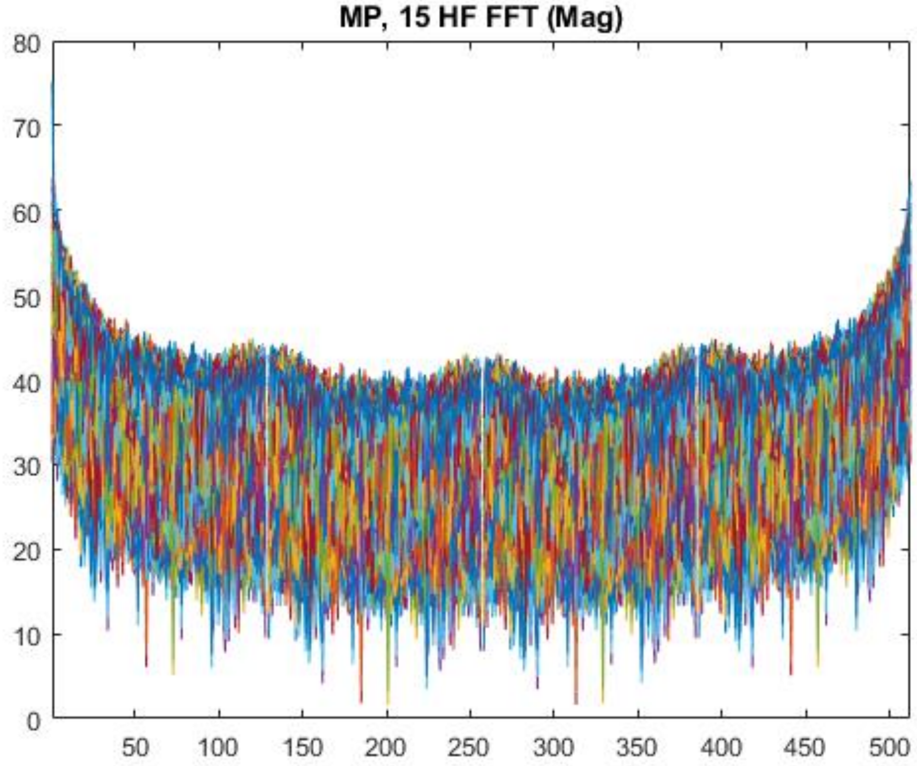


(c) The DFT of the reconstruction image

(iii) 15 highest-frequency, *(which are* $z_8, z_9, z_{10}, z_{11}, z_{12}, z_{13}, z_{14}, z_{15}, z_{16}, z_{17}, z_{18}, z_{19}, z_{20}, z_{21}, z_{22}$*)*

(a) Original noisy image

(b) Reconstruction image



(c) The DFT of the reconstruction image

Conclusion

For the results of each different situation, the removal of the high frequencies of signal really does some effect on the output image. Some obvious noisy spots are removed, comparing to the original noisy figure. However, the dyadic cases and the modified pyramid with the removal of three subbands remain lots of noise on the output image; while the modified pyramid with the removal of 15 subbands has an obvious resolution dropping (since some lower frequency details are removed as well). I can tell that the best performance among them is the modified pyramid with 10 subbands removed, which has the least noisy spots of all the output images.

For the future work, I may need to separate more different kinds of subbands, since by removing some low subbands, we encounter the drop of resolutions. Besides, I will implement different image processing approaches, and to different programming languages such as Python for better understanding of this course and applications.