EEE 508 Digital Image and Video Processing/Compression

Project -1 Wavelet Image Denoising

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Contents

1. 16-band dyadic (pyramid) decomposition

The image used was “lena512noisy.bmp”. For 16 band decomposition the pyramid was defined as in figure 1.

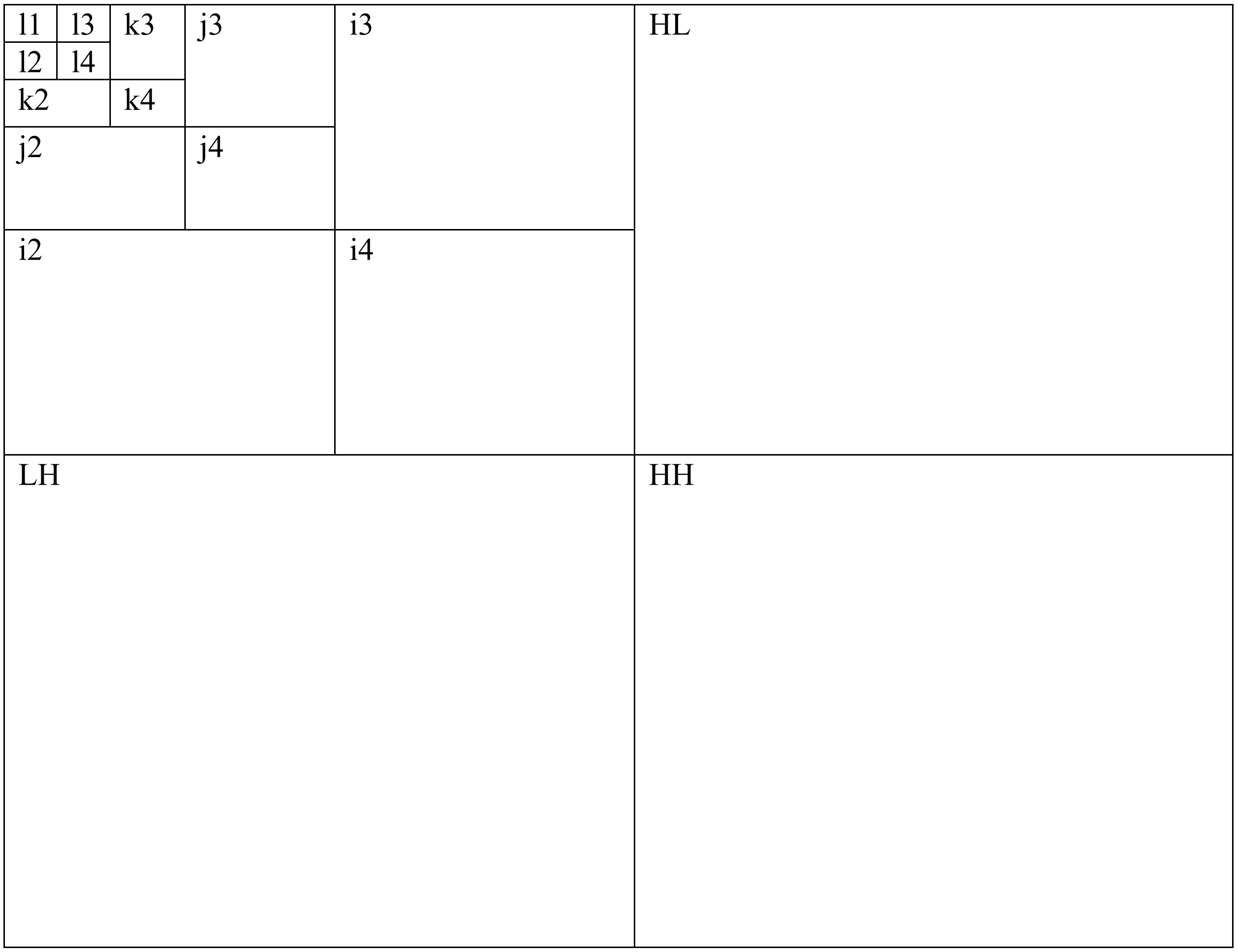

Figure 1. 16 band dyadic(pyramid) decomposition

In total there are five decomposition layers. The MATLAB in-built function **dwt2** (Discrete Wavelet Transform) filter was used to compute the sub bands of the image.

Three different reconstructions were computed. For reconstructed image 1, the highest frequency, HH represented in figure 1 was set to zero. For reconstructed image 2, three highest frequencies, HH,HL,LH represented in figure 1 were set to zero. For reconstructed image 3, six highest frequencies, HH,HL,LH,i4,i3,i2, represented in figure 1 were set to zero.

The magnitude of DFTs of the three reconstructed images were calculated using MATLAB in built functions **fft2** and **abs**.

1.1 Code

```
clc;clear all;close all;

img  = imread('lena512noisy.bmp');

%%%
%decomposing the image to 16 subbands
[LoD,HiD] = wfilters('haar','d'); % 'd' decomposition filters
[LL,LH,HL,HH] = dwt2(img,LoD,HiD); %1st level decomposition

%2nd level decomposition
[i1,i2,i3,i4] = dwt2(LL,LoD,HiD);

%3rd level decomposition
[j1,j2,j3,j4] = dwt2(i1,LoD,HiD);

%4th level decomposition
[k1,k2,k3,k4] = dwt2(j1,LoD,HiD);

%5th level decomposition
[l1,l2,l3,l4] = dwt2(k1,LoD,HiD);

[LoR,HiR] = wfilters('haar','r'); % 'r' reconstruction filters

%reconstruction with one highest frequency set to 0
k1_r1 = idwt2(l1,l2,l3,l4,LoR,HiR);
j1_r1 = idwt2(k1_r1,k2,k3,k4,LoR,HiR);
i1_r1 = idwt2(j1_r1,j2,j3,j4,LoR,HiR);
LL_r1 = idwt2(i1_r1,i2,i3,i4,LoR,HiR);

img_r1 = idwt2(LL_r1,LH,HL,[],LoR,HiR);
img_r1 = uint8(img_r1);

%displaying the reconstructed image 1
figure()
imshow(img_r1)
title('Image reconstructed with one highest value set to zero')

%reconstruction with three highest frequency set to 0

img_r2 = idwt2(LL_r1,[],[],[],LoR,HiR);
img_r2 = uint8(img_r2);

%displaying the reconstructed image 2
figure()
imshow(img_r2)
title('Image reconstructed with three highest value set to zero')

%reconstruction with six highest frequency set to 0

LL_r1 = idwt2(i1_r1,[],[],[],LoR,HiR);

img_r3 = idwt2(LL_r1,[],[],[],LoR,HiR);
img_r3 = uint8(img_r3);
```

```
%displaying the reconstructed image 3
figure()
imshow(img_r3)
title('Image reconstructed with six highest value set to zero')
```

1.2 Plots and observations

The reconstructed image 1 is represented in figure 2. There is no noticeable difference in the image from the original image. The reconstructed image 2 is represented in figure 3. There can be some smoothing seen especially around the face and the noise has reduced. The reconstructed image 3 is represented in figure 4. There is more noise reduction and smoothing than the reconstructed image 2 but the details are lost.

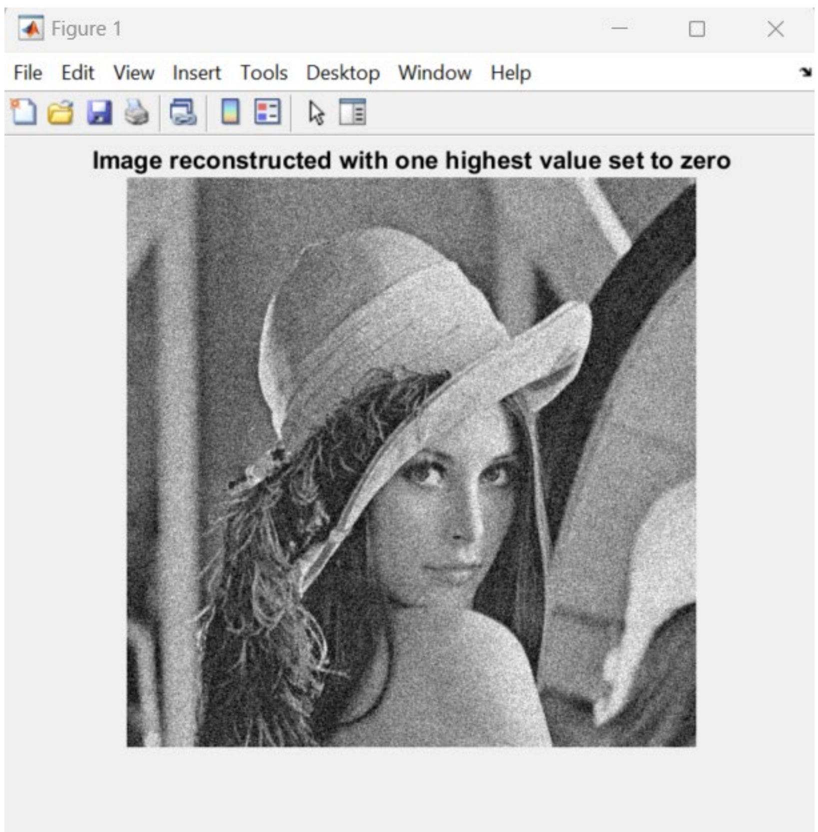

Figure 2. Reconstructed image 1.

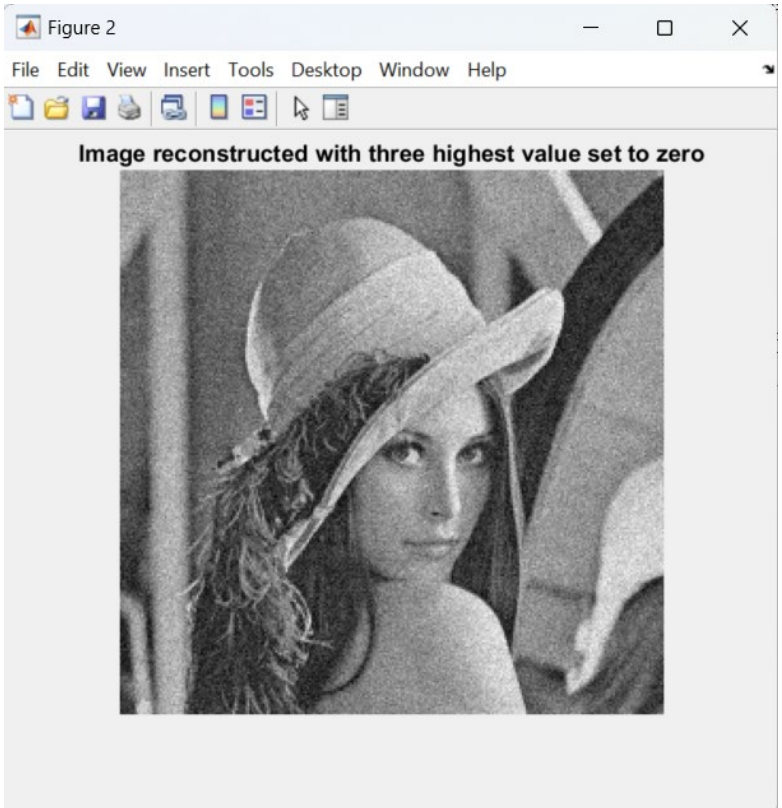

Figure 3. Reconstructed image 2.

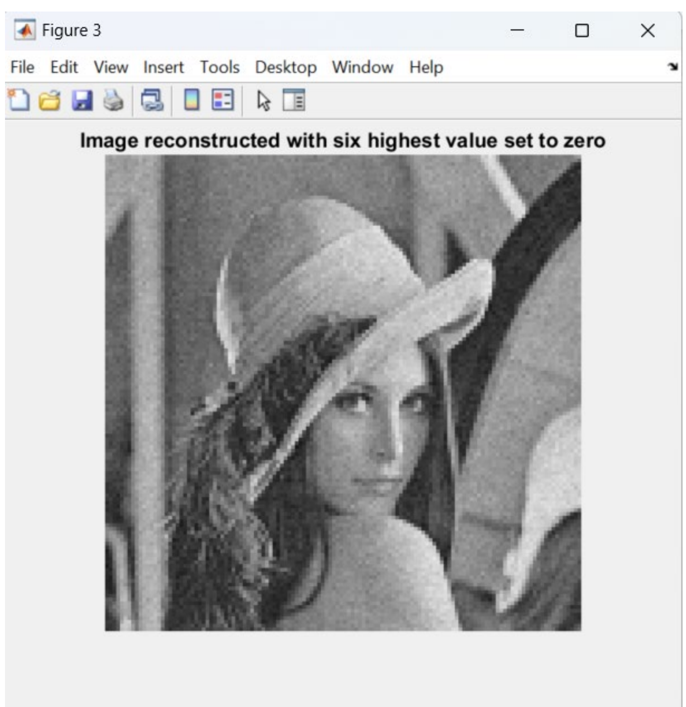

Figure 4. Reconstructed image 3.

The figure 5 represents the reconstructed image 1 and magnitude of its corresponding DFT. The brightest point in the frequency domain shows the DC components. It means it has the highest magnitude. The rest of the plot is dark because there is a huge difference between the magnitudes of the f(0,0) and other spectrums. While plotting the magnitude log was used to reduce the magnitude difference to a small size and can better visualize the details.

The figure 6 represents the reconstructed image 2 and magnitude of its corresponding DFT. It can be observed that there is change in magnitude and there are certain values that have smaller size difference compared to the center.

Figure 5. Reconstructed image 1 and magnitude of its corresponding DFT.

Figure 6. Reconstructed image 2 and magnitude of its corresponding DFT.

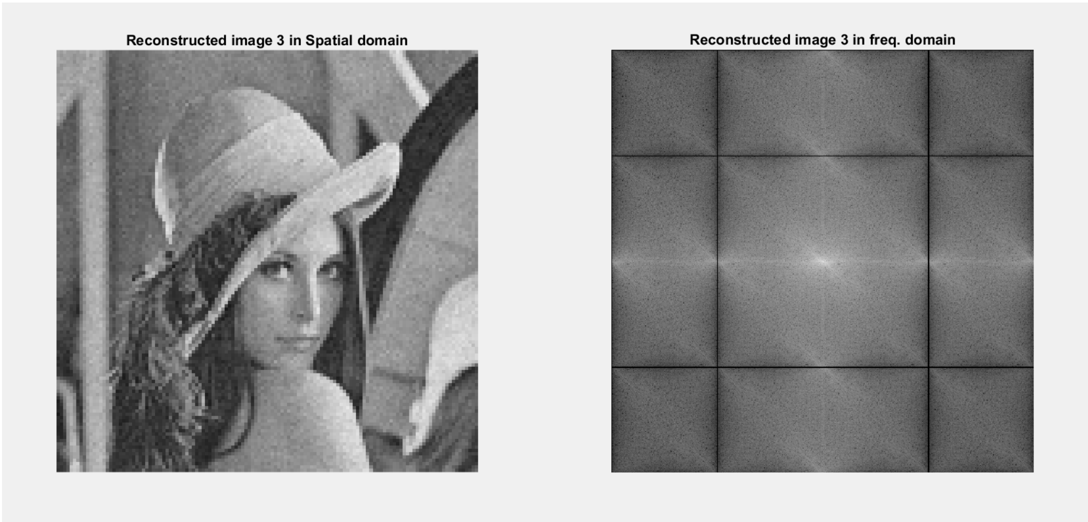

Figure 7. Reconstructed image 3 and magnitude of its corresponding DFT.

The figure 7 represents the reconstructed image 3 and magnitude of its corresponding DFT. It can be observed that there is a significant change in magnitude and there are more values that have smaller size difference compared to the center than in the magnitude plot of reconstructed image 2.

2. 22-band modified pyramid decomposition

The image used was “lena512noisy.bmp”. For 22 band decomposition the pyramid was defined as in figure ...

<table>
<tr><td>k1</td><td>k3</td><td rowspan="2">j3</td><td rowspan="3">I3</td><td rowspan="3">I9</td><td rowspan="3">I11</td></tr>
<tr><td>k2</td><td>k4</td></tr>
<tr><td colspan="2">j2</td><td>j4</td></tr>
<tr><td colspan="3">I2</td><td>I4</td><td>I10</td><td>I12</td></tr>
<tr><td colspan="3">I5</td><td>I7</td><td>I13</td><td>I15</td></tr>
</table>

I6	I8	I14	I16

Figure 8. 22 band modified pyramid decomposition

In total there are four decomposition layers. The MATLAB in-built function **dwt2** (Discrete Wavelet Transform) filter was used to compute the sub bands of the image.

Three different reconstructions were computed. For reconstructed image 1, the three highest frequencies I14,I15,I16 represented in figure 8 was set to zero. For reconstructed image 2, ten highest frequencies, I14,I15,I16,I13,I11,I10, I12,I8,I7,I6 represented in figure 8 were set to zero. For reconstructed image 3, fifteen highest frequencies, I14,I15,I16,I13,I11,I10,I12,I8,I7,I6, I5,I4,I9, I4,I3,I2 represented in figure 8 were set to zero.

The magnitude of DFTs of the three reconstructed images were calculated using MATLAB in built functions **fft2** and **abs**.

2.1 Code

```
%decomposing the image to 22 subbands
[LoD,HiD] = wfilters('haar','d'); % 'd' decomposition filters

[ll,lh,hl,hh] = dwt2(img,LoD,HiD); %1st level decomposition

%2nd level decomposition layer
[I1,I2,I3,I4] = dwt2(ll,LoD,HiD);
[I5,I6,I7,I8] = dwt2(lh,LoD,HiD);
[I9,I10,I11,I12] = dwt2(hl,LoD,HiD);
[I13,I14,I15,I16] = dwt2(hh,LoD,HiD);

%3rd level decomposition
[j1,j2,j3,j4] = dwt2(I1,LoD,HiD);

%4th level decomposition
[k1,k2,k3,k4] = dwt2(j1,LoD,HiD);


[LoR,HiR] = wfilters('haar','r'); % 'r' reconstruction filters

%reconstruction with three highest frequency set to 0
z = zeros([size(I16)]);

j1_r = idwt2(k1,k2,k3,k4,LoR,HiR);

I1_r = idwt2(j1_r,j2,j3,j4,LoR,HiR);

LL_r1 = idwt2(I1_r,I2,I3,I4,LoR,HiR);
LH_r1 = idwt2(I5,I6,I7,I8,LoR,HiR);
```

```
HL_r1 = idwt2(I9,I10,I11,I12,LoR,HiR);
HH_r1 = idwt2(I13,z,z,z,LoR,HiR);

img_r1_s22 = idwt2(LL_r1,LH_r1,HL_r1,HH_r1,LoR,HiR);
img_r1_s22 = uint8(img_r1_s22);

%displaying the reconstructed image 4
figure()
imshow(img_r1_s22)
title('Image reconstructed with three highest value set to zero')

%reconstruction with 10 highest frequency set to 0
LH_r2 = idwt2(I5,z,z,z,LoR,HiR);
HL_r2 = idwt2(I9,z,z,z,LoR,HiR);
HH_r2 = idwt2(z,z,z,z,LoR,HiR);

img_r2_s22 = idwt2(LL_r1,LH_r2,HL_r2,HH_r2,LoR,HiR);
img_r2_s22 = uint8(img_r2_s22);

%displaying the reconstructed image 5
figure()
imshow(img_r2_s22)
title('Image reconstructed with ten highest value set to zero')

%reconstruction with 15 highest frequency set to 0
LL_r3 = idwt2(I1_r,z,z,z,LoR,HiR);
LH_r3 = idwt2(I5,z,z,z,LoR,HiR);
HL_r3 = idwt2(I9,z,z,z,LoR,HiR);
HH_r3 = idwt2(z,z,z,z,LoR,HiR);

img_r3_s22 = idwt2(LL_r3,LH_r3,HL_r3,HH_r3,LoR,HiR);
img_r3_s22 = uint8(img_r3_s22);

%displaying the reconstructed image 6
figure()
imshow(img_r3_s22)
title('Image reconstructed with fifteen highest value set to zero')

%plotting the DFTs of the reconstructed images\
% calculating the magnitude of the reconstructed images
img_16_dft_mag1_s22 = abs(fftshift(fft2(img_r1_s22))); %for reconstructed image 1
img_16_dft_mag2_s22 = abs(fftshift(fft2(img_r2_s22))); %for reconstructed image 2
img_16_dft_mag3_s22 = abs(fftshift(fft2(img_r3_s22))); %for reconstructed image 3

%plotting the DFT of the reconstructed image 4
figure
subplot(121)
imshow(img_r1_s22)
title('Reconstructed image 4 in Spatial domain')

subplot(122)
imshow(log(1+img_16_dft_mag1_s22), [])
title('Reconstructed image 4 in freq. domain')

%plotting the DFT of the reconstructed image 5
```

```
figure
subplot(121)
imshow(img_r2_s22)
title('Reconstructed image 5 in Spatial domain')

subplot(122)
imshow(log(1+img_16_dft_mag2_s22), [])
title('Reconstructed image 5 in freq. domain')

%plotting the DFT of the reconstructed image 6
figure
subplot(121)
imshow(img_r3_s22)
title('Reconstructed image 6 in Spatial domain')

subplot(122)
imshow(log(1+img_16_dft_mag3_s22), [])
title('Reconstructed image 6 in freq. domain')
```

2.2 Plots and observations

The reconstructed image 4 is represented in figure 9. There is no significant difference in the image from the original image. The reconstructed image 5 is represented in figure 10. There is slight smoothing and noise reduction compared to reconstructed image 4. The reconstructed image 6 is represented in figure 11. There is significant noise reduction and smoothing than the reconstructed image 5 but the details are lost similar to reconstructed image 3.

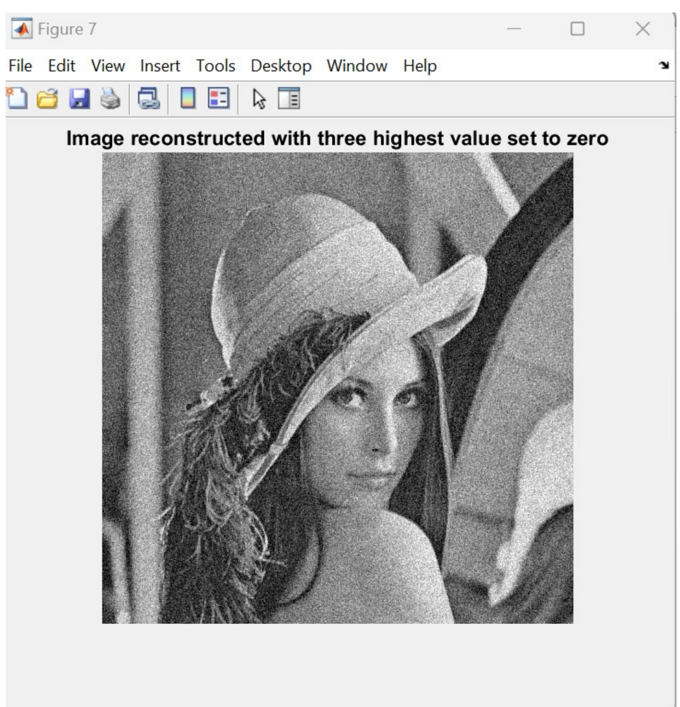

Figure 9. Reconstructed image 4.

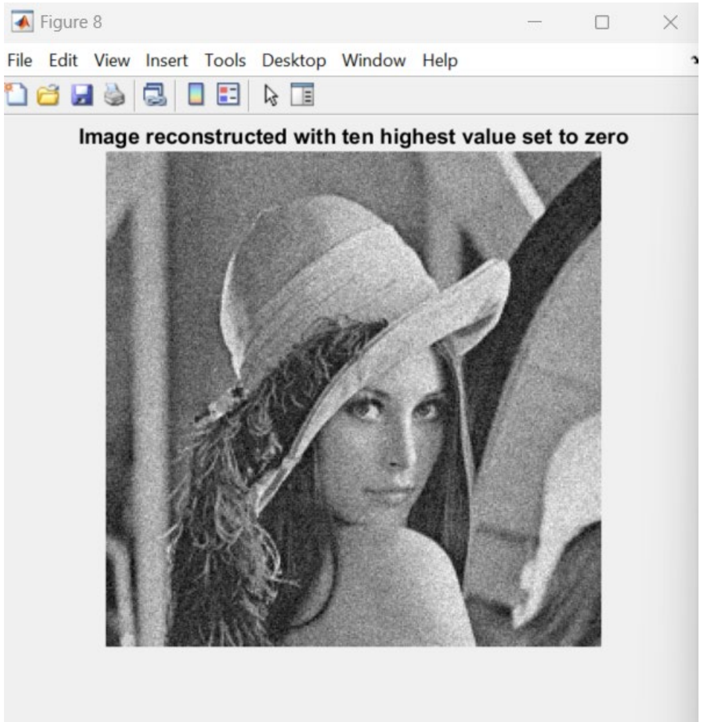

Figure 10. Reconstructed image 5.

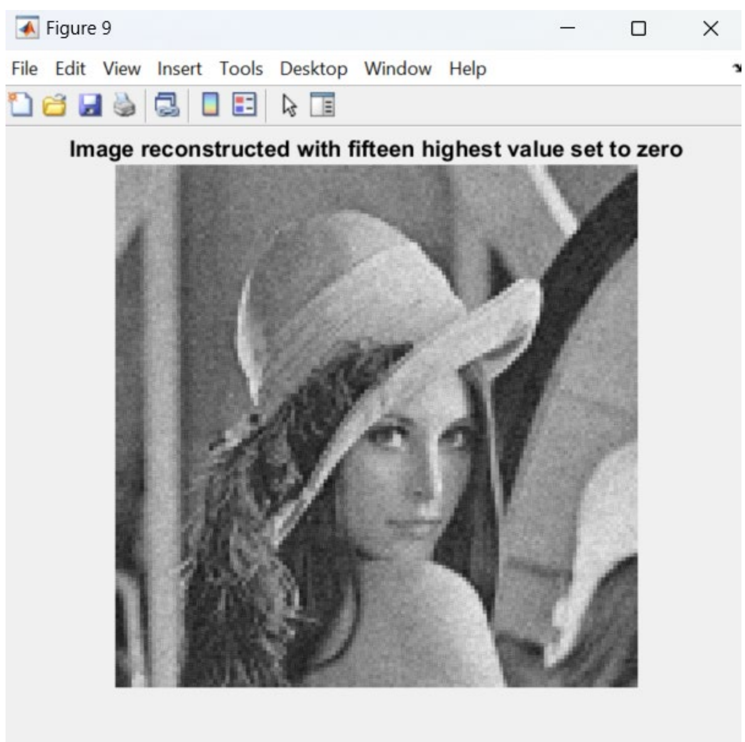

Figure 11. Reconstructed image 6.

The figure 12 represents the reconstructed image 4 and magnitude of its corresponding DFT. The brightest point in the frequency domain shows the DC components. Similar to 16 band reconstructed images, while plotting the magnitude for 22 band reconstructed images, log was used to reduce the magnitude difference to a small size and can better visualize the details.

The figure 13 represents the reconstructed image 5 and magnitude of its corresponding DFT. It can be observed that there is change in magnitude and the corners are darker then the DFT magnitude of reconstructed image 4, meaning there is a larger difference in values at the corners to the center.

Figure 12. Reconstructed image 4 and magnitude of its corresponding DFT.

Figure 13. Reconstructed image 5 and magnitude of its corresponding DFT.

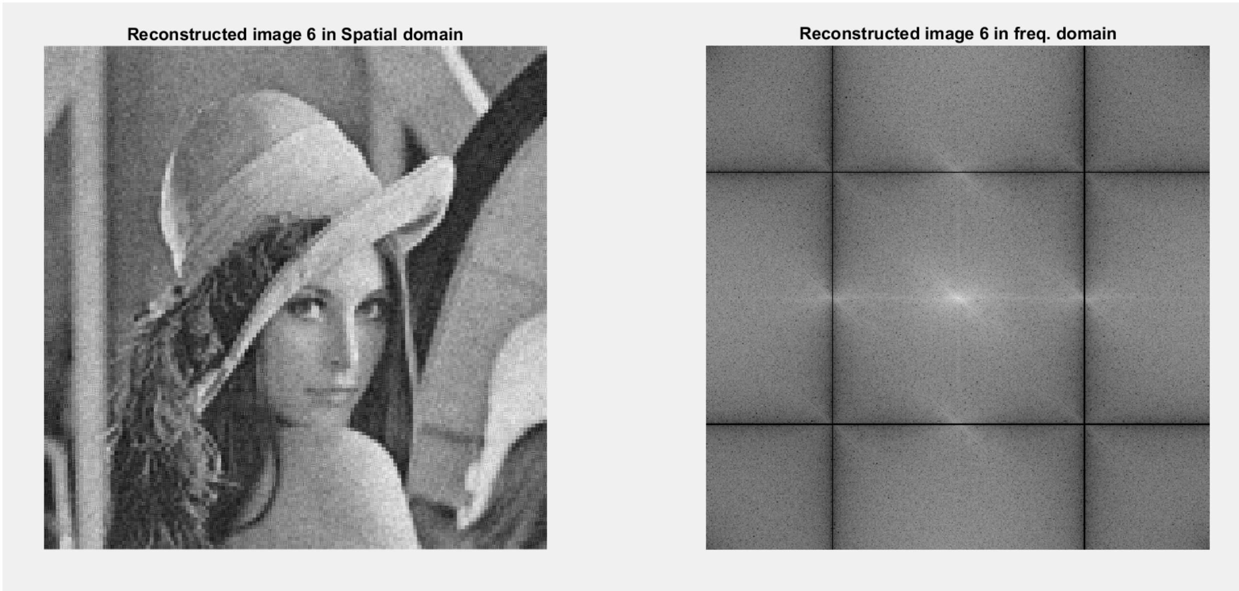

Figure 14. Reconstructed image 6 and magnitude of its corresponding DFT.

The figure 14 represents the reconstructed image 6 and magnitude of its corresponding DFT. It can be observed that there is a significant change in magnitude and there are more bright spots meaning there are values that have smaller size difference compared to the center than in the magnitude plot of reconstructed image 5.

3. DFT of the Original Image

The figure 15 represents the "lena512noisy" image. The figure 15 represents the DFT of the "lena512noisy" image The brightest point in the frequency domain shows the DC components.

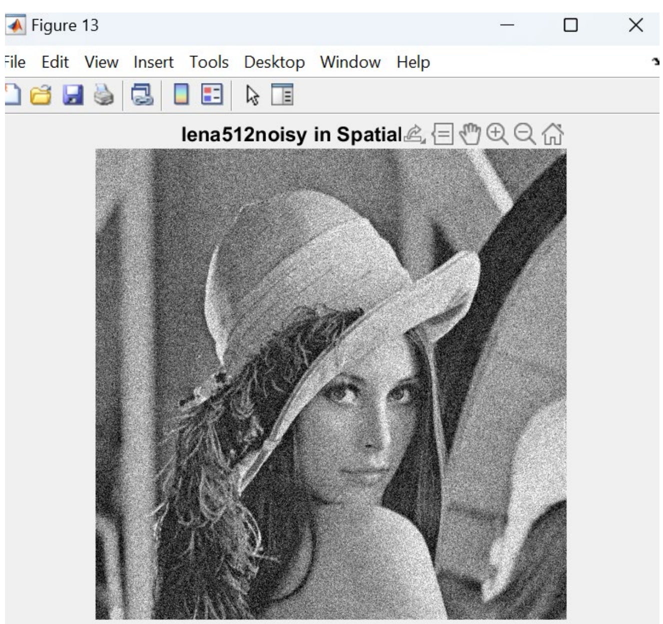

Figure 15. "lena512noisy" image.

Figure 16.DFT of the " lena512noisy" image.