A. Image noise

1. 

Figure 1: test1 image

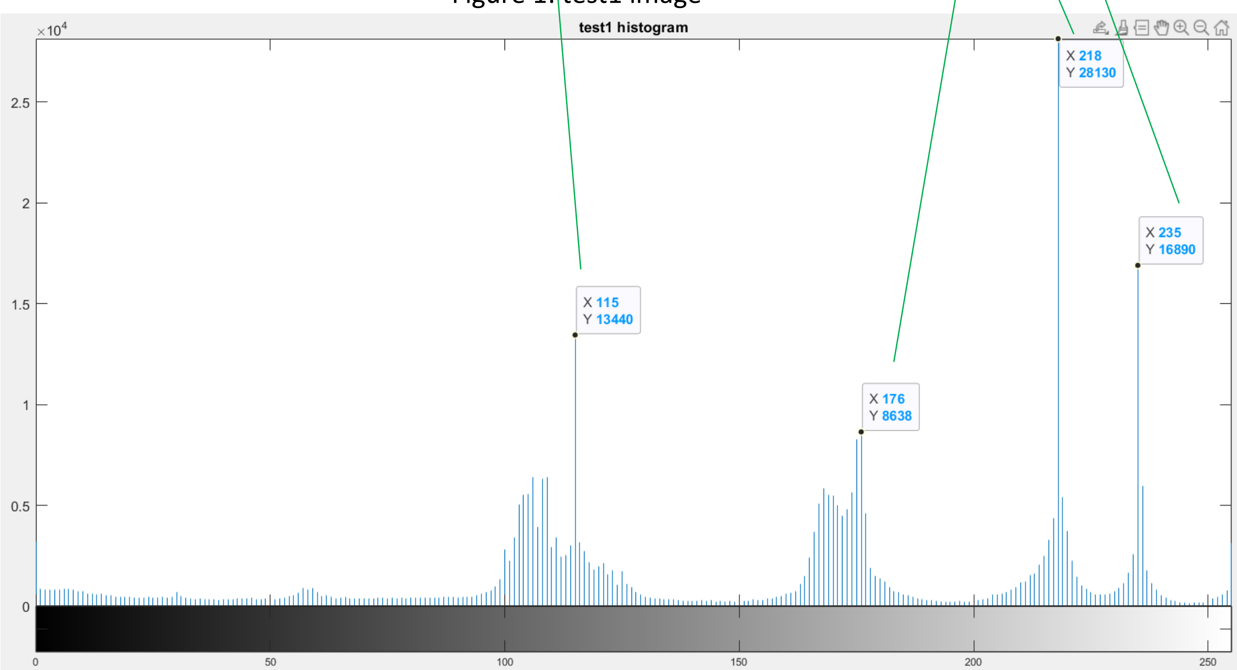

Figure 2: test1 histogram

From Figure 2, the x axis of the histogram is the range of gray levels (0 to 255), while the y axis of the histogram is the number of pixels for each gray level. In the above 2 diagrams, several peaks of the histogram have been identified and green arrows are drawn to relate the peaks of the histogram (in Figure 2) to the regions in the test1 image (in Figure 1). For instance, the gray level 235 is mostly seen in the face of the girl and gray level 218 is mostly observed in the hair of the girl.

2. (a)

```
SNR value of test1a:
   21.0588
```

Figure 3: SNR value of test1a obtained from MATLAB

Figure 4: test1a image

When we apply gaussian noise of sigma = 15 to test1 image, it can be observed that the resulting image (test1a) will consist of white noises. As seen in Figure 3, the SNR value of test1a obtained from MATLAB calculation is **21.0588dB**.

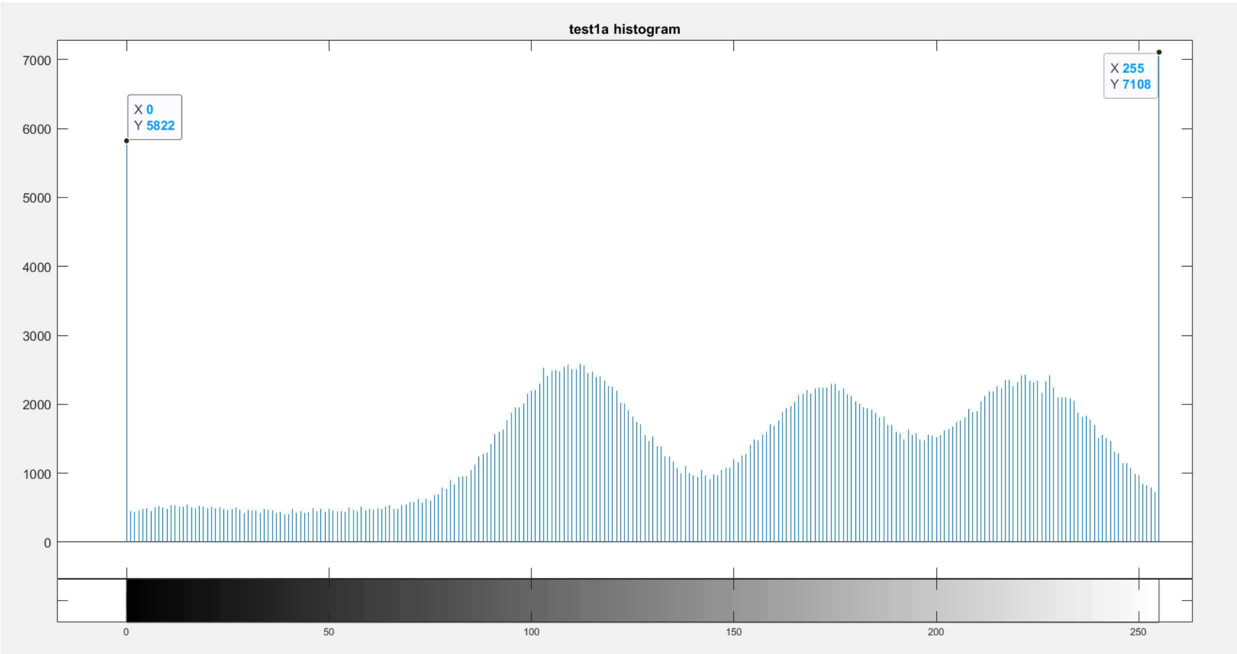

Figure 5: test1a histogram

In Figure 5, there are 3 obvious humps within the range of gray levels compared to 4 peaks identified in the original test1 image, and there are peaks found at gray level 0 and gray level 255 of the histogram.

The gaussian noise is applied to every pixel of test1 image, and every gray level of test1 image will undergo gaussian distribution. As such, the peaks in Figure 2 (before gaussian noise is applied) at gray level 115, 218 and 235 will spread across a range of gray level with a standard deviation of 15. This will result in a smoother distribution in the histogram as seen in Figure 5.

Moreover, the peaks at gray level 0 and gray level 255 is due to the gaussian distribution applied, whereby, gray level less than 0 will still be considered as gray level 0 and gray level more than 255 will still be considered as gray level 255.

(b)

```
SNR value of test1b:
    14.2184
```

Figure 6: SNR value of test1b obtained from MATLAB

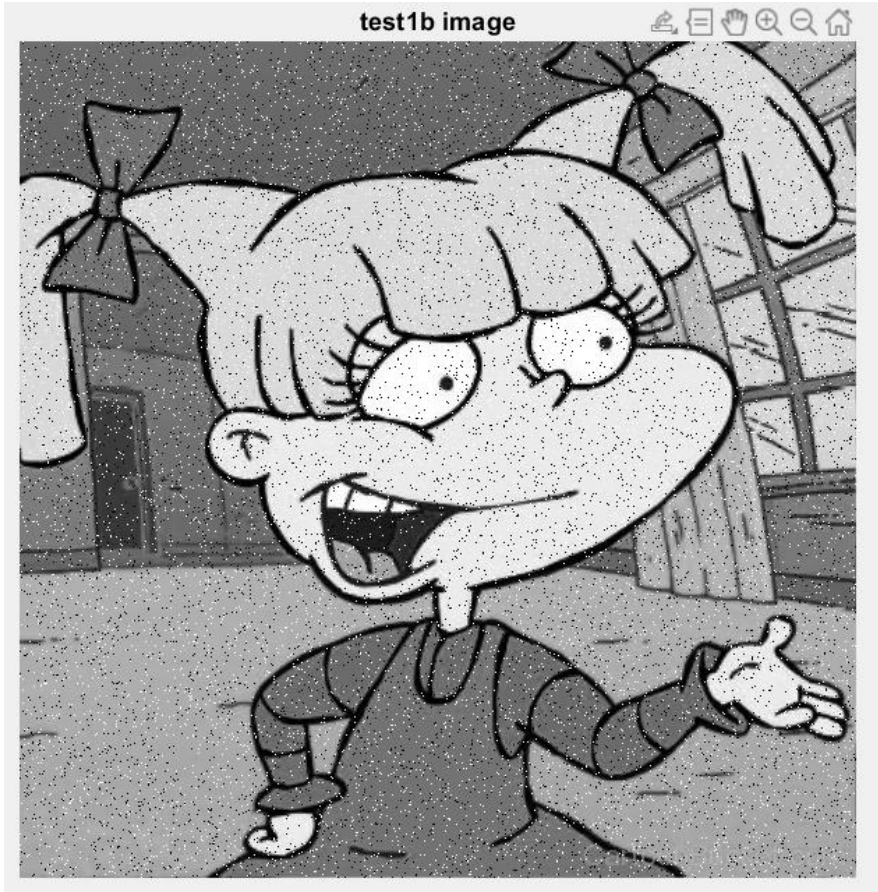

Figure 7: test1b image

When we apply salt-and-pepper noise of probability (density) = 0.05 to test1 image, it can be observed that the resulting image (test1b) will have sparsely occurring white and black pixels. As seen in Figure 6, the SNR value of test1b obtained from MATLAB calculation is **14.2184dB**.

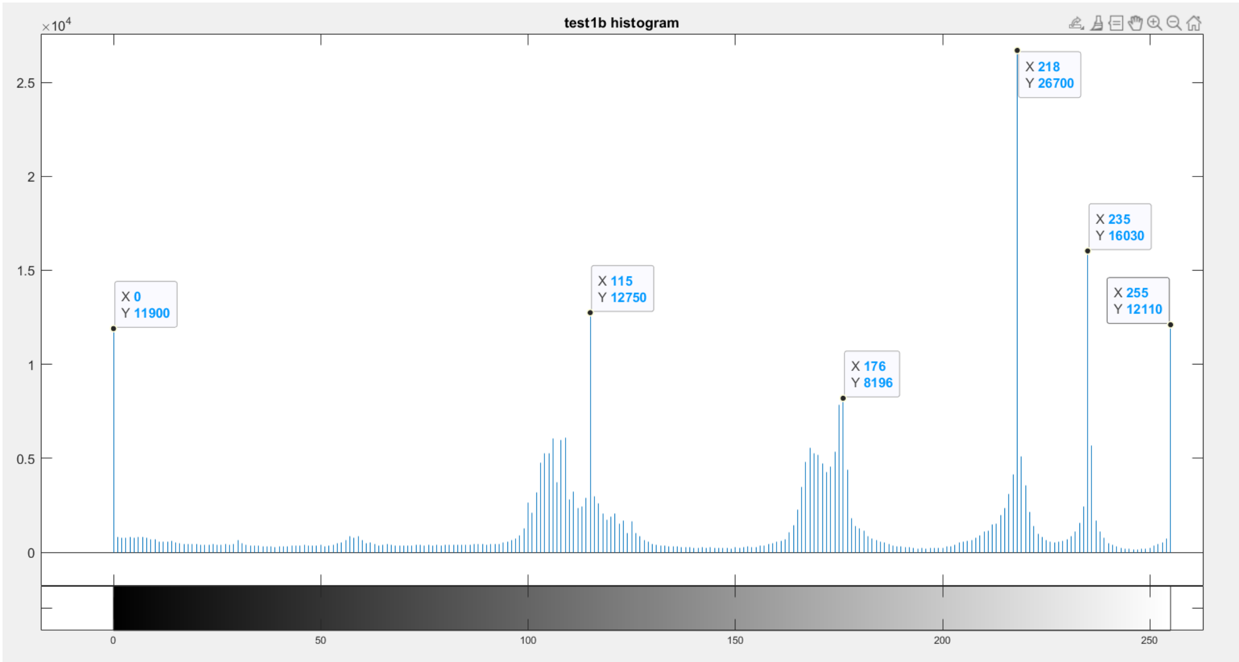

Figure 8: test1b histogram

In Figure 8, the peaks of the histogram are found at gray level 0, 115, 176, 218, 235 and 255. Compared to Figure 2 (before the salt-and-pepper noise is applied), in Figure 8, the number of pixels for all gray level is lesser except for gray level 0 and 255.

This is because the salt-and-pepper noise will randomly select the pixels of the test1 image at probability of 0.05 and add in noise of either gray level 0 or gray level 255 at the pixel. As such, this will result in the increase in the number of pixels at gray level 0 and gray level 255 and, decrease in the number of pixels at other gray levels in Figure 8 when compared to Figure 2.

3. (a)

```
SNR value of test1a with 3x3 mean filter applied:
    24.1658

SNR value of test1a with 7x7 mean filter applied:
    17.2682
```

Figure 9: SNR value of test1a with mean filter applied

Figure 10: test1a image with 3x3 mean filter applied

Figure 11: test1a image with 7x7 mean filter applied

With reference to Figure 9, the SNR value of test1a image with 3x3 mean filter applied is **24.1658dB** and SNR value of test1a image with 7x7 mean filter applied is **17.2682dB**. Figure 11 (resulting image with 7x7 mean filter applied) results in a blurrier image compared to Figure 10 (resulting image with 3x3 mean filter applied) and, the contrast of Figure 10 is better than Figure 11.

In both cases, noise is suppressed by the mean filter. However, signal is also affected, which will result in blurring in the image. Furthermore, a larger convolution mask (7x7 mean filter) will result in greater noise reduction and greater loss of image detail as seen in Figure 11.

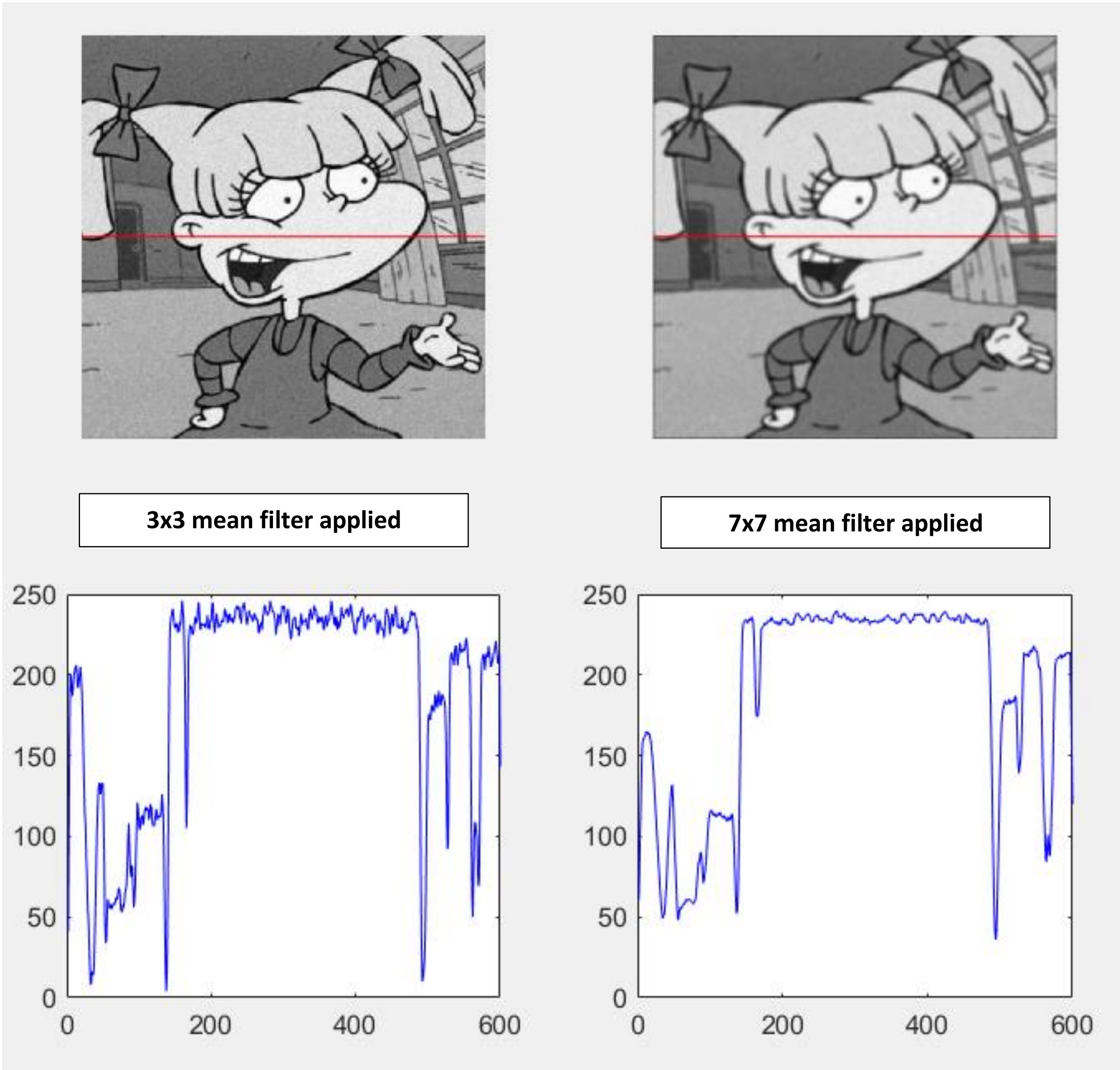

Figure 12: Image profile of the images when 3x3 and 7x7 mean filter applied

In addition, it can be observed that the image profile of the resulting image with 7x7 mean filter is smoother compared to the image profile of the resulting image with 3x3 mean filter. This is because the larger mean filter (7x7 mean filter) has removed more of the prominent features from the original image than the smaller mean filter (3x3 mean filter).

```
SNR value of test1a with 3x3 median filter applied:
   25.7466

SNR value of test1a with 7x7 median filter applied:
   20.1783
```

(b)

Figure 13: SNR value of test1a with median filter applied

Figure 14: test1a image with 3x3 median filter applied

Figure 15: test1a image with 7x7 median filter applied

With reference to Figure 13, the SNR value of test1a image with 3x3 median filter applied is **25.7466dB** and SNR value of test1a image with 7x7 median filter applied is **20.1783dB**. Figure 15 (resulting image with 7x7 median filter applied) results in a blurrier image compared to Figure 14 (resulting image with 3x3 median filter applied) and, the contrast of Figure 14 is better than Figure 15.

In both scenario, noise is suppressed by the median filter. However, signal is also affected, which will result in blurring and loss in details from the image. Moreover, a larger mask (7x7 median filter) will result in greater noise reduction and greater loss of image detail as seen in Figure 15.

In conclusion, the **3x3 median filter** is the best filter used for removing the gaussian noise in this image, with the highest SNR ratio out of all the filters. First and foremost, the size of the filter used is appropriate. Furthermore, the image contains many edges. A median filter is more suitable to preserve edges and details than a mean filter.

4. (a)

```
SNR value of test1b with 3x3 mean filter applied:
   21.0607

SNR value of test1b with 7x7 mean filter applied:
   16.8914
```

Figure 16: SNR value of test1b with mean filter applied

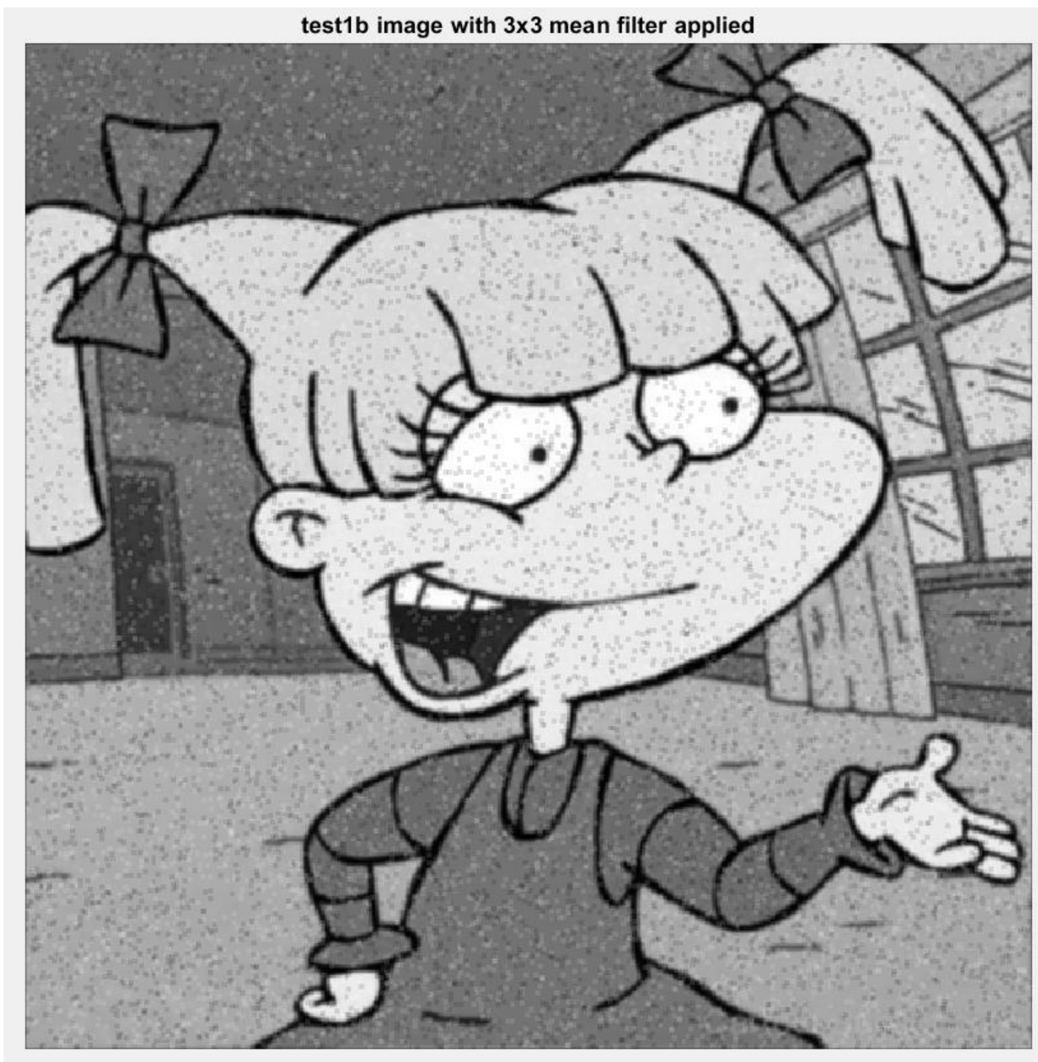

Figure 17: test1b image with 3x3 mean filter applied

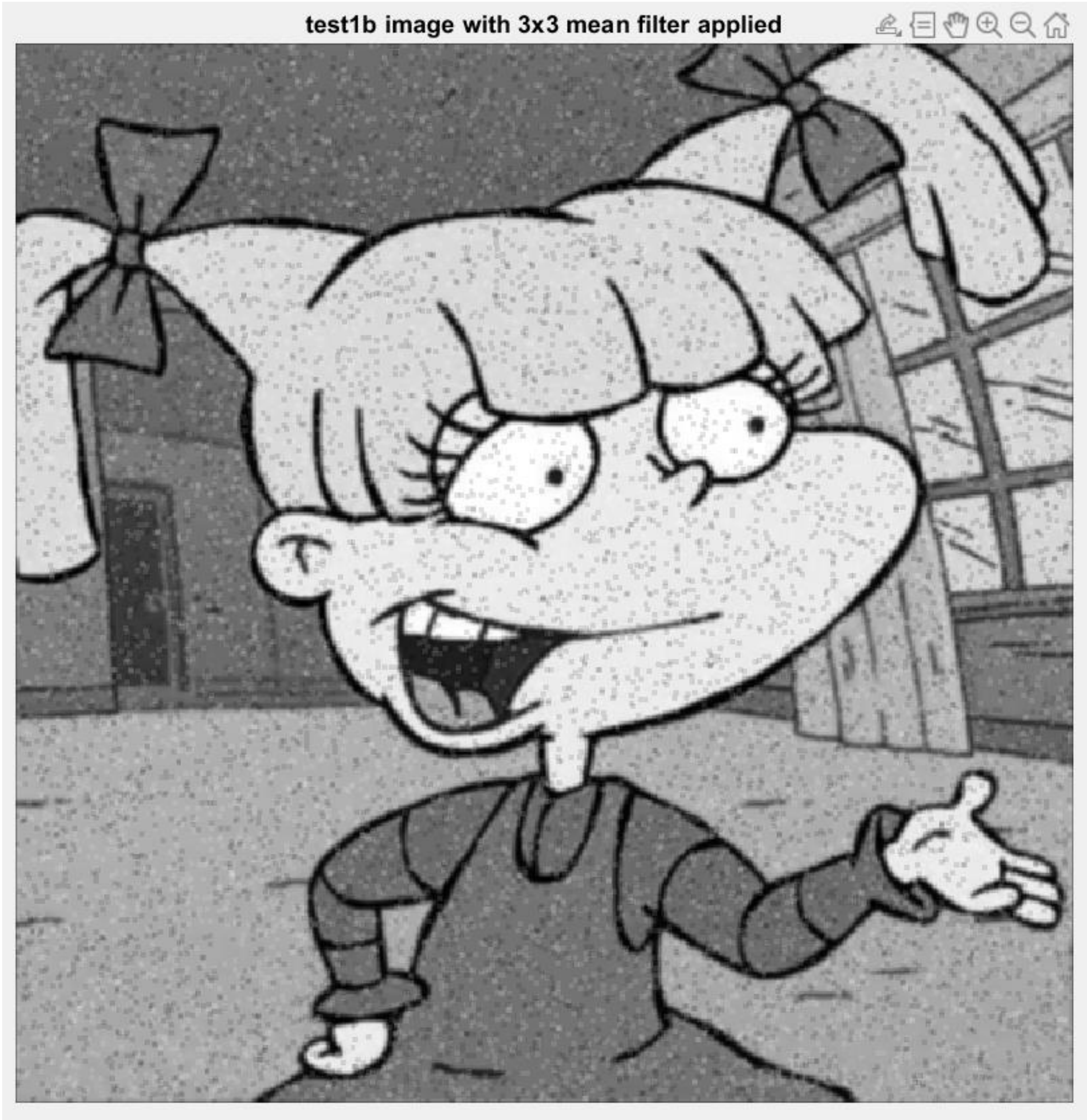

Figure 18: test1b image with 7x7 mean filter applied

With reference to Figure 16, the SNR value of test1b image with 3x3 mean filter applied is **21.0607dB** and SNR value of test1b image with 7x7 mean filter applied is **16.8914dB**. Figure 18 (resulting image with 7x7 mean filter applied) results in a blurrier image compared to Figure 17 (resulting image with 3x3 mean filter applied) and, the contrast of Figure 17 is better than Figure 18.

In both cases, noise is suppressed by the mean filter. However, signal is also affected, which will result in blurring in the image. Furthermore, a larger convolution mask (7x7 mean filter) will result in greater noise reduction and greater loss of image detail as seen in Figure 18.

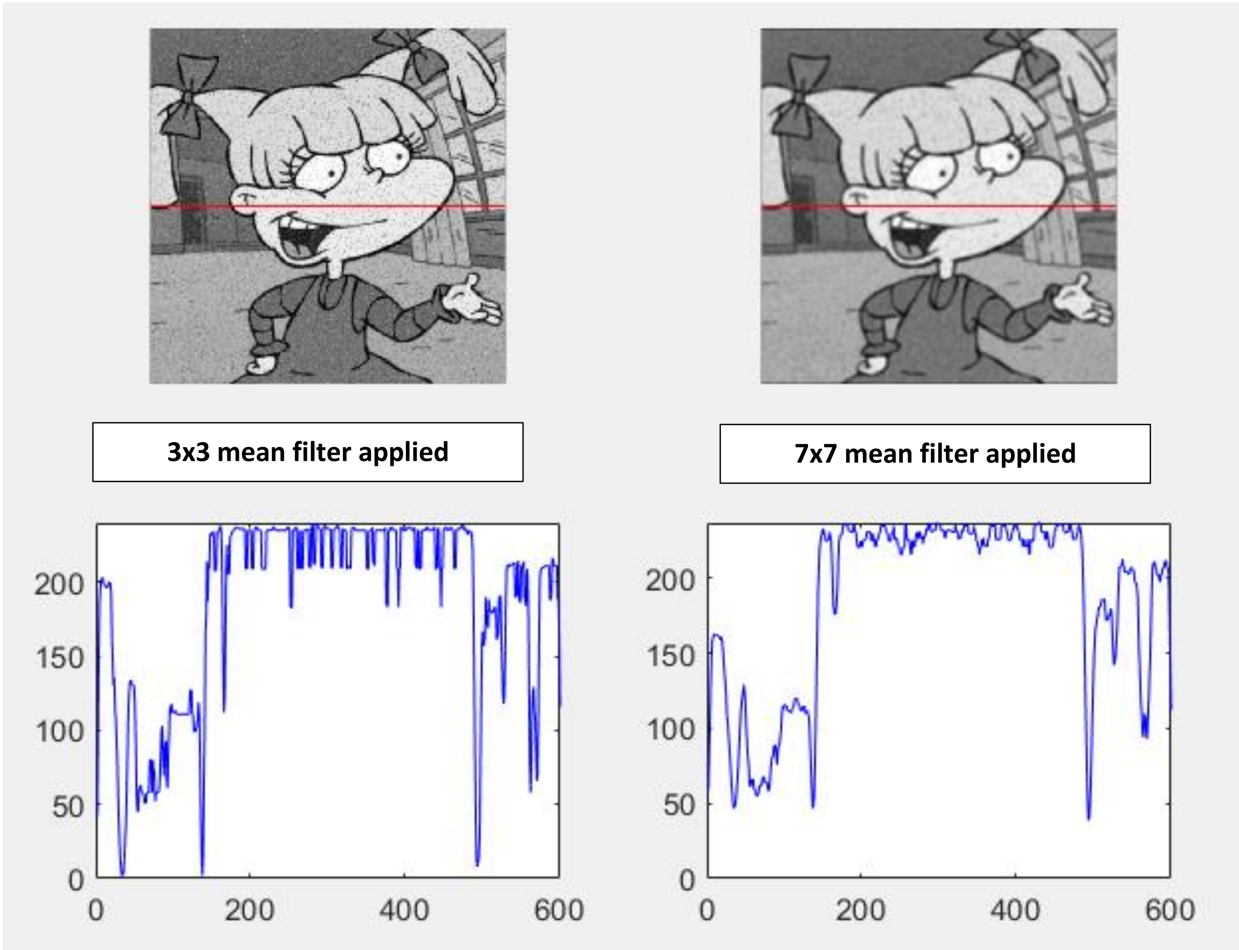

Figure 19: Image profile of the images when 3x3 and 7x7 mean filter applied

In addition, it can be observed that the image profile of the resulting image with 7x7 mean filter is smoother compared to the image profile of the resulting image with 3x3 mean filter. This is because the larger mean filter (7x7 mean filter) has removed the more of the prominent features from the original image than the smaller mean filter (3x3 mean filter).

```
SNR value of test1b with 3x3 median filter applied:
   28.8329

SNR value of test1b with 7x7 median filter applied:
   20.3808
```

(b)

Figure 20: SNR value of test1b with median filter applied

Figure 21: test1b image with 3x3 median filter applied

Figure 22: test1b image with 7x7 median filter applied

With reference to Figure 20, the SNR value of test1b image with 3x3 median filter applied is **28.8329dB** and SNR value of test1b image with 7x7 median filter applied is **20.3808dB**. Figure 22 (resulting image with 7x7 median filter applied) results in a blurrier image compared to Figure 21 (resulting image with 3x3 median filter applied) and, the contrast of Figure 21 is better than Figure 22.

In both scenario, noise is suppressed by the median filter. However, signal is also affected, which will result in blurring and loss in details from the image. Moreover, a larger mask (7x7 median filter) will result in greater noise reduction and greater loss of image detail as seen in Figure 22.

In conclusion, **the 3x3 median filter** is the best filter used for removing the salt-and-pepper noise in this image, with the highest SNR ratio out of all the filters. First and foremost, the size of the filter used is appropriate. Furthermore, the image contains many edges. A median filter is more suitable to preserve edges and details than a mean filter. Lastly, the median filter is particularly useful for salt-and-pepper noise and impulse noise, where it is good at removing outlier noises.

B. Fourier Transform

2.

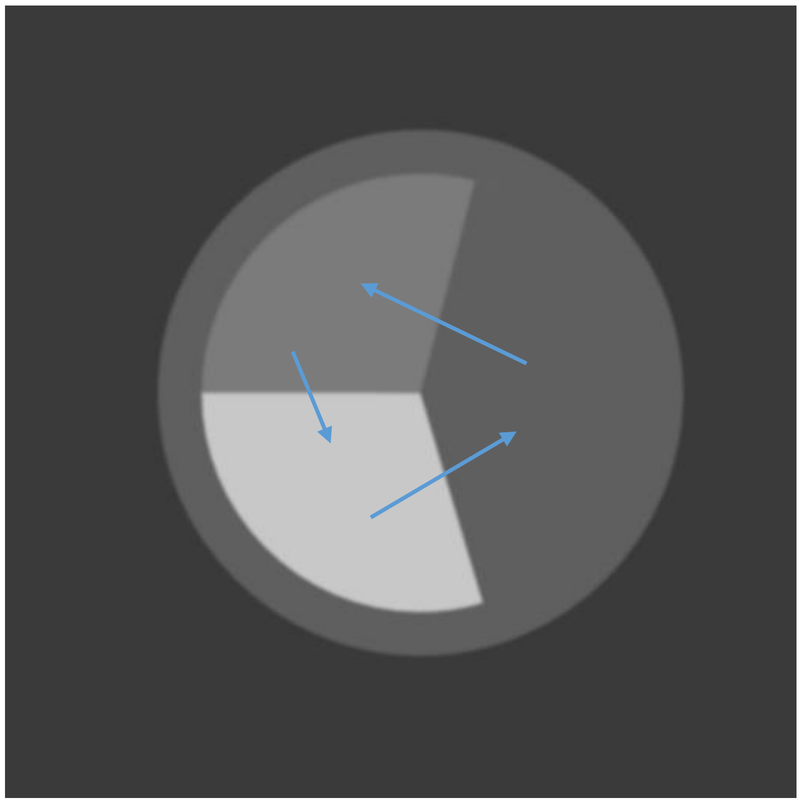

Figure 23: test2 image

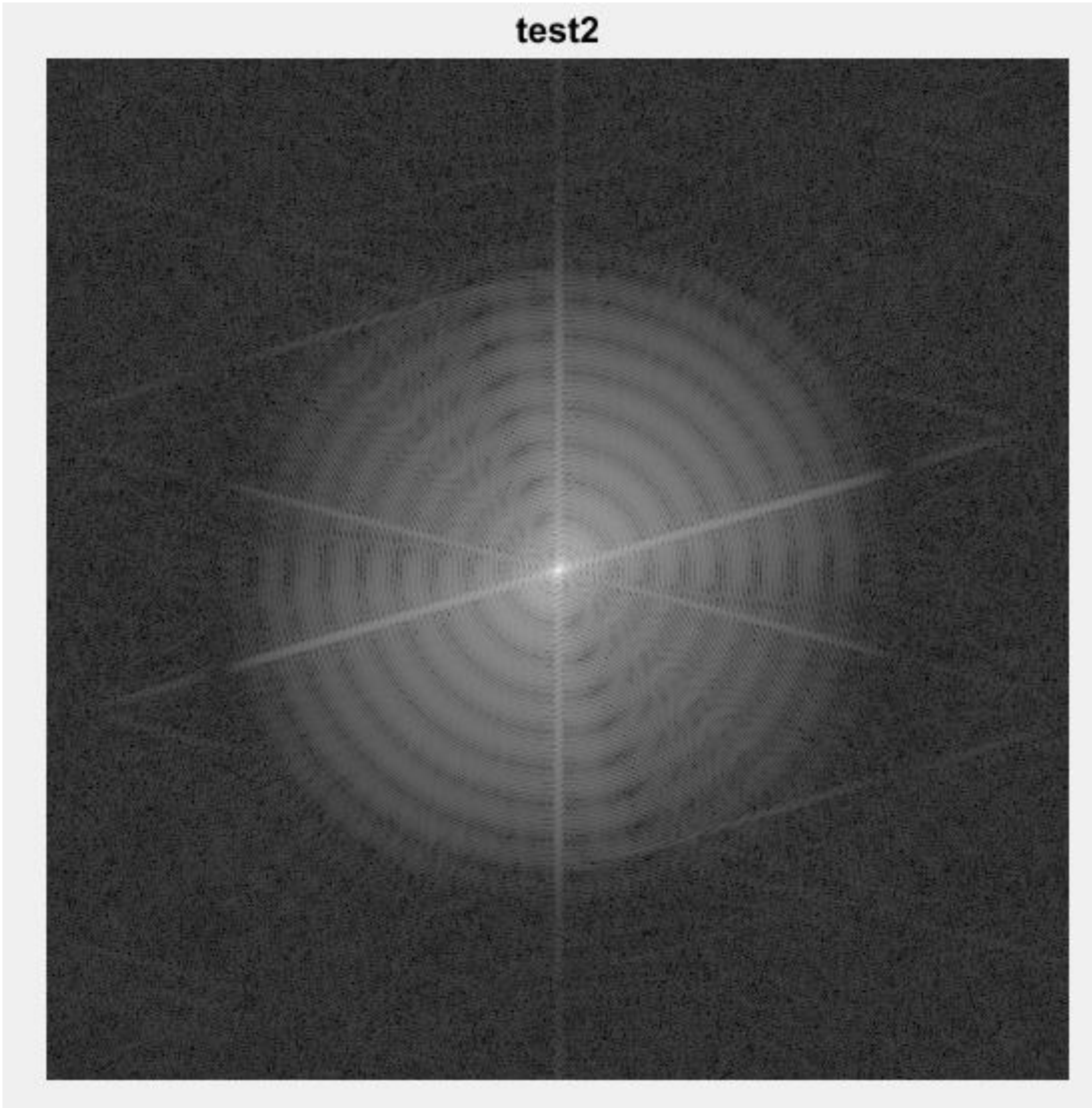

Figure 24: Fourier spectrum of test2

As seen in Figure 24, the Fourier spectrum of test2 image is symmetrical about the origin because we have shifted the origin to be at the point (u, v) = (0, 0) as specified in the question.

With reference to Figure 23, the test2 image consists of a symmetrical circular image, where the edges are found equally in all directions. As such, the Fourier spectrum of test2 image will also have a symmetrical circular plot.

Furthermore, in Figure 24, the 3 prominent bright straight lines seen in the Fourier Spectrum of test2 image correspond to the change in the gray level within the pie of the image (depicted by the blue arrows in Figure 23). These prominent lines are orientated perpendicularly to the edges in the test2 image.

3.

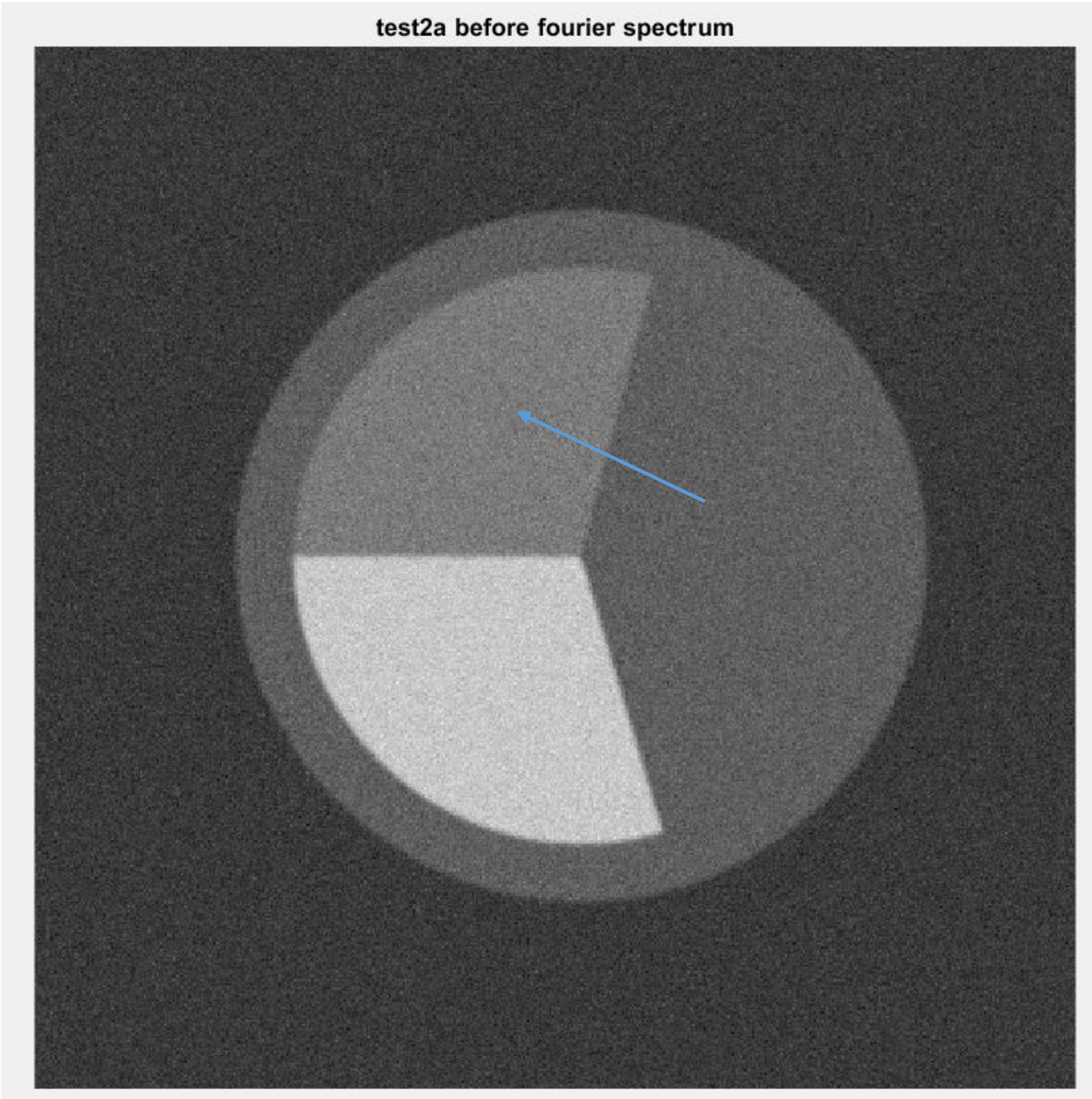

Figure 25: test2a image

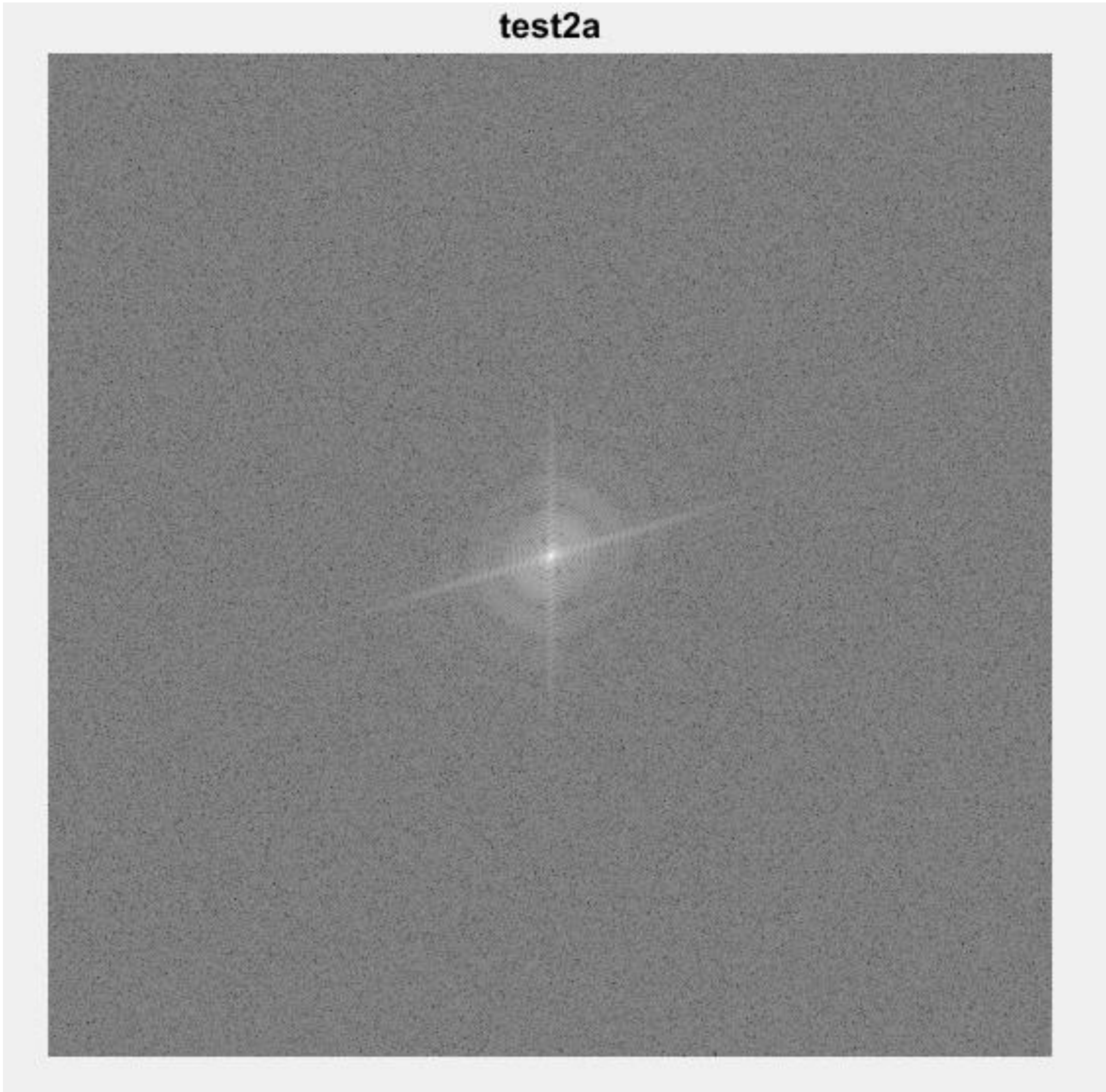

Figure 26: Fourier spectrum of test2a

With reference to Figure 26, like the Fourier spectrum of test2, the Fourier spectrum of test2a is symmetrical about the origin. Furthermore, the Fourier spectrum of test2a also follows a symmetrical circular plot and prominent bright straight lines are seen.

However, the details and the prominent bright straight lines in the Fourier spectrum of test2a is less obvious. This is due to the addition of gaussian noise to every pixel of test2, resulting in test2a image. It can also be observed that the prominent bright straight lines reduced from 3 to 2. This is because the change in the gray level from one of the pies to another (depicted by the blue arrow in Figure 25) is lesser compared to the previous case (without the gaussian noise).

Appendix

```
%testing dataset
% A = [1 2 3; 4 2 6];
%
% disp(A);
% histogram(A);

%q1
test1 = imread('test1.bmp');
%examine image test1 and its histogram
%disp(test1);

figure(1); %figure(n) finds a figure in which the Number property is equal to n, and makes it the current figure.
imshow(test1); %show the image in matlab
title('test1 image');

figure(2);
imhist(test1); %plot the histogram of the image
title('test1 histogram');

imtool(test1);
```

Codes for task A question 1

```
%%

%q2(a)
%add gaussian noise sigma = 15 to test1 giving image test1a
test1a = imnoise(test1, 'gaussian', 0, (15^2)/(256^2)); %the variance must be normalized between [0 1]

figure(3);
imshow(test1a);
title('test1a image');

figure(4);
imhist(test1a);
title('test1a histogram');

[peaksnr_test1a, snr_test1a] = psnr(test1a, test1);
disp("SNR value of test1a:");
disp(snr_test1a);
```

Codes for task A question 2(a)

```
%%

%q2(b)
%add salt-and-pepper noise of probability (density) = 0.05 to test1 giving test1b
test1b = imnoise(test1, 'salt & pepper'); %the default noise density is 0.05

figure(5);
imshow(test1b);
title('test1b image');

figure(6);
imhist(test1b);
title('test1b histogram');

[peaksnr_test1b, snr_test1b] = psnr(test1b, test1);
disp("SNR value of test1b:");
disp(snr_test1b);
```

Codes for task A question 2(b)

```
%%

%q3(a)
%apply mean filter with 3x3 window
mean_3_filter = fspecial('average', 3); %create a 3x3 mean filter
mean_3_test1a = imfilter(test1a, mean_3_filter);

figure(7);
imshow(mean_3_test1a);
title('test1a image with 3x3 mean filter applied');

[peaksnr_mean_3_test1a, snr_mean_3_test1a] = psnr(mean_3_test1a, test1);
disp("SNR value of test1a with 3x3 mean filter applied:");
disp(snr_mean_3_test1a);

%apply mean filter with 7x7 window
mean_7_filter = fspecial('average', 7); %create a 7x7 mean filter
mean_7_test1a = imfilter(test1a, mean_7_filter);

figure(8);
imshow(mean_7_test1a);
title('test1a image with 7x7 mean filter applied');

[peaksnr_mean_7_test1a, snr_mean_7_test1a] = psnr(mean_7_test1a, test1);
disp("SNR value of test1a with 7x7 mean filter applied:");
disp(snr_mean_7_test1a);

x = [0 size(test1a, 2)];
y = [size(test1a,1)/2 size(test1a,1)/2];
a = improfile(mean_3_test1a, x, y);
b = improfile(mean_7_test1a, x, y);
```

```
figure(9)
subplot(2,2,1);
imshow(mean_3_test1a);
hold on;
plot(x,y,'r');

subplot(2,2,2);
imshow(mean_7_test1a);
hold on;
plot(x,y,'r');

subplot(2,2,3);
plot(a(:,1,1),'b');
hold on;

subplot(2,2,4);
plot(b(:,1,1),'b');
```

Codes for task A question 3(a)

```
%%

%q3(b)
%apply median filter with 3x3 window
median_3_test1a = medfilt2(test1a, [3 3]);

figure(10);
imshow(median_3_test1a);
title('test1a image with 3x3 median filter applied');

[peaksnr_median_3_test1a, snr_median_3_test1a] = psnr(median_3_test1a, test1);
disp("SNR value of test1a with 3x3 median filter applied:");
disp(snr_median_3_test1a);

%apply median filter with 7x7 window
median_7_test1a = medfilt2(test1a, [7 7]);

figure(11);
imshow(median_7_test1a);
title('test1a image with 7x7 median filter applied');

[peaksnr_median_7_test1a, snr_median_7_test1a] = psnr(median_7_test1a, test1);
disp("SNR value of test1a with 7x7 median filter applied:");
disp(snr_median_7_test1a);
```

Codes for task A question 3(b)

```
%%

%q4(a)
%apply mean filter with 3x3 window
mean_3_filter = fspecial('average', 3); %create a 3x3 mean filter
mean_3_test1b = imfilter(test1b, mean_3_filter);

figure(12);
imshow(mean_3_test1b);
title('test1b image with 3x3 mean filter applied');

[peaksnr_mean_3_test1b, snr_mean_3_test1b] = psnr(mean_3_test1b, test1);
disp("SNR value of test1b with 3x3 mean filter applied:");
disp(snr_mean_3_test1b);

%apply mean filter with 7x7 window
mean_7_filter = fspecial('average', 7); %create a 7x7 mean filter
mean_7_test1b = imfilter(test1b, mean_7_filter);

figure(13);
imshow(mean_7_test1b);
title('test1b image with 7x7 mean filter applied');

[peaksnr_mean_7_test1b, snr_mean_7_test1b] = psnr(mean_7_test1b, test1);
disp("SNR value of test1b with 7x7 mean filter applied:");
disp(snr_mean_7_test1b);

x = [0 size(test1b, 2)];
y = [size(test1b,1)/2 size(test1b,1)/2];
a = improfile(mean_3_test1b, x, y);
b = improfile(mean_7_test1b, x, y);
```

```
figure(14);
subplot(2,2,1);
imshow(mean_3_test1b);
hold on;
plot(x,y,'r');

subplot(2,2,2);
imshow(mean_7_test1b);
hold on;
plot(x,y,'r');

subplot(2,2,3);
plot(a(:,1,1),'b');
hold on;

subplot(2,2,4);
plot(b(:,1,1),'b');
```

Codes for task A question 4(a)

```
%%

%q4(b)
%apply median filter with 3x3 window
median_3_test1b = medfilt2(test1b, [3 3]);

figure(15);
imshow(median_3_test1b);
title('test1b image with 3x3 median filter applied');

[peaksnr_median_3_test1b, snr_median_3_test1b] = psnr(median_3_test1b, test1);
disp("SNR value of test1b with 3x3 median filter applied:");
disp(snr_median_3_test1b);

%apply median filter with 7x7 window
median_7_test1b = medfilt2(test1b, [7 7]);

figure(16);
imshow(median_7_test1b);
title('test1b image with 7x7 median filter applied');

[peaksnr_median_7_test1b, snr_median_7_test1b] = psnr(median_7_test1b, test1);
disp("SNR value of test1b with 7x7 median filter applied:");
disp(snr_median_7_test1b);
```

Codes for task A question 4(b)

```
%q1 & q2
%load image test2 and obtain the fourier spectrum
test2 = imread('test2.bmp');

fft2_test2 = fft2(test2);
fftshift_test2 = fftshift(abs(fft2_test2));
Y = uint8(255 / log10(double(1 + max(fftshift_test2(:)))) * log10(double(1 + fftshift_test2)));

figure(1);
imshow(Y);
title('test2');
```

```
%%

%q3
%add gaussian noise sigma = 10 to test2, giving test2a
test2a = imnoise(test2, 'gaussian', 0, (10^2)/(256^2));

fft2_test2a = fft2(test2a);
fftshift_test2a = fftshift(abs(fft2_test2a));
X = uint8(255 / log10(double(1 + max(fftshift_test2a(:)))) * log10(double(1 + fftshift_test2a)));

figure(2);
imshow(X);
title('test2a');

figure(3);
imshow(test2a);
title('test2a before fourier spectrum');
```

Codes for task B question 1, 2 and 3