ECE 513: Computer Assignment 3

Image Enhancement

Danish Gufran

CSU ID: 833161673

Due Date: April 13, 2021

1 Introduction

Image Enhancement is a part of any image processing task. Image enhancement is the procedure of improving the quality and information content of original data before processing. Common practices include contrast enhancement, spatial filtering, Median filtering, and edge sharpening. The image enhancement procedure consists of a spatial domain processing and frequency domain processing, In this assignment we perform the image enhancement using both the spatial and frequency domain. The procedure followed involves the utilization of:

1. Contrast enhancement
2. Spatial filtering
3. Median filtering
4. Edge sharpening

In this assignment, we use different image files to perform and verify these image enhancement techniques. The image files considered are:

1. Pepsi (contrast enhancement)
2. Lena (spatial filtering)
3. Lena (median filtering)
4. Boat (edge sharpening)

2 Theory

Contrast enhancement

Contrast enhancement or stretching is performed by linear transformation expanding the original range of gray level. This contrast enhancement technique plays a vital role in image processing to bring out the information that exists within low dynamic range of that gray level image. Image enhancement techniques have been widely used in many applications of image processing where the subjective quality of images is important for human interpretation. Contrast is an important factor in any subjective evaluation of image quality. Contrast is created by the difference in luminance reflected from two adjacent surfaces. In other words, contrast is the difference in visual properties that makes an object distinguishable from other objects and the background. In visual perception, contrast is determined by the difference in the color and brightness of the object with other objects. Our visual system is more sensitive to contrast than absolute luminance; therefore, we can perceive the world similarly regardless of the considerable changes in illumination conditions. Many algorithms for accomplishing contrast enhancement have been developed and applied to problems in image processing.

In the assignment, we load the Pepsi.mat file to extract an image and perform the contrast enhancement and reduce noise levels. The output of which is compared and displayed by using the histogram, both histogram equalization and specification modelling techniques are performed.

Histogram Equalization

Histogram equalization is a method to process images in order to adjust the contrast of an image by modifying the intensity distribution of the histogram. The objective of this technique is to give a linear trend to the cumulative probability function associated to the image. The processing of histogram equalization relies on the use of the cumulative probability function (CDF). The CDF is a cumulative sum of all the probabilities lying in its domain and defined by:

$$cdf(x) = \sum_{k=-\infty}^{x} P(k)$$

The idea of this processing is to give to the resulting image a linear cumulative distribution function. Indeed, a linear CDF is associated to the uniform histogram that we want the resulting image to have.

The Probability Density Function or Probability Mass function for k in range of 0 to L-1 is given by

$$P(X_k) = \frac{n_k}{n}$$

"n" is the total number of the pixels in the image. The cumulative Density Function (CDF) based on the probability density function is defined as

$$CDF(X_k) = \sum_{j=0}^{k} P(X_j) = \sum_{j=0}^{k} \frac{n_j}{n}$$

$$CDF(XL-1) = 1$$

In this assignment, we use the 'histeq' on the 'Pepsi' image to implement histogram equalization and the histograms and the enhanced image is obtained.

Histogram Specification

In image processing, histogram matching or histogram specification is the transformation of an image so that its histogram matches a specified histogram. The well-known histogram equalization method is a special case in which the specified histogram is uniformly distributed. The desired histogram are determined depending on the characteristics of the histogram of the original image and the specific goals of the enhancement procedure. The desired histogram is computed by calculating the cumulative frequency distributions (CFD) from the histogram of the original image and by adjusting this histogram to be suited for the desired histogram.

Let us assume that the input image as the probability function $P_r(X)$. The target image has the probability function $P_r(Z)$. where X AND Z are the gray scale value of the Input and Target image respectively. $P_r(X)$ is the probability function of input image and $P_r(Z)$ is the probability function of target image. A transformation function that can map $P_r(X)$ to $P_r(Z)$ is need to convert input image to target image. Each of the PDF of input image can be mapped to its cumulative distribution by.

$$w = f(x) = P_X(x) = \int_0^x p_x(\alpha)dx$$

$$z = g(Y) = P_Y(y) = \int_0^y p_y(\alpha)dx$$

This technique of grey-scale mapping is used on the 'Pepsi' image to study the histogram specification method for contrast enhancement. We create the target histogram by storing the intensity values of the original image and storing it in a temporary variable. We then use a threshold value which is used to convert all the values below it by multiplying with a constant and then stored as the target intensity. This intensity is then matched using the algorithm to get the enhanced image.

Spatial Filter

Spatial filtering improves the naturally occurring linear features like fault, shear zones, and lineaments. Spatial Filtering technique is used directly on pixels of an image. Mask is usually considered to be added in size so that it has specific center pixel. This mask is moved on the image such that the center of the mask traverses all image pixels.

There are two types of spatial filtering:

1. Linear spatial filter
2. Non-Linear spatial filter

In this assignment we use Spatial low pass filter to remove the White Gaussian noise because it is one of the effective methods to remove noise. It is done by using a Linear 2-D FIR filter. We replace each pixel in the input image with the weighted sum of the neighboring image pixel with the mask.

$$N(x,y) = \sum \sum_{K,l \in W} H(i,j) I(x-k, y-l)$$

where I(x,y) is the input image, H(i,j) is the filtering coefficient, N(x,y) is the output image, and W is the mask applied. For low pass filtering, we consider.

$$\sum \sum_{K,l \in W} H(i,j) = 1$$

In this assignment we use the 'Lena' image in and add SNR 5dB of Gaussian White noise to the original image. We then use three different mask to do the filtering process. The masks each differ in their coefficients and we consider 3 mask conditions to compare the outputs, the SNR values are used to understand the image quality from these masks. We also use the frequency responses for each of the masks to verify the SNR for the best masked image.

Median Filter

The median filter is a non-linear digital filtering technique, often used to remove noise from an image or signal. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise also having applications in signal processing.

$$N(x,y) = median I(x-k, y-l), (k,l) \in W$$

where W is the window, N is the output image, and I is the input noisy image. The working of median filter is such that the kernel filter is made to run over the image pixels side by side, while replacing the pixels with its median at that filter location. The example of the same as shown. In this assignment we add a salt and pepper noise to the 'Lena' image and use different window sizes that can be used to enhance the image.

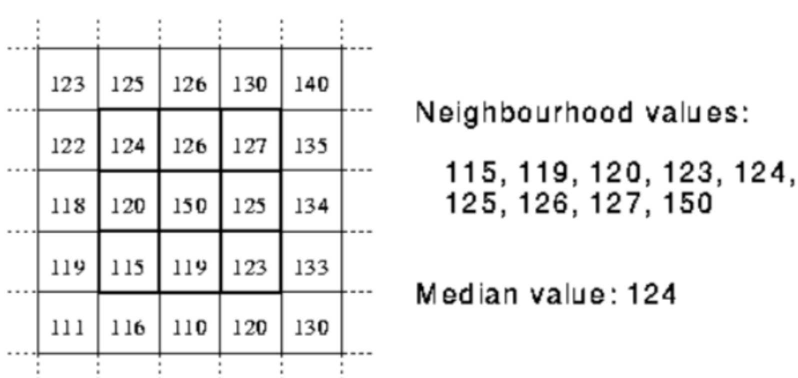

Fig 1 : Median filter (example)

Edge Sharpening

Edge enhancement is an image processing filter that enhances the edge contrast of an image or video in an attempt to improve its acutance (apparent sharpness). Edge enhancement can be either an analog or a digital process. Edge Sharpening is the process of extracting the edge details of an image by passing it through a 2-D High pass filter (HPF). Edge sharpening is a basic prepossessing step for any system that is used to analyze or identify objects on an image. This enhances the boundaries of object on the image thus making it easier for the analysis. This is done by adding the fraction of the HPF to the input image to highlight the edges. We can get the High pass filters by subtracting the Low pass filter from the original image

$$H_{HPF}(x, y) = \delta(x, y) - H_{LPF}(x, y)$$

The sharpening operation can be represented as follows.

$$N(x, y) = I(x, y) - \lambda H(x, y)$$

The ’Boat’ image to extract edge from the images using the MATLAB ’edge’ function. The Sobel and Canny Filters are used for Edge Sharpening in this assignment. A optimal λ value is used to check the clarity of the edges extracted.

Sobel Filter: The Sobel operator, sometimes called the Sobel–Feldman operator or Sobel filter, is used in image processing and computer vision, particularly within edge detection algorithms where it creates an image emphasizing edges.

Canny Filter: The Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images

Signal to Noise Ratio (SNR)

The SNR values for the reconstructed images are calculated to determine the image quality of the reconstructed image. The formula for calculating the SNR is shown below.

$$SNR = 10 log_{10} \frac{\sigma_o^2}{\sigma_e^2}$$

The σ_o^2 is the variance of the original image and σe2 is the variance of the error image. The SNR value also determines the loss in the compression of the image.

3 Results

Contrast Enhancement

The contrast enhancement was performed on the Pepsi.mat. The file of this image is as shown below.

Fig. 2: Pepsi image

The contrast enhancing is performed by using two different bins. The bin sizes considered for this image are 7 and 255. These configurations are applied and studied by constructing two different histograms to understand the contrast enhancement better.

The two histogram techniques are:

1. Histogram Equalization
2. Histogram Specification

Histogram Equalization

The original image, which is the Pepsi image was run through the algorithm for contrast enhancement. The algorithm inputs bin sizes considered were 7 and 255. The results are as shown.

Fig 3: Histogram Equalization Output

The result show changes in the original image, this is by visually inspecting the image. The histogram of each of the image will give a better understanding of the contrast enhancement.

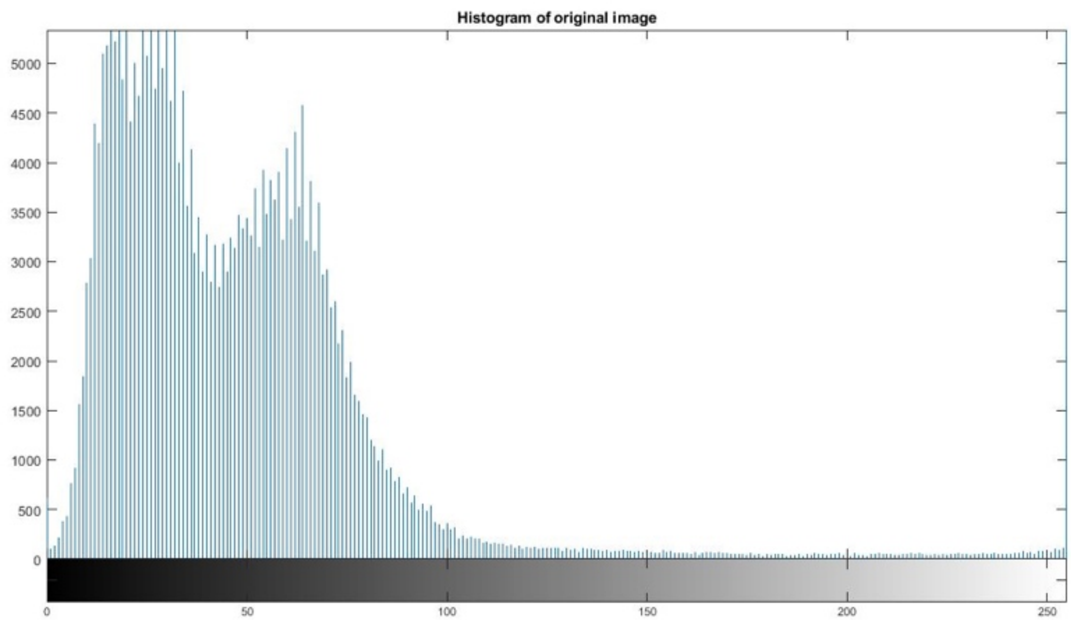

Fig 4: Histogram of the original image

The above histogram is constructed for the original image for comparison with the contrast enhanced images. These histograms are fond found below.

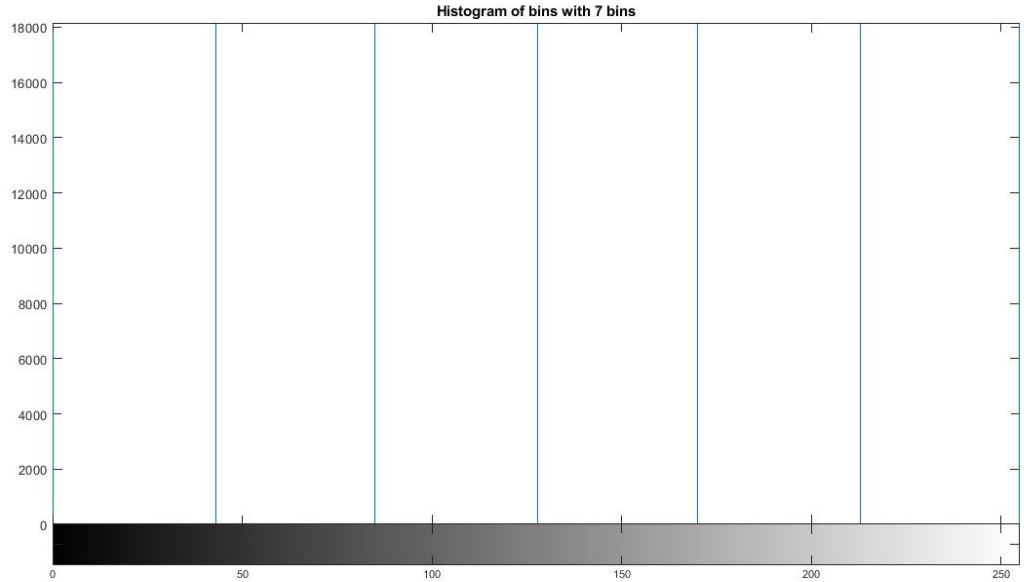

Fig 5: Histogram for 7 bins

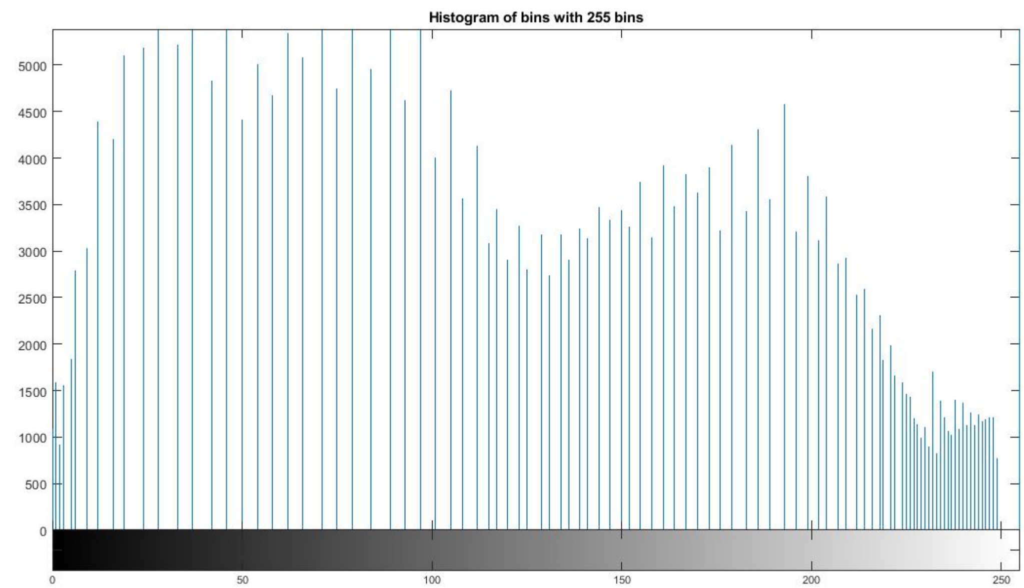

Fig 6: Histogram for 255 bins

The information from the above histograms indicate that the image with the higher number of bins has a better image quality than the image with the lower bins. The image with 255 bins has a better contrasted image than the image with 7 bins.

Histogram Specification

This form of histogram representation is done by mapping out the intensity levels of the original image with respect to the target image. This technique of grey-scale mapping is used on the ’Pepsi’ image to study the histogram specification method for contrast enhancement. We create the target histogram by storing the intensity values of the original image and storing it in a temporary variable. We then use a threshold value which is used to convert all the values below it by multiplying with a constant and then stored as the target intensity. This intensity is then matched using the algorithm to get the enhanced image.

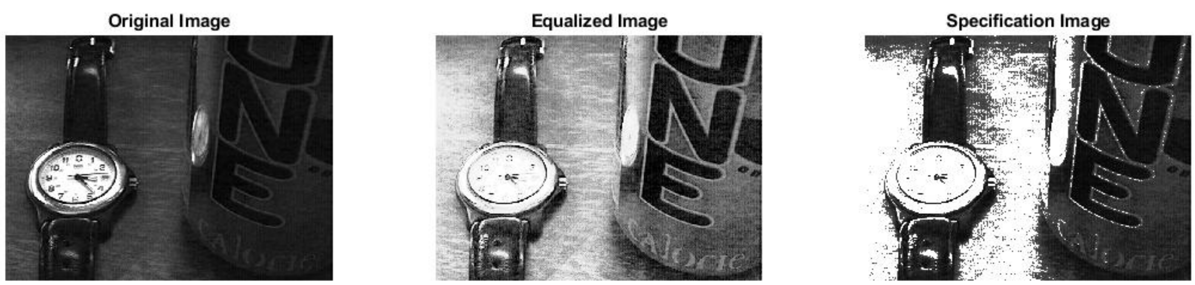

Fig 7: Histogram specific output images

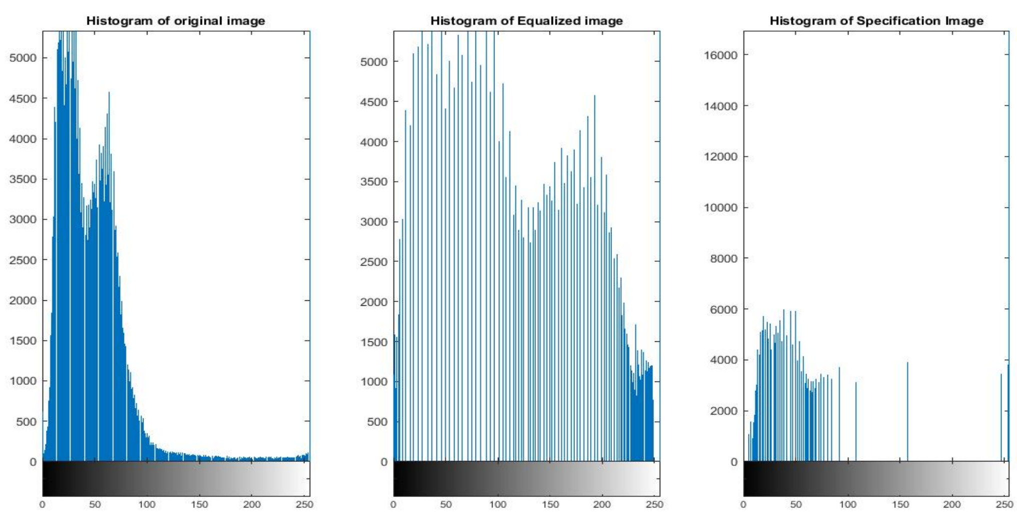

Fig 8: Histogram of output images

After observing the histogram of the output images, we can observe that the histogram specification output has lesser saturation than the histogram equalization, therefore histogram specification has better results that the equalization.

Spatial Filtering

For this assignment we use three masks, which are shown below.

MASK 1		
1\9	1\9	1\9
1\9	1\9	1\9
1\9	1\9	1\9

MASK 2		
0	1\8	0
1\8	1\2	1\8
0	1\8	0

MASK3			
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16

Fig 9: Three masks

The first step to understand the working of these filters, we need to apply some external noise to it so that we can understand the working of this filter by removing the applied noise. For this assignment we will be applying 5dB of white Gaussian noise to the input Lena image.

Fig 10: Original Image

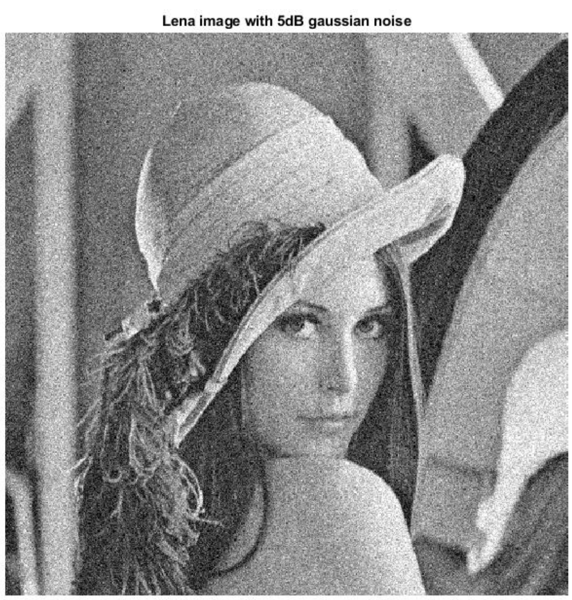

Fig 11: Image with 5dB white gaussian noise

To the applied white noise Gaussian noise image we will apply the three masks explained earlier to it understand its response.

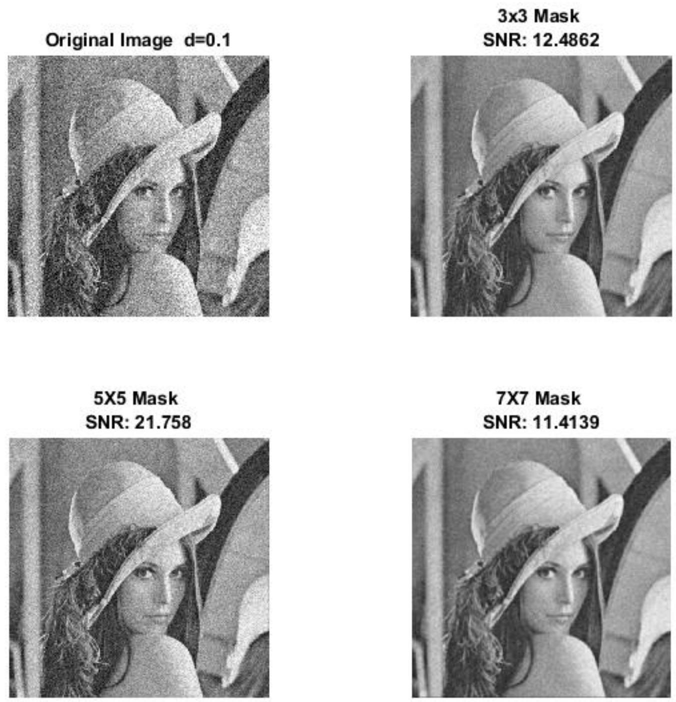

Fig 12: Images with the masks applied

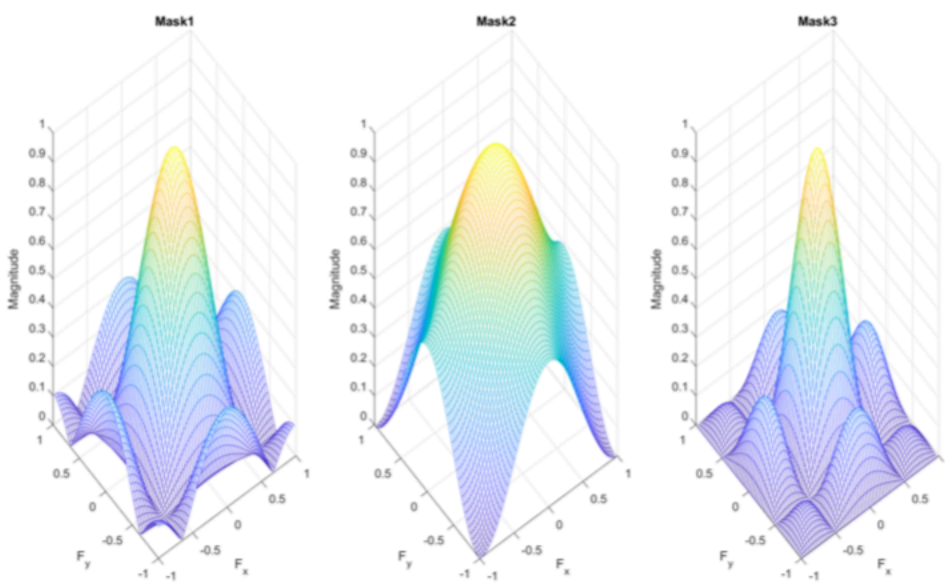

Fig 13: Frequency response for each mask

It is observed that when the size of the mask increases so is its blurring effect. The mask 2 has better bandwidth as compared to masks 2 and 3, also its high SNR value makes it desirable. We can conclude that mask 2 is most effect to reduce white Gaussian noise for noise removal and smearing artifacts.

Median Filter

In median filter we experiment with the salt and pepper noise levels of 0.1 and 0.2

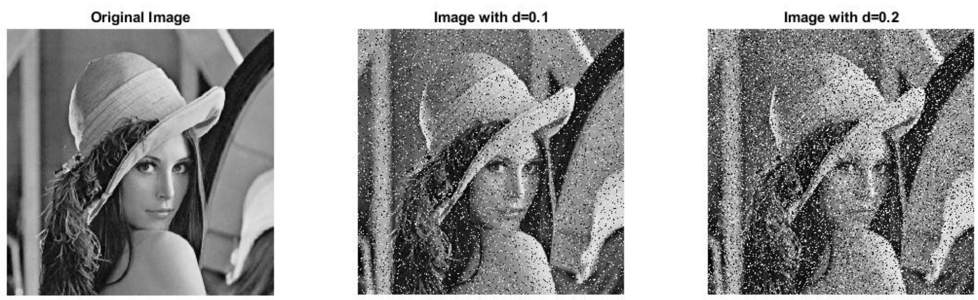

Fig 14: Image with different levels of salt and pepper noise

We apply a similar masking technique here as well. The masked output is as shown.

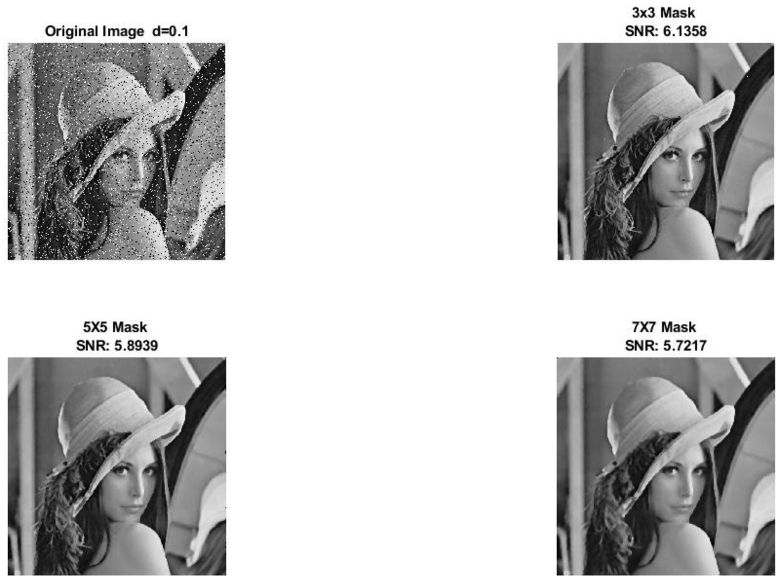

Fig 15: Masked image with noise level 0.1

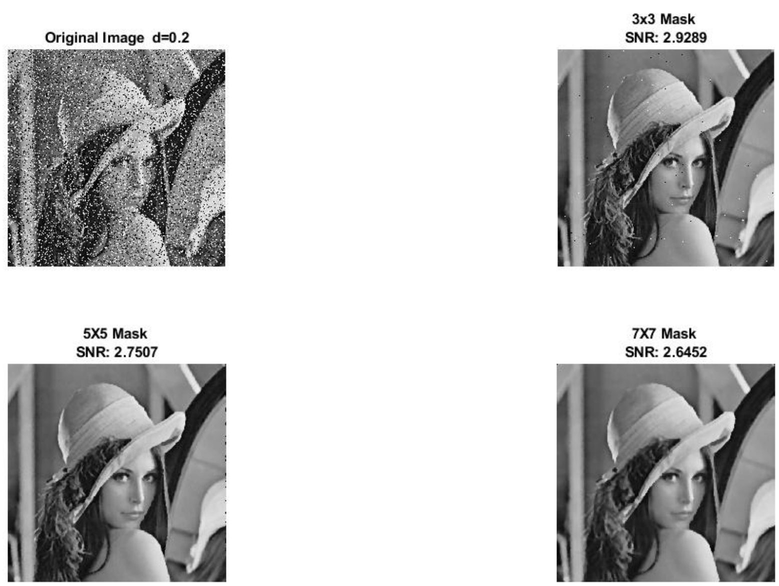

Fig 16: Masked image with noise level 0.2

it can be observed that the 5x5 filter does not perform that well for a noise level of 0.2 . Comparing both it can be inferred these filters can work well up to a noise level of 0.1. The 3x3 filter has the best SNR value for both the noise levels d1 and d2.

Edge sharpening

The edge sharpening is experimented on two filters Sobel and Canny. We consider two lambda values for each of the filters. This is shown below.

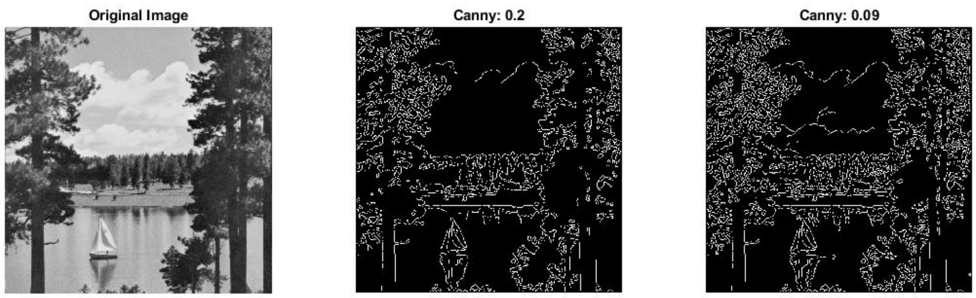

Fig 17: Edge detection using Sobel filter

Fig 18: Edge detection using Canny filter

Form the images above we can conclude that Canny filter performs better than Sobel filter. This is due to the following reasons.

• Edges candidates which are not dominant in their neighborhood aren't considered to be edges.

• While moving along the candidates, given a candidate which is in the neighborhood of an edge the threshold is lower.

It is observed that as the λ value decreases the edges are more sharper and more edges can be seen. The λ value of 0.09 gives better result in the canny filter than 0.2 on the 'Boat' image.

Conclusion

This assignment has been informative in understanding the working of different filters and how each filter can perform on different noise levels. It can be concluded that there is no right filter for any noise there is always some research and development required to deal with noisy images. Also extracting information from images is an essential part of any image processing application and this type of image enhancement techniques are very useful. Image enhancement techniques makes it easier for high level application such as object detection and Image recognition etc.

References

[1] Dr. Azimi lecture slides

[2] Maini, Raman Aggarwal, Himanshu. (2010). A Comprehensive Review of Image Enhancement Techniques. Journal of Computing. 2.

[3] https://en.wikipedia.org/wiki/Histogram equalization

[4] G. Park, H. Cho and M. Choi, "A contrast enhancement method using dynamic range separate histogram equalization," in IEEE Transactions on Consumer Electronics, vol. 54, no. 4, pp. 1981-1987, November 2008.

[5] Pavithra, P. et al. "Image Enhancement by Histogram Specification Using Multiple Target Images." (2010).

[6] https://en.wikipedia.org/wiki/Histogram matching.

[7] https://en.wikipedia.org/wiki/Signal-to-noiseratio