Comparison of various Image Restoration filters

Digital Image Processing

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GACS-7205

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Content:

Abstract: **In digital Image processing, Image restoration is a process to take corrupt image as an input & than to provide enhanced or improved image as an output to the user. Image can be corrupted due to various types of image noises, motion blur or camera mis-focus. There are several image filters available to remove such kind of corruptness from images. We have discussed various kinds of filters in this paper such as Wiener filter, Adaptive wiener filter, Average filter & Median filter. We have done various experiments with different filters by increasing noise density through Mat lab. In our experiments, we have calculated MSE, PSNR & SNR for different filters with different noise densities. We have compared all of the calculated values using a table. At the end, we found that Adaptive Wiener filter is best among 4 filters to remove noise from an image.**

Keywords: **Salt & pepper noise, Speckle noise, Poisson noise, Wiener filter, Adaptive Wiener filter, Median filter, Average filter, Mean Square error, Peak signal to noise ratio, Signal to noise ratio.**

Introduction:

In past couple of decades, digital image processing has undergone many developments with the escalation of Science and Technology. Computers also have gone through many developments. Many media storage devices have been invented which stores digital data. Apart from this, many computer and mobile applications are developed over these years. With this advancement in technology, it becomes very necessary to keep excellent quality of images. There are various factors which can degrade quality of the image taken by photographer or sent by sender to receiver. Image degradation comes in many types like various types of noises, Camera mis-focus and motion blur. In this paper, our main focus will be on types of image noises & motion blurring which leads to image degradation. Image noise is an electronic noise. In most of the cases, it doesn't present in the original object images. It comes with the disparity of brightness or by the color details of given image. It can basically be created from a scanner, sensor or a digital type of camera. Sometimes it is hard to avoid noise in an image. In this paper, we will highly focus on Salt and Pepper noise, Gaussian noise and Poisson noise. We will use mentioned noises to add distortion to the input image. Blurriness in an image occurs when is image is taken of fast moving object. It also degrades the quality of images.

Now Image Restoration comes into picture. The main target of Image Restoration is to remove all types of defects from the image which degraded image quality. It is an inverse process of Image degradation & restores image quality. There are various Image restoration techniques available in Digital Image Processing field. Image filters like Wiener filter, Median filter, Inverse filter, Gaussian filter, Averaging filter etc. can be used for image restoration. In this paper, we will focus on Adaptive

& Optimal Wiener filter, Median & averaging filter. We will compare performances of all mentioned filters.

In next sections, we will discuss Image degradation & restoration model in detail. Apart from this, details of various types of noises and filters will also be discussed. Moreover, we will discuss results came out by doing various experiments by changing density of various noises & restoration of those images with various types of filters. Conclusion of all the experiments will also be discussed in one the section. We will also discuss about the future work which can be done on this project.

Image Degradation/ Restoration model

In the given model, degradation process is designed with degradation function that combined with an additive noise. After adding noise, it gives degraded image & feed it to restoration process. It takes input image *f(x, y)* to generate a degraded image *g(x, y)*. Where H is degradation function. The degraded image is demonstrated in spatial domain by following function.

$$g(x, y) = H(x, y) * f(x, y) + \eta(x, y)$$

Here in given equation * indicates convolution.

However, convolution in the spatial domain is same as multiplication in frequency domain.

$$G(u, v) = H(u, v) F(u, v) + N(u, v)$$

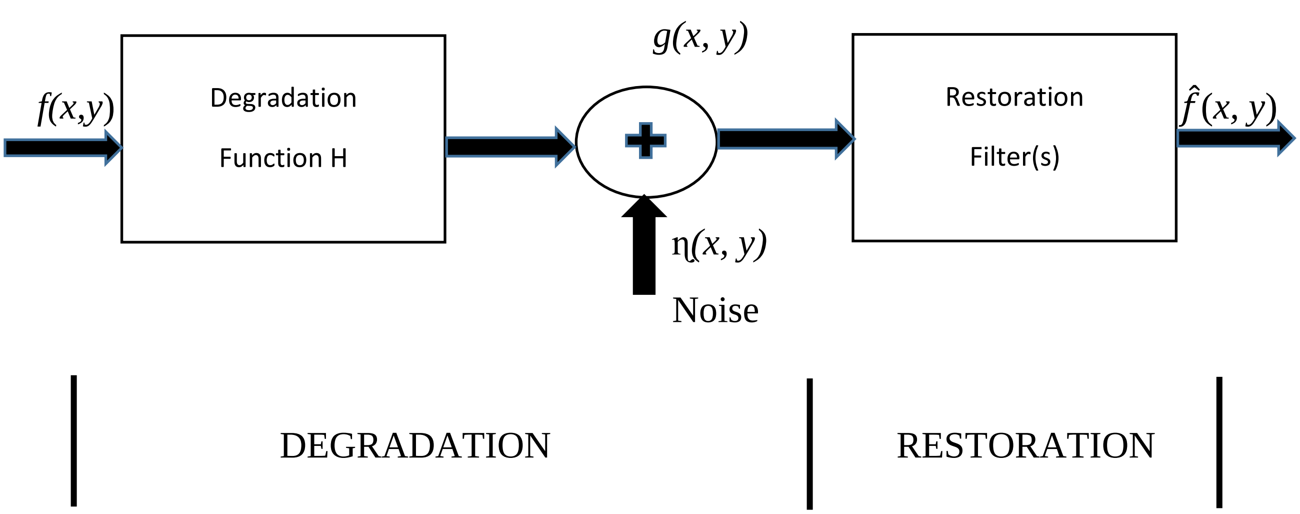


Fig.1 Image Degradation/ Restoration model

Types of image noises:

There are various types of additive noises present which leads to degradation of images. We will discuss few of them in this paper.

a) **Salt and Pepper noise:**
It is also known as impulse noise, where impulse is referred to as intensity spikes in an image. There are only 2 possible values, which are black & white dots present in an image. It is basically caused by sharp and sudden changes in Image signals & errors in data transmission. Other reasons of occurrence of this type noise are malfunctioning of pixels due to false memory locations and errors in digitization process of a camera. The corrupted or distorted pixel values are set to minimum or maximum value which makes image pixels looks like 'Salt & pepper' present in it. [1]. Moreover, if the given image is of 4 bits in size, the value of salt noise would be 15 & value of pepper noise would be 0.

Fig 2. Original & image with Salt & pepper noise

b) **Speckle Noise:-**
It is the noise which occurs due to the effect of environmental conditions on the imaging sensor during creation of images. [2] Speckle noise frequently occurs in medical images like ultrasound images & x-rays image. During creation of images from sensors, corrupted & uncorrupted pixels scattered all over the image which leads to creation of noise in generated image.

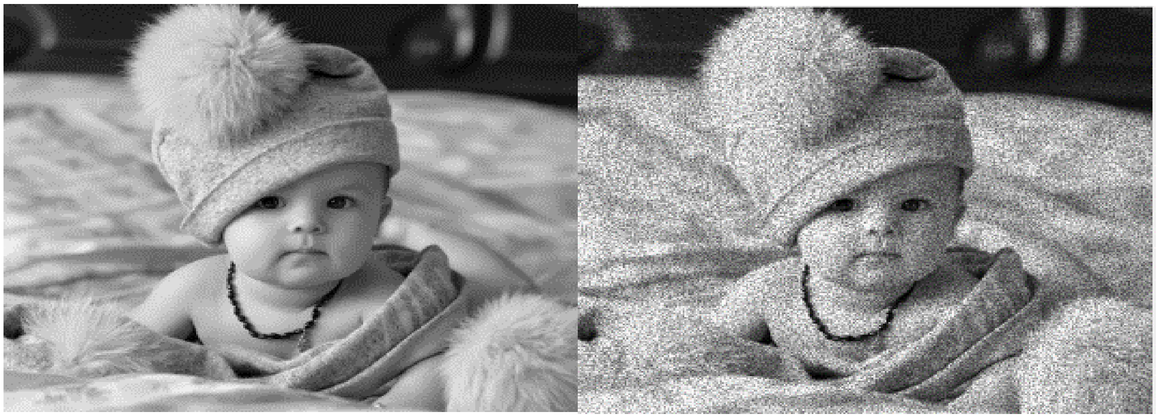


Fig 3. Original & Image with Speckle noise

c) **Poisson noise:**

Poisson noise is also known as shot noise. It is a type of electronic noise. In electronics shot noise creates from discrete nature of electric charge. It also generates in photon counting in optical devices, where it is attached with particle of nature. [3]

Fig 4. Original & Image after adding Poisson noise

d) **Motion blur:**

Motion blur caused by taking a photograph of a fast moving object. It can be significant when photograph is clicked in low light & object is moving. Other reason of occurrences of motion blur when photographer shake the camera while clicking the photograph. The example of most frequent motion blur instances is when photograph is clicked of the number plate of fast moving car.

Fig 5. Original & Image after adding motion blur

Various Image restoration filters:

In this paper, we will discuss about various Image restoration filters. Our major focus will be on Optimal Wiener filter, Adaptive Wiener filter, Median filter & Average filter.

a) **Wiener filter:**
Wiener filter is also known as Minimum mean square error filter. In this type of filter, both the degradation function & statistical characteristics are incorporates noise into the restoration process. [5] The main goal of this type of filter is to minimized mean square error between restored & corrupted image.

$$e^2 = E(f-\hat{f})^2 \qquad (1)$$

Where f is corrupted image & $\hat{f}$ is restored image & $E(.)$ is the expected value of the argument. Let noise and the image are uncorrelated.
Expression for minimum of the error function & Wiener filter

$$\hat{F}(u,v) = \left[\frac{H^*(u,v)}{|H(u,v)|^2 + S_\eta(u,v)/S_f(u,v)}\right] G(u,v) \qquad (2)$$

Here, $H(u,v)$ = degradation function

$H^*(u,v)$ = Complex conjugate of $H(u,v)$

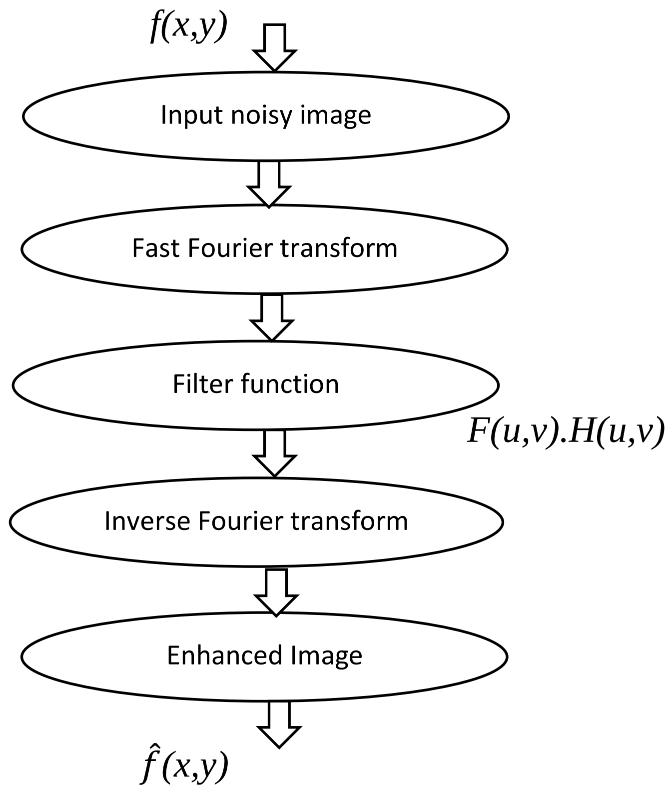
$|H(u,v)|^2 = H^*(u,v).\ H(u,v)$

$S_\eta(u,v) = |N(u,v)|^2$ = Power Spectrum of the noise

$S_f(u,v) = |F(u, v)|^2$ = Power Spectrum of the undegraded image

Wiener filter doesn't have the same problem like Inverse filter with zeroes in the degradation function, unless entire denominator is zero.

Flow chart of using FFT in frequency domain to write mat lab code



Adaptive Wiener filter: It is a type of linear filter. In this type of filter, Wiener filter can be applied adaptively. It generates better results than basic Wiener filter. It preserves edges & high frequency parts of the images. Adaptive Wieiner filter performs great amount of image smoothing where variance is small between corrupted & restored image. We have used Wiener2 function from Mat lab to implement it.

b) Median filter:

Median filter is one of the powerful filter to remove Salt and pepper noise from the images. It is very useful in removing noise from the corrupted image while preserving edges of the images. The core criteria for this type of filter works as follows, it moves through whole of the corrupted image pixel by pixel & replace every pixel value with the median of its neighbouring pixels.

Mathematically, it is one of the simplest filter to understand & implement. Neighbourhood size can be defined & overall it is known as window, which slides over all of the Image & change pixel values. I median filter all the pixel values are calculated & then values are sorted. Once sorted, middle value of the window is replaced. Median is the best filter to remove salt and pepper noise from the image. However, median filter is slow in overall process.

Example: Suppose there is 6x6 input image. We will use 3x3 window size to replace one of the pixel value of given image.

We will replace circled pixel value with the median of the window 3x3.

Input window: 1, 4, 0,2,2,4,1,0,1

Sorted :- 0,0,1,1,1,2,2,4,4

Median of sorted input is 1.

1	4	0	2	3	5
2	2	4	6	0	4
1	0	1	3	5	4
6	0	3	2	4	3
5	6	0	1	6	4
2	0	1	2	3	3

Replace circled value from above matrix with calculated median 1

1	4	0	2	3	5
2	1	4	6	0	4
1	0	1	3	5	4
6	0	3	2	4	3
5	6	0	1	6	4
2	0	1	2	3	3

Similarly, Window of size 3x3 slides over rest of the image & replace every pixel value with the median of the window.

Output Image after replacing all pixel values with corresponding median values.

2	2	2	2	3	4
1	1	2	3	4	4
2	2	2	3	4	4
5	1	1	3	4	4
5	2	1	2	3	3
2	1	1	2	3	3

c) Average filter

Average filter is quite same like median filter. It also used in image smoothing process & to remove different types of noises from the image. In this filter, window size can be defined at the start of the image smoothing process. After that, window slides over the image pixel by pixel & replace every pixel value with the average of the neighbouring pixels. There is a disadvantage of this kind of filter. When window moves to the edges of the image, all the edge pixel values are replaced with average neighborhood values which leads to blurry edge pixels.

Example: Consider input image of pixel 6x6. We will use window size of 3x3

In average Filter, values of border of the images remain unchanged.

Input window values: 1, 6, 0,6,2,4,1,0,1

Average of input values: round (1+6+0+6+2+4+1+0+1)/9 = 3

1	6	0	2	3	5
6	2	4	6	0	4
1	0	1	3	5	4
6	0	3	2	4	3
5	6	0	1	6	4
2	0	1	2	3	3

Replace circled value with the calculated Average =3

1	6	0	2	3	5
6	3	4	6	0	4
1	0	1	3	5	4
6	0	3	2	4	3
5	6	0	1	6	4
2	0	1	2	3	3

Similarly, Window of size 3x3 slides over rest of the image & replace every pixel value with the Average of the window. It will not change border values of images.

Output Image after replacing values with average of the window values.

1	6	0	2	3	5
6	3	3	3	4	4
1	3	3	4	4	4
6	3	2	3	4	3
5	3	2	3	4	4
2	0	1	2	3	3

System Specifications:

Hardware Architecture:

- Processor used: Intel i5
- RAM size : 4 GB

Software Architecture:

- MATLAB R2017b

Experiments:-

1. **Image Restoration with Adaptive Wiener filter**

Density for salt & pepper noise = 0.05

Density for Speckle noise = 0.07

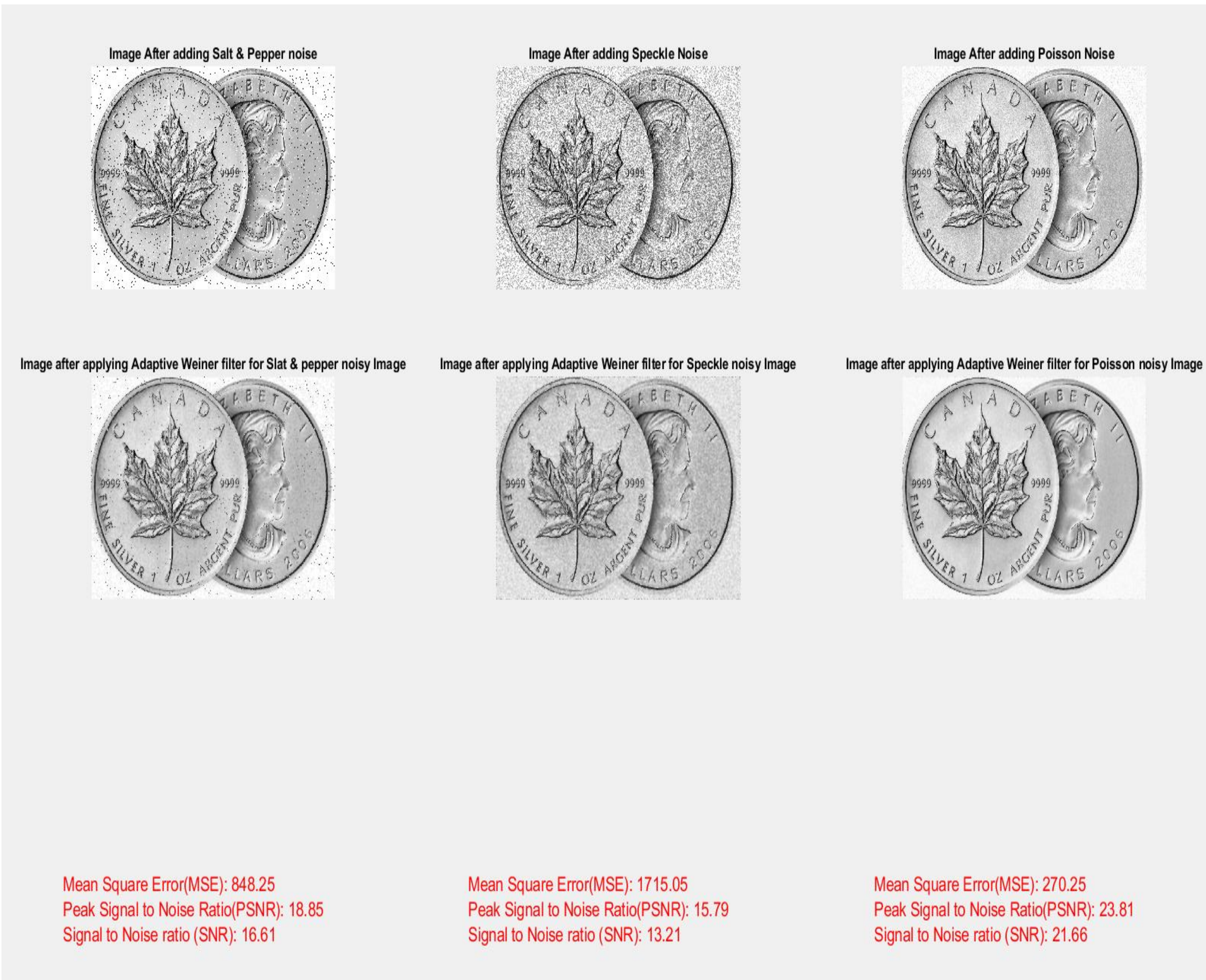


Fig 6. Results using Adaptive Wiener filter

First row of images are noisy images. Noises used are Slat & Pepper noise, Speckle noise & Poisson noise. Second row of images are filtered images after using Adaptive wiener filter.

Third row shows the MSE, PSNR & SNR of Corrupted & Enhanced image.

2. **Image Restoration with Optimal Wiener filter:**
   Density of Salt & Pepper noise: 0.04
   Density of Speckle noise: 0.03

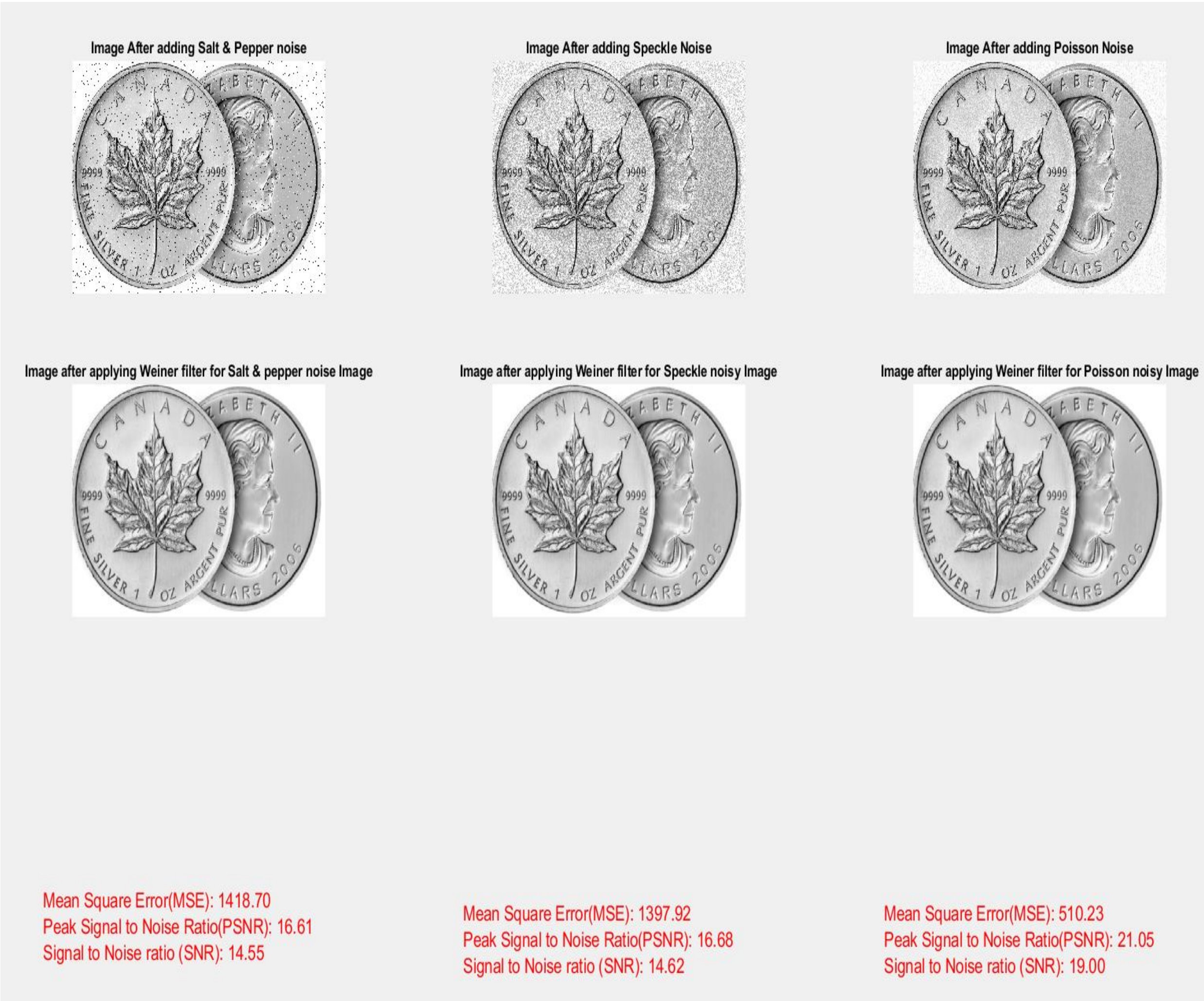


Fig. 7 Results after using Optimal Wiener filter

First row of images are noisy images. Noises used are Slat & Pepper noise, Speckle noise & Poisson noise. Second row of images are filtered images after using Optimal wiener filter.

Third row shows the MSE, PSNR & SNR of Corrupted & Enhanced image.

3. **Image restoration with Average filter:**
   Density of Salt & Pepper noise: 0.2
   Density of Poisson noise: 0.1

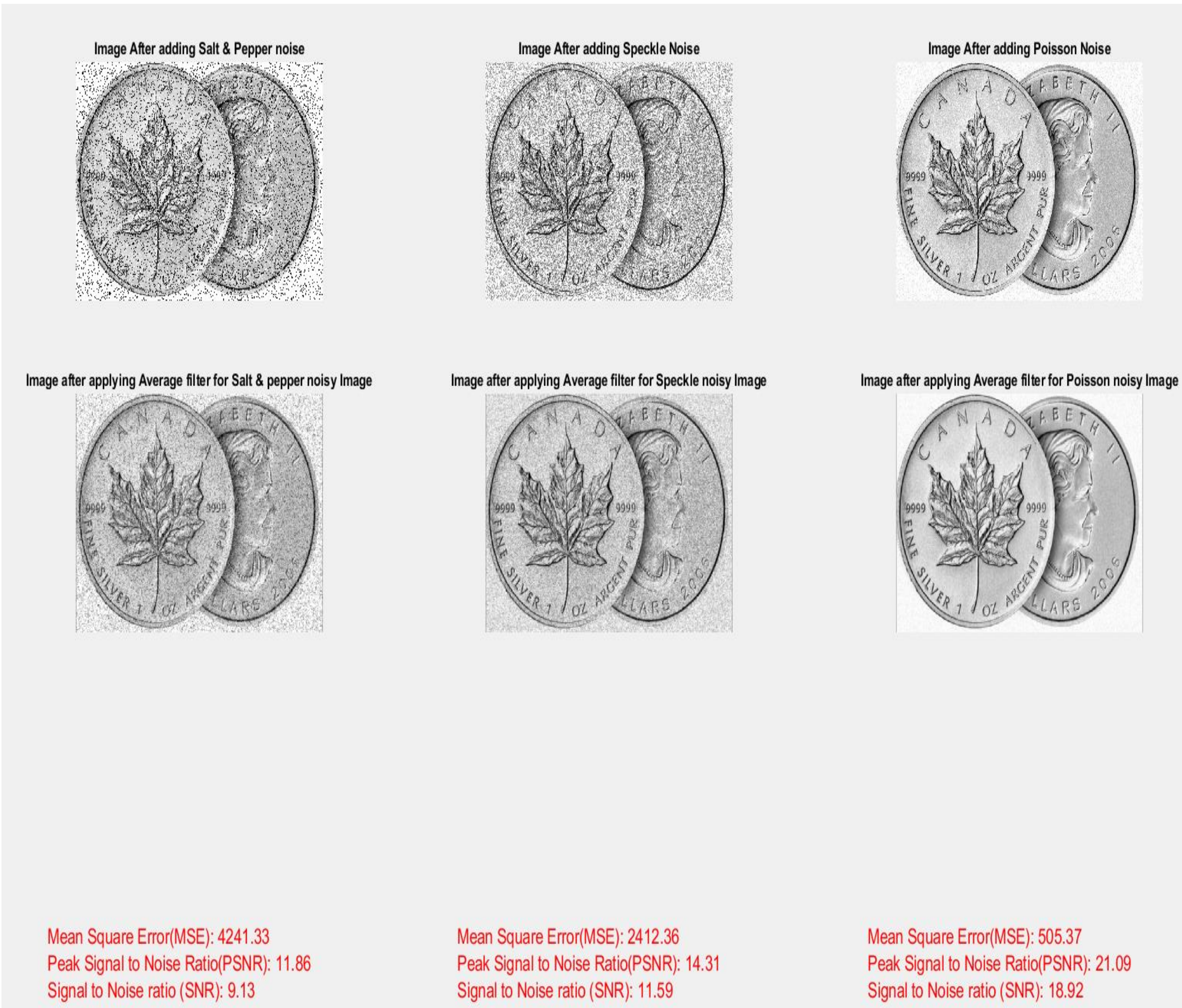


Fig 8. Results using Average filter

First row of images are noisy images. Noises used are Slat & Pepper noise, Speckle noise & Poisson noise. Second row of images are filtered images after using Average filter.

Third row shows the MSE, PSNR & SNR of Corrupted & Enhanced image.

4. **Image Restoration with Median filter:**

   Density of Salt and pepper noise: 0.4

   Density of Speckle noise: 0.3

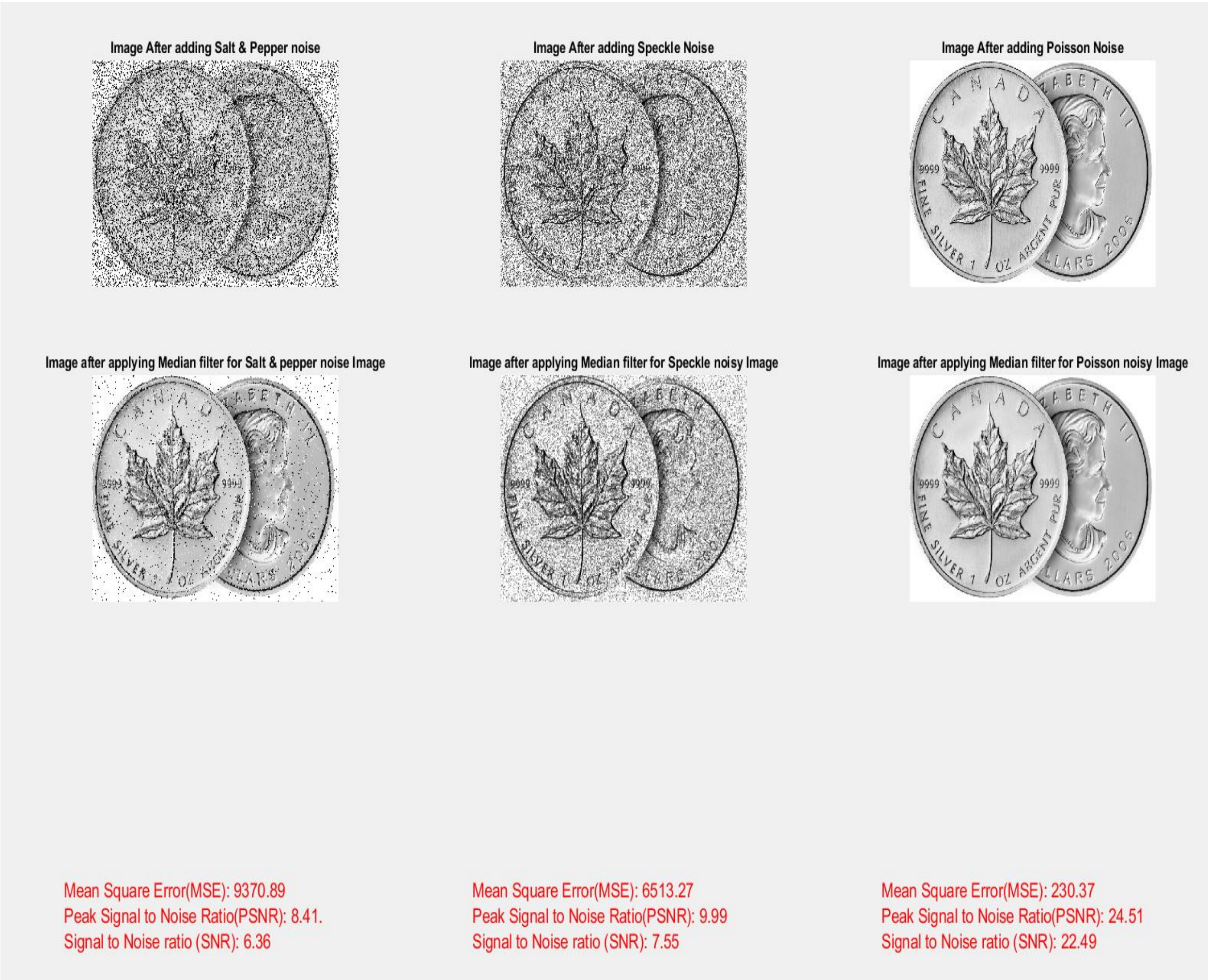


Fig. Results using Median filter

First row of images are noisy images. Noises used are Slat & Pepper noise, Speckle noise & Poisson noise. Second row of images are filtered images after using Adaptive wiener filter.

Third row shows the MSE, PSNR & SNR of Corrupted & Enhanced image.

Comparison Table (Salt & Pepper Noise)

	Noise Density =0.03	Noise Density =0.05	Noise Density =0.07	Noise Density =0.1	Noise Density =0.3
Adaptive Wiener Filter	MSE = 544.81 PSNR= 20.77 SNR= 18.59	MSE =852.60 PSNR=18.82 SNR=16.58	MSE =1157.10 PSNR=17.50 SNR=15.19	MSE = 1611.65 PSNR=16.06 SNR=13.65	MSE =4932.23 PSNR=11.20 SNR=8.11
Wiener Filter	MSE = 1178.06 PSNR=17.42 SNR= 15.36	MSE = 1646.43 PSNR=15.97 SNR=13.91	MSE = 2094.77 PSNR=14.92 SNR=12.86	MSE =2750.82 PSNR=13.74 SNR=11.68	MSE =7267.90 PSNR=9.52 SNR=7.45
Average Filter	MSE = 972.37 PSNR=18.25 SNR= 16.06	MSE =1373.39 PSNR=16.75 SNR=14.50	MSE = 1774.54 PSNR=15.64 SNR=13.32	MSE =2359.57 PSNR=14.40 SNR=11.99	MSE =5935.44 PSNR=10.40 SNR=7.35
Median Filter	MSE =906.68 PSNR=18.56 SNR=16.54	MSE =1365.95 PSNR=16.78 SNR=14.76	MSE = 1836.52 PSNR=15.49 SNR=13.48	MSE =2499.29 PSNR=14.15 SNR=12.14	MSE = 7071.42 PSNR=9.64 SNR=7.61

Comparison Table (Speckle Noise)

	Noise Density =0.03	Noise Density =0.05	Noise Density =0.07	Noise Density =0.1	Noise Density =0.3
Adaptive Wiener Filter	MSE = 893.08 PSNR=18.62 SNR=16.28	MSE = 1330.59 PSNR=16.89 SNR=14.42	MSE =1721.03 PSNR=15.77 SNR=13.19	MSE = 2251.47 PSNR=14.61 SNR=11.87	MSE =5154.95 PSNR=11.01 SNR=7.46
Wiener Filter	MSE = 1397.52 PSNR=16.68 SNR= 14.62	MSE =1909.61 PSNR=15.32 SNR=13.26	MSE =2396.86 PSNR=14.33 SNR=12.28	MSE = 3093.22 PSNR=13.23 SNR=11.17	MSE =7386.74 PSNR=9.45 SNR=7.38
Average Filter	MSE = 1102.99 PSNR= 17.71 SNR=15.35	MSE =1516.79 PSNR=16.32 SNR=13.85	MSE =1896.33 PSNR=15.35 SNR=12.78	MSE =2414.56 PSNR=14.30 SNR=11.59	MSE =5494.16 PSNR=10.73 SNR=7.24
Median Filter	MSE =1080.51 PSNR=17.79 SNR=15.63	MSE =1568.54 PSNR=16.18 SNR=13.98	MSE = 2021.78 PSNR=15.07 SNR=12.85	MSE = 2671.87 PSNR=13.86 SNR=11.59	MSE =6498.02 PSNR=10.00 SNR=7.56

Comparison Table (Poisson Noise)

	Poisson Noise
Adaptive Wiener filter	MSE=269.97 PSNR=23.82 SNR=21.67
Wiener Filter	MSE=510.00 PSNR=21.06 SNR=19.00
Average Filter	MSE= 505.27 PSNR=21.10 SNR=18.92
Median Filter	MSE= 230.37 PSNR=24.51 SNR= 22.49

Conclusions:

The Mean Square Error (MSE) is the cumulative squared error between the corrupted and the enhanced image, whereas Peak Signal to Noise Ratio (PSNR) & Signal to Noise Ratio (SNR) is a measure of the peak error.

Comparison results for different filters depicts that MSE error with Adaptive Wiener filter is lower than Wiener filter, Median filter & Average filter. Whereas, SNR & PSNR is higher with Adaptive Wiener filter. Which Shows that image filtered through Wiener filter have less error/ Distortion & noise in it. Where higher values of PSNR & SNR indicates higher quality of image.

As a contribution in this project, we tried to implement wiener filter in Mat lab by using fast Fourier transformation of an image. Than we try to use a filter function for image smoothing. At the end, we tried to get enhanced image with inverse Fourier transformation. Moreover, we tried to put 3 types of noises & 4 types of filters into 1 Mat lab code. After comparing all 4 types of filters on different types of noises we found that Adaptive Wiener filter is best among all 4 discussed filter for Image restoration.

Applications of above discussed filters:

- Image restoration filters are used widely in the area of astronomy. Where sometimes images are taken from fast moving spacecraft's which leads to degradation of images. Images restoration filters are used to restore these degraded image.[4]
- Image Restoration filters are used to remove Poisson noise from the chest X-rays. Which leads to display clear image in X-rays.
- Image restoration filters are also used to restore degraded images due to various reasons such as motion blur, various types of noises & Camera mis-focus

Future Work:

Currently, user have to add Noise density from Mat lab command window for every type of filter discuss in this paper. Developer can improve lot of things in this project in future. Graphic User interface can be introduced where user will be able to run whole program at once. After that from appeared screen, user will be able to select the any kind of Image degradation noise from dropdown list. After selecting any noise, user will be able to add density of noise to test. Moreover, Buttons can be introduced to each type of filter. By selecting any filter, it will be applied to noisy image. At the end, it will give Enhanced image.

Moreover, other types of image degradation noise & blur functions can be used. In addition, other filters can also be used to compare results.

References:

[1] https://en.wikipedia.org/wiki/Salt-and-pepper_noise

[2] A comparative study in approaches to speckle Noise reduction in images, Alenrex Maity, Anshuman Pattanaik, Santwana Sagnika & Santosh Pani

[3] Wikipedia.org/wiki/Shot_noise

[4] Image Restoration and the various restoration techniques used in the field of digital image processing. Ishfaq Bashir, Adil Majeed, Owais Khursheed, June 2017

[5] Digital Image Processing, Rafael C. Gonzalez & Richard E. Woods (book)

- **[6]** Image Restoration Techniques: A Survey. Monika Maru, M.C Parikh International Journal of Computer Applications (0975 – 8887) Volume 160 – No 6, February 2017
- **[7]** A Survey on Image Restoration by Comparing the Different Deblurring Process and Filtration Navpreet Kaur1 , Varun Sanduja, Volume 4, Issue 6, Ver. II (Nov - Dec. 2014), PP 56-61
  [8] Introduction to image restoration and comparison of various methods of image restoration 1Vaimin Raval,2 Prof.Lokesh Gagnani, International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 1, Issue 10, December 2012