# Application of Spatial Domain Filters on Noisy Images using MATLAB

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## ABSTRACT
Noise is an unwanted information present in an image. Such unwanted information in an image can be removed with filters. In digital image processing, filters can be applied on an image in two ways, which include spatial and frequency domain. This paper mainly deals with the application of spatial domain filters on noisy images for the purpose of identifying the efficiency of the filters in terms of enhancing the quality of the image by removing the noise present on it.

## Keywords
Salt & Pepper Noise, Gaussian Noise, Speckle Noise, Mean Filter, Median Filter, Gaussian Filter and Wiener Filter.

## 1. INTRODUCTION
Noise present in an image affects the originality of the image and makes the process of interpretation of the image more difficult. Generally, an image gets affected by noise during its acquisition, transmission and storage. There are several ways that noise can be introduced into an image, depending on how the image is created. For example,

- If the image is scanned from a photograph made on film, the film grain is a source of noise. Noise can also be the result of damage to the film, or be introduced by the scanner itself.
- If the image is acquired directly in a digital format, the mechanism for gathering the data (such as a CCD detector) can introduce noise.
- Electronic transmission of image data can introduce noise. [1]

Based on its nature, noise can be modeled as either an additive or a multiplicative process.

$$g(x,y) = f(x,y) + n(x,y)$$

$$g(x,y) = f(x,y) * n(x,y) \qquad [2]$$

f(x, y) - Original image, n(x, y) - Noise, g(x, y) -Noisy image.

The above notations represent both the additive and multiplicative noise models. All such types of noise present in an image can be removed with filters. A filter is a technique with which certain frequency components can be chosen or rejected. The spatial filter is one of the most important tools in an image processing. The filters in image processing can be characterized into three categories, which include convolution based filters, order statistics filters and hybrid filters. [2]

This paper mainly deals with the application of filters, which include Mean, Median, Gaussian and Wiener filters on noisy images, and the calculation of RMSE and PSNR on the filtered images with a view to identifying the efficiency of these filters in terms of minimizing noises present in the images.

In ref [3], the author has pointed out that Wiener filter performs better in removing Gaussian noise as well as Poisson noise than other filters, and Median filter provides better results for Gaussian noise and Poisson noise. But In this paper, it has been pointed out that mean filter performs better in removing Gaussian noise than median filter.

In ref [3], the author has dealt with the conversion of 24-bit images into 8-bit images before adding noise to the images and the application of Median and Wiener filters on them. But this paper deals with the application of Median and Wiener filters directly on 24-bit images without doing conversion from 24-bit to 8-bit.

In ref [2], the author has implemented the two equations given below to characterize the quality of 8-bit images. But this paper deals with the modification of these equations to be used on 24-bit images. The details of the modifications made on these two equations shown under the title of Image Quality Measuring Tools.

$$MSE = \frac{1}{MN} \Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} \left[ f(x,y) - \hat{f}(x,y) \right]^2$$

$$PSNR = 20 \log_{10} \frac{255^2 MN}{\Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} \left[ f(x,y) - \hat{f}(x,y) \right]^2} \ dB \quad [2]$$

In ref [5], the author has indicated that Mean and Gaussian filters remove Gaussian noise. But, in this paper, it has been indicated that wiener filter performs well in removing Gaussian noise present in an image than mean and Gaussian filters.

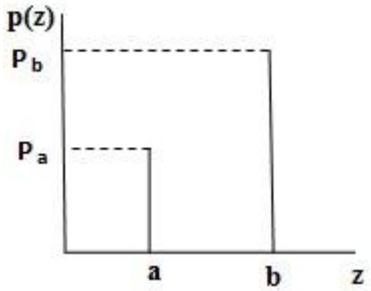
Norbert Wiener proposed the concept of Wiener filtering in the year 1942. There are two methods: (i) Fourier-transform method (frequency-domain) and (ii) mean-squared method (spatial-domain) for implementing Wiener filter. The former method is used only for complete restoration (denoising and deblurring) whereas the later is used for denoising. [6]

In ref [7], the author has applied wiener filter on noisy images using frequency domain method and said that the wiener filter performs well in removing Speckle, Poisson and Gaussian noise present in an image. But this paper has dealt with the application of wiener filter on noisy images using spatial domain and its outcome has been shown under the title of Application of Spatial Domain Filters on Noisy images.

## 2. SALT AND PEPPER NOISE
This is a type of noise, which is also known as impulse noise, shot noise, and binary noise. It is caused by sensor and memory problems due to which the pixels are assigned incorrect maximum values. [2]

The Probability density function (PDF) of Impulse noise

$$p(z) = \begin{cases} p_a & \text{for } z = a \\ p_b & \text{for } z = b \\ 0 & \text{otherwise} \end{cases}$$




[4]

**Figure 1 : PDF of Salt & Pepper noise**

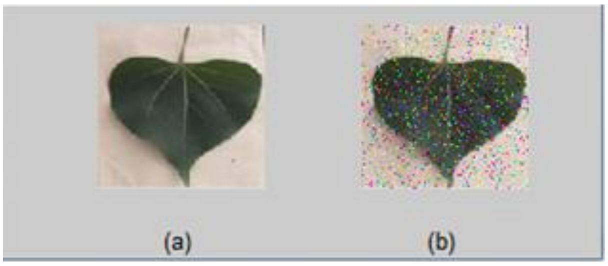



**Figure 2: (a) original (b) image with Salt & Pepper noise [D = 0.07]**

## 3. GAUSSIAN NOISE

The random noise that enters the system can be modelled as Gaussian or normal distribution. The Gaussian distribution is a well known bell-shaped curve. This is mathematically denoted as $F = S \pm N_a$ , where $N_a$ is the Gaussian probability density function (PDF) and S is the noiseless image. The Gaussian noise affects both the dark and light areas of an image. The Gaussian distribution is

$$P(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-m)^2}{2\sigma^2}} \qquad [2]$$

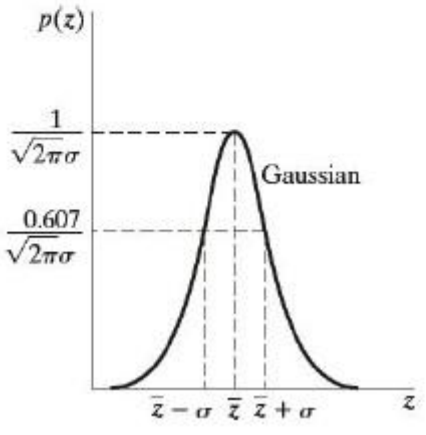



**Figure 3: PDF of Gaussian noise** [4]

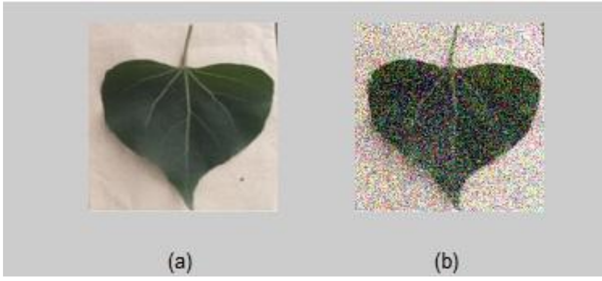



**Figure 4: (a) Noiseless image (b) Image with Gaussian Noise, mean=0; variance=0.03**

## 4. SPECKLE NOISE

This noise is a type of multiplicative noise. It is generally found in medical images and appears as bright specks in the lighter parts of an image.

$$I = S + (S * N_g) \qquad [2]$$

The above mathematical notation represents speckle noise, where $N_g$ is the random noise, which has zero-Mean Gaussian probability distributive function

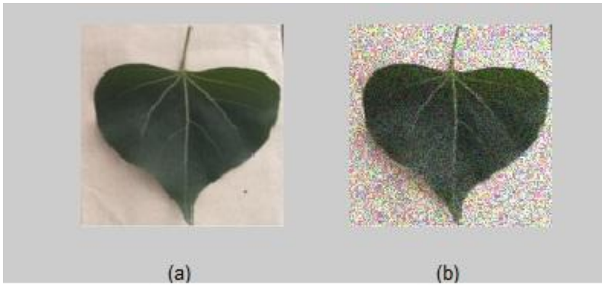
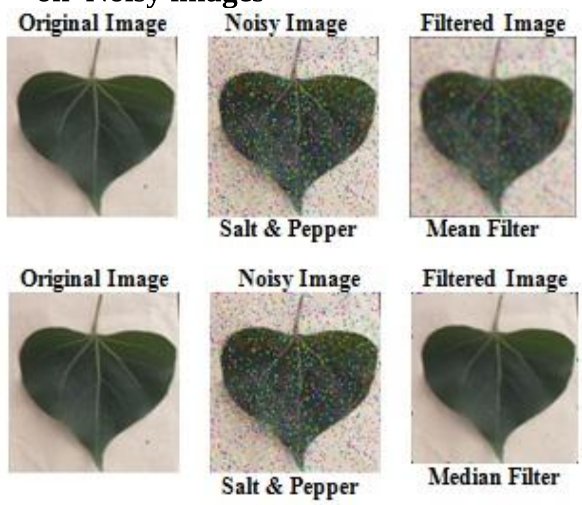
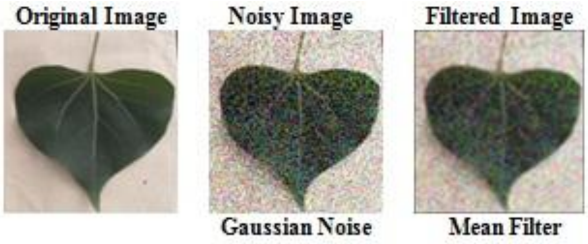


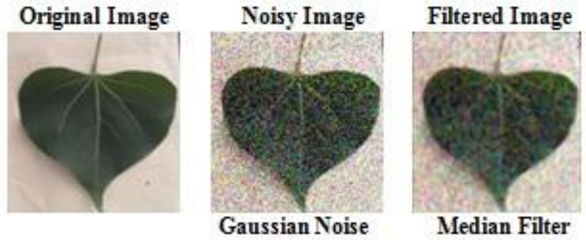

**Figure 5: (a) Noiseless image (b) Image with speckle noise of mean=0 and variance = 0.05**

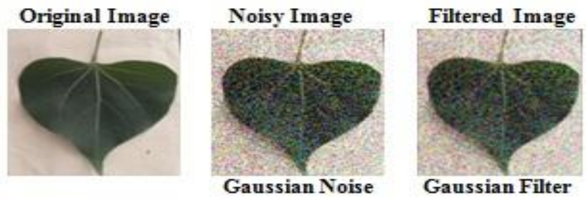
## 5. Application of Spatial Domain Filters on Noisy images













## 6. IMAGE QUALITY MEASURING TOOLS

Mean square error (MSE) and Peak signal-to-noise ratio (PSNR) are image quality measuring tools. These tools are very helpful in measuring the quality of a filtered image.

$$MSE = \frac{1}{MN} \Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} [\, f(x,y) - \hat{f}\,(x,y)]^2$$

$$PSNR = 20 \log_{10} \frac{255^2 MN}{\Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} [\, f(x,y) - \hat{f}\,(x,y)]^2} \; dB$$

[2]

In ref [2], the author has implemented the above two equations to characterize the quality of an 8-bit image. As this paper deals with 24-bit image, the format of the above two equations followed by this paper is given below.

$$MSE = sum(\frac{1}{MN} \Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} [\, f(x,y) - \hat{f}\,(x,y)]^2)$$

$$PSNR = sum(20 \log_{10} \frac{255^2 MN}{\Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} [\, f(x,y) - \hat{f}\,(x,y)]^2}) \; dB$$

**Table 2: Mean Square Error**

| Noise Type | Filtering Techniques | | | |
|---|---|---|---|---|
| | **Mean** | **Median** | **Gaussian** | **Wiener** |
| Salt & Pepper | 53.62 | 6.80 | 34.12 | 32.31 |
| Gaussian | 69.79 | 77.82 | 93.47 | 68.61 |
| Speckle | 55.68 | 66.56 | 74.40 | 54.78 |

**Table 3: Peak signal-to-noise ratio [values in db]**

| Noise Type | Filtering Techniques | | | |
|---|---|---|---|---|
| | **Mean** | **Median** | **Gaussian** | **Wiener** |
| Salt & Pepper | 213.68 | 267.51 | 225.45 | 226.88 |
| Gaussian | 206.85 | 203.95 | 199.18 | 207.28 |
| Speckle | 212.82 | 208.03 | 205.14 | 213.14 |

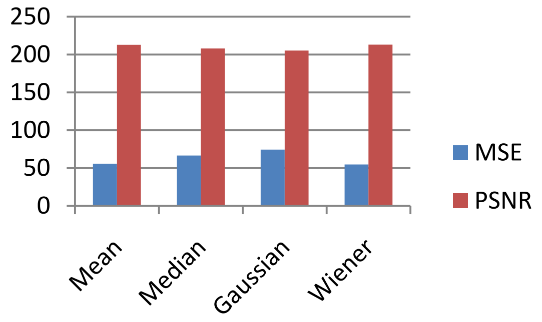



**Figure 6 : MSE & PSNR values of a filteredimage having Salt & Pepper Noise**

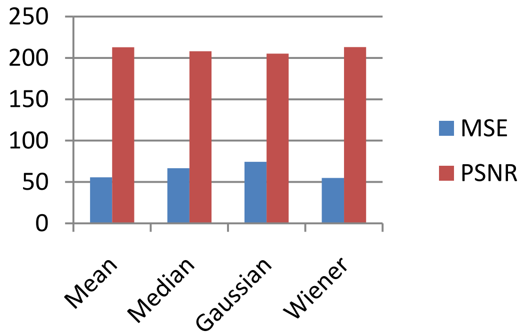



**Figure 7 : MSE & PSNR values of a filtered image having Gaussian Noise**

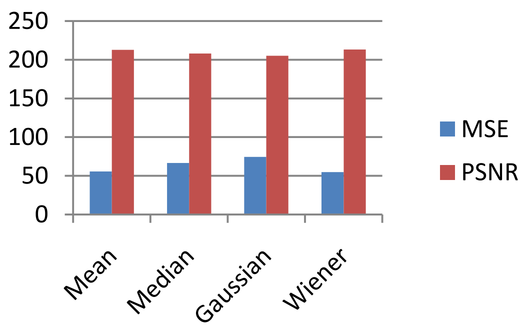



**Figure 8 : MSE & PSNR values of a filtered image having Speckle Noise**

A filter must be able to produce an image which has low MSE and high PSNR

From the above principle, tables and graphs, the facts that have been identified are given below in the form of a table.

**Table 4: Noise and suitable-filter**

| **Noise –Type** | **Suitable – Filter** |
|---|---|
| Salt & Pepper | Median |
| Gaussian | Wiener |
| Speckle | Wiener |

## 7. CONCLUSION

This paper has dealt with the application of spatial domain filters on 24-bit images and identified the following facts

- Median filter performs well in removing salt & pepper noise present in an image than Mean, Gaussian and Wiener filters.
- Wiener filter performs well in removing Gaussian and speckle noise present in an image rather than Mean, Median and Gaussian filters.

And this paper has proposed two new equations based on the existing equations given below.

$$MSE = \frac{1}{MN} \Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} \left[ f(x,y) - \hat{f}(x,y) \right]^2$$

$$PSNR = 20 \log_{10} \frac{255^2 MN}{\Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} \left[ f(x,y) - \hat{f}(x,y) \right]^2} dB$$

[2]

The above two equations can be used to characterize the quality of an 8-bit filtered image. If these two equations are applied on a 24-bit filtered image, MSE and PSNR values are calculated for each 8-bit of the image separately. As a result of which three different values of MSE and PSNR get displayed for a 24-bit image. This paper has illustrated the modification that can be applied on the above two equations not only to make them suitable for 24-bit images but also to get a single MSE and PSNR value for a 24-bit image.

## 8. REFERENCES

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