NOISE REMOVAL TECHNIQUES FOR DIGITAL IMAGE PROCESSING

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Abstract:

Various kinds of noise are introduced into digital images during various processes such as image acquisition, compression, storing, retrieval and transmission. Consequently it is utmost necessary to employ noise removal technique in the first stage of various image processing systems. Random fluctuations in intensity, variations in illumination, or inadequate lighting can further degrade the image. Furthermore, noise must be eliminated to improve the accuracy and precision of image processing applications. An effective noise removal technique for each noise is required that exhibits simplicity, less computational complexity and effective noise removal. In this paper, noise removal techniques for Salt and Pepper, Speckle, Gaussian and Poisons noise are presented. It was observed that median filter is efficient in removing Salt and Pepper, Speckle, Gaussian and Poisons noise. An effective noise removal technique for each noise is demonstrated and comparative analysis is presented for better selection of filtering technique for accentuating image processing applications.

Keywords: *Salt and pepper, Gaussian, Poisons, Speckle, Noise removal techniques*.
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1. Introduction

Mobile and internet technology advancements facilitated image acquisition, transmission, and sharing, as well as real-time video streaming, video calls, and conferencing. [1-3]. Many mobile devices have built-in cameras for image/video acquisition as well as communication technologies for transmission/reception, but different types of noise, such as Salt and Pepper, Speckle, Gaussian, and Poisons noise, have an impact on image quality's [4–6]. Random variations in intensity, variations in illumination, or insufficient lighting can all degrade the image further. An effective noise removal technique for each noise is required that exhibits simplicity, less computational complexity and effective noise removal [7 – 9].. Digital filters are used in images to suppress either high frequencies (levelling out the image) or lower frequencies (sharpening/edge detection). Non-linear digital filters behave very differently than linear digital filters.. The output response of non-linear filters does not act in accordance with the scaling or shift in variance principles.

There are different methodologies are suggested by different filters for eliminating to high density noise. The use of weighted mean filtering and fuzzy logic [10], “impulse noise removal method based on non-uniform sampling & supervised piece wise auto regressive modelling” [11], “vector filter based on geometric information” [12], mean filter based on morphological image processing [13], “local mean and variance” to detect noisy pixels [14] and Newton–Thiele filter for removal of salt and pepper noise have been demonstrated. All these techniques suggest that median filter is not able to remove high density salt and pepper noise [15] – [17].

In this paper, various types of noise are introduced into digital images during image acquisition, storage, compression, transmission, and retrieval. As a result it is utmost necessary to employ noise removal technique in the first stage of various image processing systems. Furthermore, noise must be drawn out to improve the precision and accuracy of image.In this paper, noise removal techniques for Salt and Pepper, Speckle, Gaussian and Poisons noise are presented. An effective noise removal technique for each noise is demonstrated, and a comparative analysis is presented for better filtering technique selection for image processing applications.

2. Related Work

Many factors contribute to noise in an image during the image transmission or accession process. It is determined by the type of disruption [18].Our goal is to get rid of noise.This section, we discussed various kinds of noise and how to eliminate it using various filter algorithms. There are various types of noise present in an image, including:

2.1 Salt and Pepper Noise

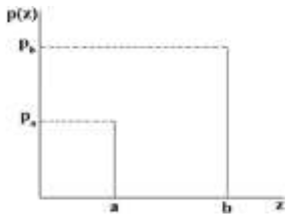

Fig. 1. The PDF of Salt and Pepper noise

Salt and pepper noise is an impulse noise caused by data transmission errors.It occurred as a result of an unexpected variation in image signal sharpness [19]. The noisy pixels in images that have been altered by salt and pepper noise can only occupy the minimum and maximum values in the dynamic range. In an 8-bit, the value for salt noise is 255 and for pepper noise is 0 its probability distribution function (pdf) is shown in fig. 1 and depicted using equation (1). Salt and pepper noise arises due to break down of pixel component in camera sensor, faulty memory location or timing errors in digitization process [20 - 21].

$$P(z) = \begin{cases} Pa & for\ z = a \\ b & for\ z = b \\ 0 & otherwise \end{cases} \quad (1)$$

2.2 Speckle Noise

Speckle noise is often known as multiplicative noise. Coherent imaging systems, such as laser, radar, and acoustics, exhibit this kind of noise [22].Speckle noise is similar as Gaussian noise. Its PDF follows gamma distribution [23 - 25] depicted using equation (2).

$$F(g) = \frac{g^{\propto-1} e^{\frac{-g}{a}}}{\propto-1!a^{\propto}} \quad (2)$$

2.3 Gaussian Noise

Gaussian noise is typically found in amplifiers or detectors, so it is referred to as electronic noise. It also occurs as a result of natural sources such as atomic thermal variations and the discrete nature of warm object radiation [26] Gaussian noise is evenly distributed across a signal this means that in a noisy image, each pixel is the sum of the true pixel value and some random Gaussian distributed noise value, as represented by equation (3). Principle of Gaussian noise in digital image occurs during acquisition.

$$P(z) = \frac{1}{\sqrt{2\pi}\propto} e^{-(z-\mu)^2/2\propto^2} \quad (3)$$

2.4 Poisson Noise

Though the nature of noise is arbitrary, it has a specific distribution. The major source of Poisson noise is assembly of photons at the receiver side in a arbitrary way. This noise acts in accordance with the Poisson distribution, which is defined by the equation (4) and its nature is shown in fig 2 [27].

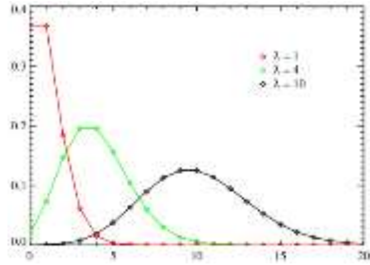

Fig. 2.Behaviour of Poisson Distribution at different values of λ

$(k:\lambda) = P(X = k) = \frac{\lambda^k}{k!} e^{-\lambda}$; $k = 0,1,2,3, \ldots \ldots \ldots . \infty$ (4)

Where λ= E(X) = Var(X),*e*- The base of natural logarithmic function and *k* - the number of success we are concerned in.

3. Types of Digital filters used for removal of noise

3.1 Mean filter or Averaging filter

The mean (or averaging) filter replaces each pixel with the mean of the values in its immediate neighbourhood. The largeness of the neighbourhood supervises the amount to be filtered. In spatial averaging operation, each pixel is substituted by a mean (average) of its neighbourhood pixels. The low-pass filter preserves the smooth region in the image and it removes the sharp variations leading to blurring effects [28].

Limitations of averaging filter:

1. As a result of averaging operations, the image becomes blurry.
2. Blurring effects feature localization.
3. A single pixel with a relatively irregular value can influence the pixel's mean value.
4. When the averaging operation is applied to an image that has been altered by impulse noise, the impulse noise is weakened and dispersed but not eliminated.

3.2 Gaussian filter

Another type of smoothening filter is Gaussian filter. By use of Gaussian function its weights are determined by the form of a Gaussian kernel. Gaussian smoothing is a type of averaging with a 2D Gaussian kernel. [29].

3.3 Median Filter

Median filters are non-linear statistical filters that are commonly used in the spatial domain. A median filter smoothes the image by using the median of the neighbourhoods. To find each pixel value in the processed image, the median filter performs the following operations [30].

1. All pixels found by the mask in the vicinity of pixels in the primary image are stored in ascending/descending order.
2. The median of the sorted values is calculated and chosen as the processed image's pixel value.

3.4Bilateral Filter

A Bilateral filter could be a non-linear filter that has the ability of protective the sting. The potency of each constituent is replaced by a weighted average of intensity values from nearby pixels. [31].

4. Experimental Results

Experiment has performed to determine the most effective filter algorithm i.e. It was determined which filter removes noise more effectively than other algorithms on various images. Enhancing an image or improving its quality can be subjective i.e. as per the applications of user there may be variation which algorithm provides better image quality. It is paramount to develop a quantitative measure that compares image quality. Different algorithms can be compared using the same sets of test images to determine which algorithm produces the best results. The higher the PSNR value, the better the image quality. Thus it is necessary to calculate PSNR and MSE in order to determine the quality of the image. Mean Square error (MSE) is used to measure the average square of errors between the corrupted image and the original image. MSE is expressed as in equation (5)

$MSE = \frac{1}{mn} \sum \sum ||f(i,j) - g(i,j)||^2$ (5)

Where

*e*ISSN1303-5150

g - the matrix of corrupted image,
f- the matrix of original image,
m- no. of rows of pixels of the image
i - index of that row,
n - no. of columns of pixel of the image,
j - index of that column.
Peak Signal to Noise Ratio (PSNR) is defined as the ratio of the maximum possible signal value to the power of distorting noise that affects image quality. PSNR is expressed as in equation (6)

$$PSNR = 20\log_{10}\left(\frac{MAXf}{MSE}\right) \qquad (6)$$

We can deduce from the above equation that PSNR is directly proportional to image quality. Here *MAXf* is the maximum signal value that exists in our original image.

4.1 Experiment 1

We have added salt and pepper noise in an image and the result obtained is as shown in fig 3 and fig. 4 respectively.The calculated value of PSNR and MSE is shown in table 1 below.

Fig. 3. Lena Image original and corrupted by salt and pepper noise

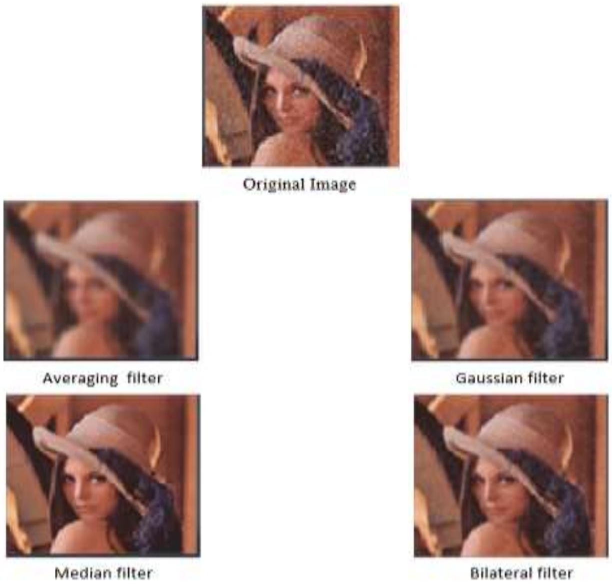

Fig. 4. Images after applying different filter algorithm

Table 1. PSNR and MSE for different filter algorithm

Filter Algorithm	PSNR (dB)	MSE
Averaging filter	33.84	27.05
Gaussian filter	34.74	21.96
Median filter	35.51	18.17
Bilateral filter	33.84	27.05

From Table 1 it is comprehended that the value of PSNR is the highest for Median filter and the value of MSE is the lowest for Median filter. Hence it is concluded that Median filter is the best filter algorithm for removing salt and pepper noise.

4.2 Experiment 2

Fig. 5. Lena image original and corrupted by Gaussian noise

Further we have added Gaussian noise in an image and the result obtained is as shown if fig 5and 6 respectively. The calculated value of PSNR and MSE is shown in table 2 below.

From Table 2 it is seen that the value of PSNR is the highest for Median filter and value of MSE is the lowest for Median filter. Hence it is concluded that Median filter is the best filter algorithm for removing Gaussian noise.

Table 2. PSNR and MSE for different filter algorithm

FilterAlgorithm	**PSNR(dB)**	**MSE**
Averaging filter	32.21	39.32
Gaussian filter	32.96	33.15
Median filter	34.58	22.82
Bilateral filter	32.21	39.32

Fig. 6. Images after applying different filter algorithm

4.3 Experiment 3

We have added Poisson noise in an image and the result obtained is as shown if fig 7 and 8 respectively. The calculated value of PSNR and MSE is shown in table 3 below.

Fig. 7. Lena image original and corrupted by Poisson noise

From Table 3 it is seen that the value of PSNR is the highest for Median filter and value of MSE is the lowest for Median filter. Hence it is concluded that Median filter is the best filter algorithm for removing Poisson noise.

Table 3. PSNR and MSE for different filter algorithm

FilterAlgorithm	**PSNR (dB)**	**MSE**
Averaging filter	43.52	2.91
Gaussian filter	46.46	1.48
Median filter	51.55	0.48
Bilateral filter	43.52	2.91

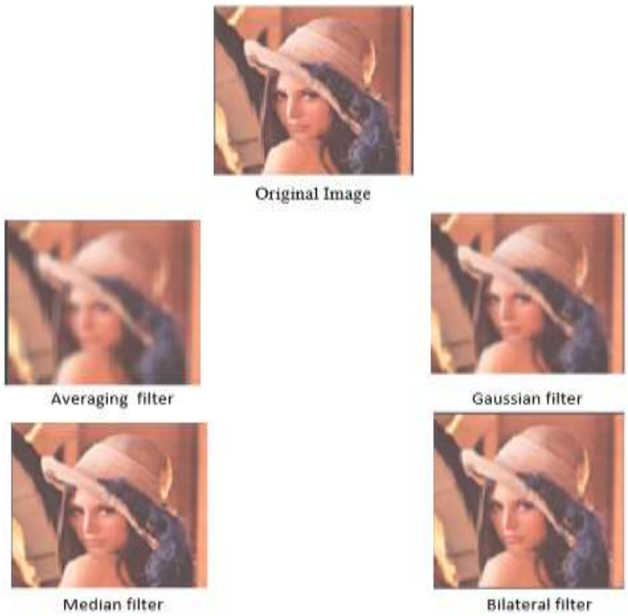

Fig. 8. Images after applying different filter algorithm

4.4 Experiment 4

We have added Speckle noise in an image and the result obtained is as shown if fig 9 and 10 respectively.

Fig. 9. Lena image original and corrupted by Speckle noise

Fig. 10. Images after applying different filter algorithm

From Table 4 it is seen that the value of PSNR is the highest for Median filter and value of MSE is the lowest for Median filter. Hence it is concluded that Median filter is the best filter algorithm for removing Speckle noise. An effective noise removal technique for each noise is demonstrated and comparative analysis is presented for better selection of filtering technique for accentuating image processing applications. It was observed that median filter is efficient in removing Salt and Pepper, Speckle, Gaussian and Poisons noise.

Table 4. PSNR and MSE for different filter algorithm

Filter Algorithm	PSNR (dB)	MSE
Averaging filter	34.75	21.92
Gaussian filter	35.51	18.40
Median filter	37.16	12.58
Bilateral filter	34.75	21.92

5. Conclusion

In this paper, noise removal techniques for Salt and Pepper, Speckle, Gaussian and Poisons noise are presented. The image is also corrupted by random variations in intensity, variations in illumination or poor distinction. An effective noise removal technique for each noise is demonstrated and comparative analysis is presented for better selection of filtering technique for accentuating image processing applications. It was observed that median filter is efficient in removing Salt and Pepper, Speckle, Gaussian and Poisons noise. Although the values of PSNR are for median, Gaussian and bilateral filter are within ± 10%, but the simplicity, low computational complexity and high speed are the important advantages of median filter. Further various algorithms on application of median filter to improve accuracy can be addressed.

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