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Performance Analysis of Noise Removal Techniques For Digital Images

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ABSTRACT

Noise has impairment effect on image so it destroys its information. In order to overcome this problem, it is necessary to remove noise before extracting information and image processing as one of the preprocessing steps. A brief overview of various sources and types of image noise as well as noise removal technique of digital images has been produced in this paper. The general idea of this paper is to perform segmentation of the corrupted image before using noise removal filter. Noise removal filter has been used to eliminate noise for each segment of image individually after segmentation process. Then comparative study between noise removal filtering for whole image and segmentation based method has been produced with performance analysis in terms of MSE and PSNR. In this paper, MSE and PSNR are calculated for the resultant reconstructed image compared with the original image. Six image samples are used to test the Segmentation based noise removal approach. The segmentation based technique has shown best results in terms of MSE and PSNR in comparison with traditional noise removal method based filter.

Simulation result show that MSE is less and PSNR is high using segmentation based noise removal method especially for image which has more details, so it superior performance as compared to the traditional method.

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1 . Introduction

Generally, noise was defined as random signal causes impairment effect on color intensity of image[1]. Noise added to image according to many sources during capture or transmitted in communication system[2]. There are different types of noise, the most common type of noise that affect the image is impulsive noise[3], Which is generated in devices such as sensor of camera and communication channel due to human made error (physical error) [4]. The image noise can be generated by transmission channel, during the propagation , during acquisition by receiver and input devices. There are three main sources of image noise[4]. First source is Image acquisition such as atmospheric interference(environmental conditions) , defects in image reception, scanning for damage original surfaces, electronic sensor errors, temperature of sensor[5]. Second source is Image transmission may be caused by different sources, such as car ignition systems, channel bit errors, industrial machinery in the vicinity of the receiver, transient switching in power lines, atmospheric lightning, and various unprotected switches[6]. Third source is Device faults such as loud sensors, channel faults, or faulty storage devices, timing errors in the process of digitization, quantization noise[6].

There are different types of noise can be classified according to different considerations, as its structural properties, noise can be additive, phase, and multiplicative, and according to its model, it can be Gaussian, Poisson, impulsive, non-Gaussian, Rayleigh, uniform [4]. The common type of image noise according to its resource and model are: Gaussian, impulse, salt and paper, Poisson, SPECKLE, Rayleigh, Gamma, Exponential, uniform, Structured, Poisson-Gaussian, Quantization, periodic noise, Brownian and white noise[7] .

There is a wide range of applications involving image processing such as medical imaging, edge detection, pattern recognition, image compression, and security application [1]. Therefore, noise removal process is the most important pre-processing step in image processing before information extraction in order to obtain true information and image enhancement [8]. With this aim of noise removing, many works were proposed and many algorithms were designed[8]. Since noise characterized by wide bandwidth, it considered as a high frequency component of image. Therefore, the most common filters using as noise removal filter was low pass filter such as

mean and median filter[9]. Noise reduction methods based on fuzzy technique were produced and developed by many research[10][11]. Promising result was obtained by Ville et.al. They were using two stages fuzzy filter, fuzzy derivation computed in first stage and used it to smooth in the second stage[12]. There are various fuzzy based filter designed with the aim of eliminating noise such as iterative fuzzy control filter, FIRE-filter, weighted fuzzy mean filter[13][14]. With the aim of achieving better two common measurement metrics (MSE and PSNR), this study proposed a new technique of noise reduction based on segmentation and filtering. This paper presents a general review of sources and types of noise. A comparative study is presented on the performance of various noise removal techniques for digital image.

The discovery of noise and the work to remove it are important things in our lives and in the future of various fields. One of the most important areas is space and cosmic discovery, in which noise is an essential factor that must be eliminated. In 1996, the first picture was taken of the celestial body. It is possible to observe the high noise rates, which cannot be distinguished because of the impurities in the space, in addition to the weakness of the sensitivity used to accomplish this task, resulting in a high degree of deformation. In 2005 there was another image of the Pluto, but the difference in clarity can be seen due to improved sensor sensitivity and the processes that have been followed to reduce distortion. Then, in 2016, a clear progress was made in obtaining a picture that highlights the celestial planet with all its details, terrain and gaps clearly and accurately. This experiment is therefore an extension of future experiments especially in noise removal methods.

The rest of this paper is organized as follows. First, the related work is described in Section 2. Section 3, describes methods and materials. Sections 4 and 5, explain proposed work and evaluation metrics respectively. Sections 6, discusses the results and analysis of the noise removal methods. Finally, the conclusions are presented in Section 7.

2. Related Work

The noise reduction based on a new fuzzy filter for images under additive noise was presented in [15]. In this work there are two stages based filter; fuzzy derivatives for 8 directions are calculated then these derivatives were used in the second stage in order to achieve image smoothing depending on the value of neighboring pixels. As a result this method characterized by flexibility as compare with other filters.

a new median-based switching filter was produced by Wang and D. Zhang [16]. This filter was called progressive switching median (PSM). This filter applied two filter: impulse detector and noise filter in iterative progressive manner. Simulation results in this research show that this method better than traditional median-based filters especially with high power of noise.

Wavelet based image de-noising for image under Gaussian noise was produced by Kamran et.al. [17]. Neigh-shrink denoising method with suitable threshold was proposed in this research. As a result this method was better than other methods based on traditional Neigh-shrink denoising in term of PSNR.

In 2006, Kachouie and Fieguth [18] investigated a new denoising method based on a combined Bayes Shrink Wavelet-Ridgelet denoising. This method make benefit of the advantage
of each filter, so it achieved better result in term of SNR.

For Ultrasound (US) images a new linear filtering based denoising method under Gaussian noise depending on wavelet coefficients of the image, are proposed by Gupta and A. Garg [19]. Experimental results of this method show effective performance for standard Boat image and real US images.

A new denoising method based on combination of wavelet transform (WT) and Singular Vector Decomposition (SVD) was produced by Patil (2015) [20], depending on powerful advantage of wavelet transform (WT) in denoising image processing. Simulation results show good performance in case of proposed method as compare with WT in term of less MSE.

3. Methods and materials

3.1 Noise Removal Techniques

There are more than one technique based noise removal of digital image . below review of most common technique:

1. Spatial Technique Based On Image Filtering

Generally, the noise removal methods based filter can be divided in to common main types: linear and non-linear filtering according to the linearity of used filter[1].

a. linear Filter

For special type of noise such as Gaussian noise, linear noise has been used. Averaging or Gaussian filters, mean filter are considered as linear filter. The convolution between image and filter brings the value of each pixel into closer correspondence with the values of its neighbors[21].

b. Adaptive Filter

Wiener filter is adaptive filter that overcome the disadvantage of linear filter where the linear filter cause the blur effect on image. Wiener filter based on wiener function which depend on image variance. When variance is large the wiener filter cause less effect[22].

For white additive Gaussian noise (AWGN) the wiener produced better result than linear filter where it perform all preliminary computations and keeping edges and other high-frequency parts of an image[23].

c. Nonlinear Filter

On the contrary from linear filter, nonlinear filter produce superior results of noise removal in terms of MSE and PSNR, so it overcome the blur effect caused by linear filter although it complex more than linear filter. There are many types of nonlinear filter such as: Median filter (order-statistic filtering), Standard median filter Switched median filter, Adaptive median filter, Maximum Filter, and Minimum Filter[6]

2. Transform Based Technique

The number of changes in gray level with distance in an image represent the frequencies of image. The noise of image is example of high frequency of image since it is characterized by wide bandwidth so it randomness feature cause high change in gray level across small distance. Using image transform to transform the image from time domain to frequency domain will decompose the image to its frequencies so this transform can be used as noise removal methods by eliminate high frequencies which represent noise in an image. The most common image transfer used as noise removal is wavelet transform[24]. There are other frequency domain transform can be used such as Discrete Cosine Transform (DCT), Contourlet transformation, curvelet transformation[25]. All these transformation decompose the image to low and high coefficients, then by eliminate high coefficients depending to adaptive linear, nonlinear , statistical model of thresholding process, so it used as noise removal methods[26][27].

3.2 Normalized-Cut-Segmentation based Technique

This method is used for segmenting image based on using color (RGB color), texture (mean, variance, skewness and kurtosis) and spatial data[28]. This algorithm six parameters: Color similarity denoted by (SI), Texture similarity denoted by (ST) , Spatial similarity denoted by (SX), Spatial threshold denoted by (r: less than r pixels apart), The smallest Ncut value, and The smallest size of area[28].The smallest Ncut value it used as threshold to keep partitioning

The smallest size of area is denoted as (sArea) and consider as threshold to be accepted as a segment[28].

Depending on Graph theory the Ncut segment algorithm segment two regions by removing edges that connecting these two regions, where theses removed edges determined the degree of dissimilarity between two parts as in equation (3.1)[29]:

$$cut(A,B) = \sum_{u\in A, v\in B} w(u,v) \qquad (1)$$

Where A, B are two disjoint parts. u, v are edges. $w(u,v)$ is weighted edges and $\sum_{u\in A, v\in B} w(u,v)$ is total edges weight which determined dissimilarity degree.

The normalized cut (Ncut) is defined as :

$$N\,cut(A,B) = \frac{cut(A,B)}{assoc(A,V)} + \frac{cut(A,B)}{assoc(B,V)} \qquad (2)$$

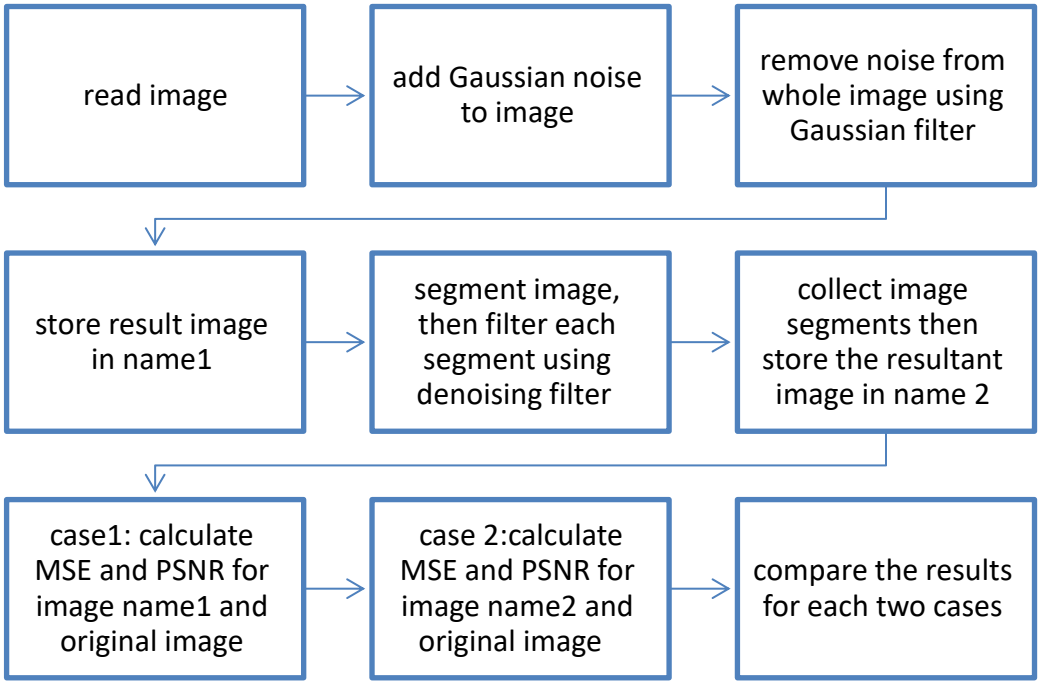
Where $assoc(A,V) = \sum_{u\in A, t\in V} w(u,t)$ which defined as total connection from A to all nodes in graph. Similarly, $assoc(B,V)$ has been defined.

Below algorithm illustrates the noise removal technique based on segmentation:

Input: noisy image
Output: free noise image
Step1: reading image .
Step2:adding Gaussian noise to image.
Step3: preprocessing steps
Finding size of image s←size(image)
Converting image to column vector
Step4: extract texture features (mean, variance, skewness, kurtosis).
Step5: using eigen system algorithm for segmentation with suitable windows depending on texture features(solve $(D - W)x = \lambda Dx$ for eigenvectors with the smallest eigenvalues then use the second smallest eigenvalues to segmentation).
Step6: extracting each segment and filtering it with suitable noise removal filter.
Step7: reconstructing and collecting the segments.
Generally, edge based technique has important advantage where essential information can be extracted. So, noise (high frequency part) for each segment will detected and removed separately, i.e., filter will control on noise in case of segmentation based on edge (high frequency) more than filter whole image. the various image regions contain distinct features, so different set of filter parameters should be applied in each particular region, in order to achieve an optimal noise suppression effect and improve the performance of noise removal technique.

4. Proposed work

In this study a new method of noise reduction based on filtering and segmentation of digital images is produced in order to achieve enhanced, smooth, and suitable image for processing in many image based applications. Figure (1) illustrates the main components of the proposed work.



Figure(1): main components of the proposed work

5. Evaluation Metrics

mean square error and peak signal to noise ratio are used as evaluation metrics in order to evaluate the performance of noise removal techniques.

For image $I(m,n)$ with $M * N$ dimensions, the MSE is defined as:

$$MSE = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left[I(m,n) - \hat{I}(M,N)\right]^2 \quad (3)$$

Where $\hat{I}(M,N)$ is reconstructed image

Then PSNR can be defined via MSE as:

$$PSNR = 10\log_{10}\left(\frac{{MAX_I}^2}{MSE}\right) \quad (4)$$

$$PSNR = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (5)$$

$$PSNR = 20\log_{10}(MAX_I) - 10\log_{10}(MSE) \quad (6)$$

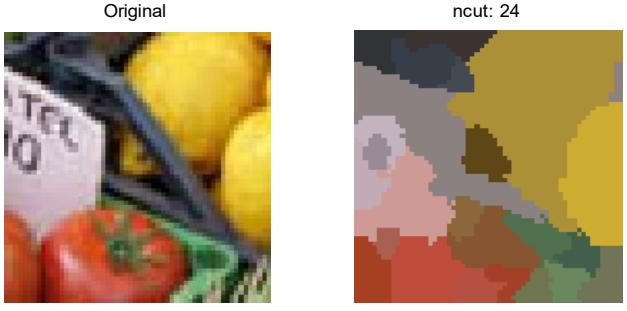
Where, MAX_I is the large gray level in image [5][29].

6. Results and Analysis

Six colored images are used as test to simulate the segmentation method. Gaussian noise with 0.01 variance has been added to produce noise image. Simulation has been introduced using MATLAB

Simulation for segmentation using "normalized-cut"-segmentation-using-color-and-texture-information

Figures (2) and (3) show the resultant image after segmentation .



Figure(2): first resultant segmented image

Figure(3): second resultant segmented image

Simulation of noisy image and noise removal Segmentation based and traditional algorithm using Gaussian filter with 0.01 variance and window([2,2]).
Figures (4) shows the resultant reconstructed images after noise removal for six images respectively.

Image 1

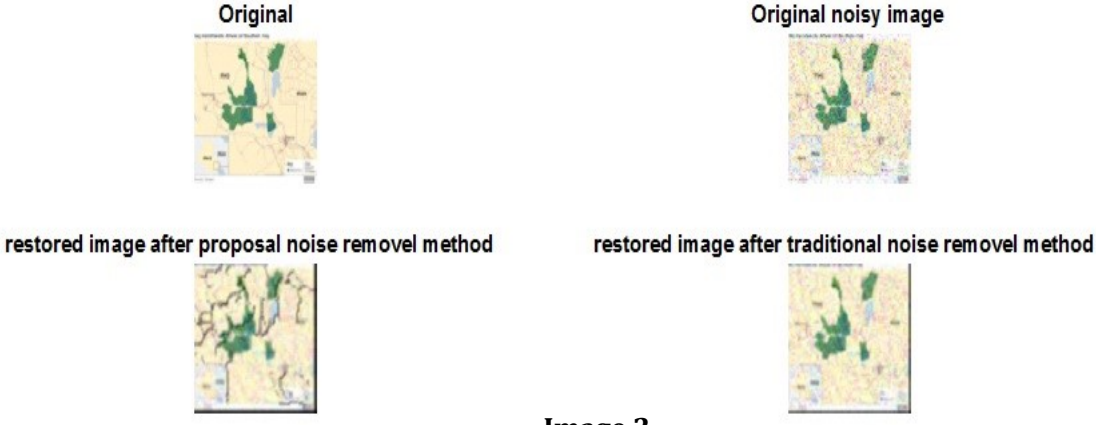


Image 2

Image 3

Image 4

Image 5

Image 6

Figure(4): shows the original and reconstructed six images after two noise removal methods

It is clear from Figure (4) that the resultant restored images using the Segmentation based method are enhanced compare with the traditional method for six various testing image.

Analysis And Comparisons Study

As it shown in table (1) and (2) there is a difference in MSE about (4-6) units where the MSE is less and PSNR is high using the Segmentation based method especially for image which has more details. Therefore, segmentation based noise removal method has superior performance as compared to the traditional method.

Table (1): Illustrates the performance of two noise removal methods in term of MSE for six tested image

Method	Images' number					
	Image1	Image2	Image3	Image4	Image5	Image6
Segmentation based method	22.2216	11.7470	20.0933	20.3876	20.2781	18.5369
Traditional	28.0059	17.7328	26.5188	24.3465	25.0774	22.7982

Table (2): Illustrates the performance of two noise removal methods in term of PSNR for six tested image

Method	Images' number					
	Image1	Image2	Image3	Image4	Image5	Image6
Segmentation based method	47.1045	51.4279	49.0967	48.9841	48.9603	49.3584
Traditional	46.2698	49.6394	47.8917	48.2134	48.0377	48.4598

Table (3) shows the MSE between original and de-noised sixth tested image under three values of Gaussian noise variance (noise power) using Segmentation based and traditional noise removal method. It is obvious that there is increase in MSE proportional with Gaussian noise variance. On the other hand the difference of MSE between the Segmentation based and traditional noise removal method is not effected by increase of Gaussian noise variance.

Table (3): Illustrates the performance of two noise removal methods in term of MSE for sixth tested image under three values of Gaussian noise variance (noise power)

Method	Gaussian noise variance		
	0.01	0.05	0.5
Segmentation method	18.5369	35.0254	78.6896
Traditional	22.7982	40.6709	80.6080

7. Conclusion

In Conclusion, this paper aims to remove noise which has been defined as random signal cause impairment of color intensity of image. Mean and median filter were the most common low pass filters using as noise removal filters. Noise should be removed from image before any processing of information extraction from image to avoid damage effect of noise on image. This research aims to produce a new Segmentation based noise removal method based on segmentation. A comparative study is presented on the performance analysis of traditional filters based noise removal and Segmentation based method in terms of MSE and PSNR. The best method is the one that gives less MSE. Numerical results showed that there is about (5 units) MSE difference between Segmentation based method and other traditional method so the Segmentation based method in this research is the best since it gives less MSE and high PSNR. In the future work, we are planning to use wavelet and DCT transform as noise removal filter, create a comparative study for the best filter and method of noise removal with the same idea of our Segmentation based method in this research in terms of MSE and PSNR, perform a comparative study for the best image segmentation method with the same idea of Segmentation based method in this research in terms of MSE and PSNR. Finally, we are planning for using the idea of the Segmentation based method in image compression.

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