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Performance analysis of segmentation based image noise removal technique

A Research

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا
الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)

صَدَقَ اللَّهُ الْعَلِيِّ الْعَظِيمُ

سورة المجادلة الآية (11)

DEDICATION

To our beloved country Al-IRAQ

To Souls of Martyrs of IRAQ

To our father's soul

To the source of love & tenderness, our father and mother

To the flowers of our life, our dear brothers and sisters

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*Sincerely and greatly I feel urged to praise almightily “**ALLAH**” the most gracious and most merciful and his prophet “**MOHAMMED**” and his kinsfolk because this research has been completed under their benedictions.*

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Abstract

This research proposes a new technique for image noise removal based on image segmentation. 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 proposal method has been produced with performance analysis in terms of MSE and PSNR. Simulation result show that MSE is less and PSNR is high using proposal segmentation based noise removal method especially for image which has more details, so it superior performance as compared to the traditional method.

Chapter One

Introduction

1.1 Problem Statement

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 type of noise, the most common type of noise that affect the image is impulsive noise[3]. Where the impulsive noise generated in devices such as sensor of camera and communication channel due to human made error (physical error) [4]. There is a wide range of applications involved image processing such as medical imaging, edge detection, pattern recognition, image, image compression and security application [1]. So, noise removal process is first most important pre-processing step in image processing before extract information in order to obtain true information and enhanced image[5]. With this aim of remove noise, many work was proposed and many algorithms was designed[5]. Since noise characterized by wide bandwidth, so it consider as high frequency component of image. Therefore, most common filters was using as noise removal filter were low pass filter such as mean and median filter[6]. Noise reduction methods based on fuzzy technique was produced and developed by many research[7][8]. Promising result was obtained by Ville et.al. They was using two stage fuzzy filter, fuzzy derivation computed in first stage and used it to smooth in the second stage[9]. There are various fuzzy based filter was designed with aim of eliminating noise such as iterative fuzzy control filter, FIRE-filter, weighted fuzzy mean filter[10][11]. With the aim of achieving better two common measurement metrics (MSE and PSNR), this study proposed new technique of noise reduction based on segmentation and filtering.

1.2 motivations

Noise have impairment effect on image so it destroy its information. In order to overcome this problem it necessary to remove noise before extract information and image processing as one of the preprocessing steps.

The discovery of noise and work to remove it is most important things in our lives and the most important things in the future in various fields. One of the most important areas is space and cosmic discovery, in which noise is an essential factor and 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. While 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.

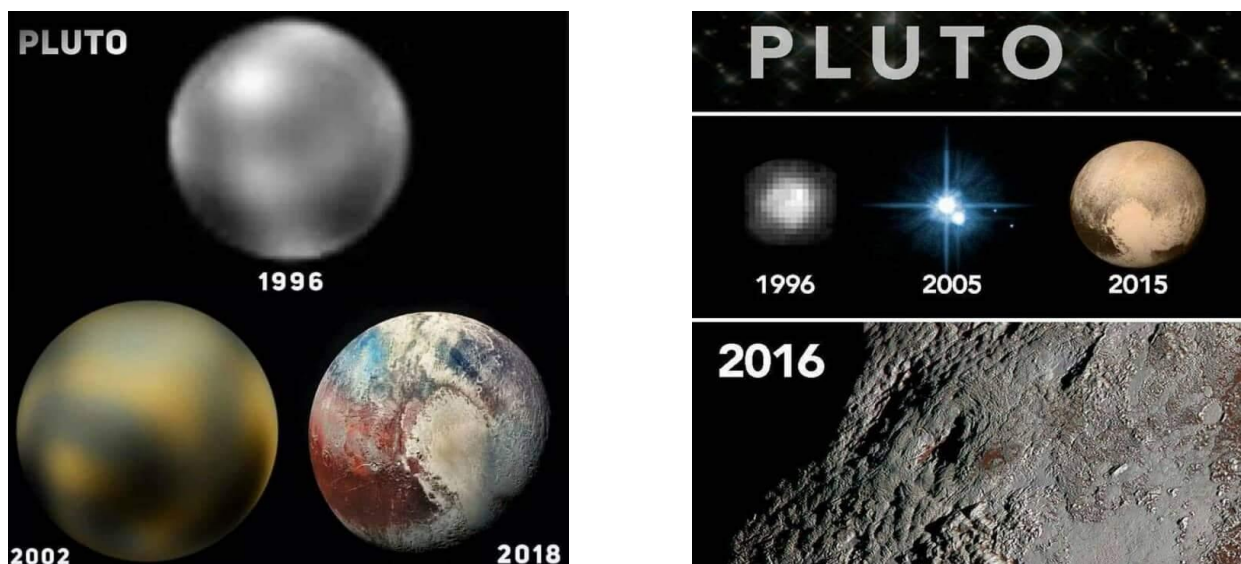


Figure (1.1): shows The images of the planet Pluto over the years from 1996 to 2018

1.3 Aims of the Study

- 1- Produce new method of noise reduction based on filtering and segmentation in order to achieve enhanced, smooth and suitable image for processing in many image based applications.
- 2- Comparative study with performance analysis between proposed and traditional noise reduction methods using mean-squared error (MSE) as performance measure and (PSNR), where best method is the one that gives less MSE.

1.4 Research Organization

The rest of this research is organized as follows.

- 1- Theoretical background is described in chapter two
- 2- Chapter three describes design and implementation of proposal work
- 3- Chapter four discusses the result and performance analyses of proposed technique
- 4- The conclusions and future works are presented in chapter five

Chapter Two

Theoretical Background

2.1 Image Noise (Definition, Source, Type)

Generally, noise can be defined as an undesirable signal that intervenes with the communication or measurement of another signal. A noise itself is a signal that transmits information concerning the source of the noise [12].

Noise is random function of time so it does not have mathematical description. The signals description is required in order to analyze its effect on the performance of the system under consideration [13]. Image noise can be defined as a random variation of brightness or color information in image.

2.1.1 Source of Noise

Generally, the noise is generated and corrupts signal during transmission, receiver of signal processing, and propagation. So the most source is caused by natural environment such as temperature (increase temperature of system component such as connection wires and board, change movement direction of electrons and leads to destructive collision effects on current generating temperature noise), humidity, pressure. Another sources are caused by physical environment(human-made) such as non-stability of voltage in power supply, variation in parameter in signal processing system, vacillation of generator and power amplifier, fluctuations of electron concentration, randomness of electron motion [14]. Also there is electromagnetic noise generated in radio, television. lighting can be considered as a source of electrostatic noise. digital and analog signal processor is another source to generate processing noise such as coding of data and lost packets in communication [12].

Noise in physical source environment cannot be modelled as Gaussian noise because of human -man interference, so it can be modelled as impulsive noise [15].

Image noise is generated by sensor and circuitry of a scanner or digital camera. It can also produce in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is generated during image capture which consider as another source of image noise that disorganize the desired information.

2.1.2 Noise Type Classification

There are different kinds of noise encountered in application. According to its structural properties, noise can be additive, phase, and multiplicative, and according to its model, it can be Gaussian, Poisson, impulsive, non-Gaussian, among other models [4]. The noise can be classified according to its interference, time and frequency characteristic [4][12].

A. Classification According to How the Noise Interference (Structural Properties)

1- **Additive Noise:** it is noise that gets added to the signal which be worst case with Gaussian process due to information theory especially in wireless network [16]. The most common type of additive noise is additive white Gaussian noise (AWGN), Additive non-Gaussian Noise, Additive Color Noise, Additive Impulse Noise.

2- **Phase Noise:** noise that causes distortion and variations in the phase of signal with general formula [17]:

$$y = (A + a(t)) \cos(w_0 t + \Delta\phi(t)) \quad (2.53)$$

Where $\Delta\phi(t)$ is random phase fluctuations which represent phase noise.

The type of phase noise is Thermal, Shot and Flicker Noise. Phase noise has damaged effect in radar and communications system where in radar system it weakens the ability to process Doppler information [18]. phase noise considers performance measurement since part of amplitude energy convert to phase noise thereby the total noise is considered phase noise completely [19].

3- **Multiplicative Noise:** The noise which multiplies or modulates intended signal. This noise is main limiting factor that has distortion effect on signal and

degrading the performance of signal, since it causes distortion in frequency, amplitude, and phase of signal [4]. multiplicative noise is more practical than additive noise and found in biological, physical, and aerospace engineering system [20]. Multiplicative noise is more difficult than additive noise since the signal multiply by it not add to it. The multiplicative noise also called speckle noise when it corrupts the imaging system: synthetic aperture radar, sonar, laser images, microscope images [21].

B. Classification According to Time and Frequency Characteristic

1- **White Noise:** It is the most common type of noise which has equal constant intensities for all frequencies. Its power spectrum density PSD is flat and constant. It has Gaussian distribution and it is generated mostly by thermal source. Because PSD of white noise $G_x(f)$ is constant, therefor, the autocorrelation function $R_x(\tau)$ of this noise is delta function that mean its time samples are not correlated according to Wiener-Kinchin Theorem (WKT) [22]:

$$G_x(f) \stackrel{F}{\leftrightarrow} R_x(\tau)$$

2- **Colored Noise:** At variance with white noise, the colored noise is broadband noise with wide bandwidth and non-constant PSD. There are many kinds of this noise such as brown noise, autoregressive noise and pink noise.

3- **Impulsive Noise:** it is number of random amplitude pulses with random and short duration generated by different source such as click from keyboard of computer, switching noise [12]. Impulsive noise severely causes damage and weakness performance of most important applications such as: image, processing and communication system [4][2]. According to its very high amplitude and short duration characteristic, impulsive noise causes great impairments and high error rate during transmission data in power line communication system (PLC) [23]. To reduce impulse noise effect in PLC system, powerful, robust and simple implement orthogonal frequency division multiplexing (OFDM) technique was used, because the noise effect is propagating over numerous subcarriers due to the discrete Fourier transform at the receiver [2]. In network there are two classes

of noise background noise which is modelled as Gaussian noise and impulsive noise that is modelled as Poisson-Gaussian noise [3]. Due to important advantage of relay network in wireless communication such as self-heading, self-configuration and reliability against failures, simulation of relay wireless channel under impulsive noise was produced by [23] to help designer for choosing robust channel and optimum design. New algorithm was proposed by [24] to alleviate impulsive noise that was degrade the power line communication system performance using sparse Bayesian learning.

C. Image Noise Type Classification according to the probability density function (pdf)[25]:

of each model is given below.

1- Gaussian-Distributed Model

Multiplicative noise that is mostly encountered in electrical systems has zero mean Gaussian probability density function (pdf) with variance (power) σ^2 as follows:

$$p(n) = \frac{1}{\sigma\sqrt{2\pi}} e^{-n^2/2\sigma^2} \quad (2.1)$$

2- Rayleigh-Distributed Model

If pdf of random variable X is given by:

$$p(x) = (x/B)e^{-\frac{x^2}{2B}}; \quad x \geq 0, B = b^2 \quad (2.2)$$

is said to be Rayleigh, where b is a real positive parameter called Rayleigh parameter. This distribution has a mean and variance given by:

$$\mathcal{E}\{X\} = b\sqrt{\pi/2}; \quad \text{var}(X) = B \frac{(4-\pi)}{2}.$$

Hence, Rayleigh noise has a non-zero mean. The second moment (power) of Rayleigh noise is given by:

$$p = \mathcal{E}\{X^2\} = 2B$$

where p denote the power of noise, hence,

$$b = \sqrt{p/2}.$$

Note that, unlike the case of Gaussain noise where its power equals its variance, the Rayleigh noise power $p \neq B \frac{(4-\pi)}{2}$ since $\mathcal{E}\{X\} \neq 0$.

3- Uniformly-Distributed Model

A random variable X is said to have uniform distribution on $[a,b]$ if its pdf is given by:

$$p(x) = \frac{1}{b-a}; -\infty < a < b < \infty \quad (2.3)$$

The mean and variance of this distribution are given by:

$$\mu = \mathcal{E}\{X\} = \frac{a+b}{2}; \text{var} = \mathcal{E}\{(X - \mu)^2\} = \frac{(b-a)^2}{12}$$

If the interval is symmetric, i.e., $a = -b$, then:

$$\mathcal{E}\{X\} = 0; \text{var} = \text{power} = \frac{b^2}{3}.$$

A uniform random variable r on a symmetric interval $[-b,b]$ can be generated using a standard uniformly distributed random variable u as follows:

$$r = -b + 2b \cdot u$$

Any standard generator of uniform random variables on $[0,1]$ can be used to simulate u , like the function `rand` on MATLAB.

4- Impulsive Noise

Impulsive noise is mostly encountered power line communication (PLC) system, it can be modelled as [3]:

$$i_k = b_k \cdot g_k \quad (2.4)$$

Where b_k is Poisson process that is modeling the arrival time of impulsive noise at instant k with parameter λ which denote the rate of unit per second.

A random variable X is said to be Poisson if its pdf is given by:

$$P(X = x) = e^{-\lambda} \frac{\lambda^x}{x!}; \quad x = 0, 1, 2, \dots$$

$$\mathcal{E}\{X\} = \lambda; \quad \text{var}(X) = \lambda.$$

Where $P(X = x)$ is the probability of event of x arrivals in unit time, thereby when X represents the time count of arrival of impulsive noise, then it distributed with above Poisson PDF.

g_k is Gaussian process that is used to model the amplitude of impulsive noise with zero mean and variance (power) σ^2 , so the total power of impulsive noise is [3]:

$$n_p = \frac{\sigma^2}{\lambda} \tag{2.5}$$

2.2 Related Works

The noise reduction based a new fuzzy filter for images under additive noise was presented [26]. In this work there are two stage based filter, fuzzy derivatives for 8 directions are calculated then these derivatives was used in the second stage in order to achieve image smoothing depending on 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 [27]. 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 [28]. Neigh-shrink denoising method with suitable threshold was

proposed in this research. As a result this method was better than other method based on traditional Neigh-shrink denoising in term of PSNR.

A new denoising method based on a combined Bayes Shrink Wavelet-Ridgelet denoising was investigated by [29]. 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 basef denoising method under Gaussian noise depending on wavelet coefficients of the image, are proposed by [30]. 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 [31] depending on powerful advantage of wavelet transform (WT) in denoising image processing. Simulation results show good performance in case of proposed methods as compare with WT in term of less MSE.

Chapter Three

Design and Implementation

Our proposed method based on image segmentation and filtering with the aim of achieve high PSNR and less MSE. There are many algorithms based image segmentation, “normalized-cut”-segmentation-using-color-and-texture-information method has been used with Gaussian filter with the aim to remove image noise in proposed technique of this research.

3.1 Normalized-cut-segmentation

This method is used for segmenting image based on using color (RGB color), texture (mean, variance, skewness and kurtosis) and spatial data[32]. This algorithm six parameters: Color similarity, Texture similarity, Spatial similarity, Spatial threshold, The smallest Ncut value, and The smallest size of area. This parameters are defined as[32]:

Color similarity is denoted by (SI)

Texture similarity is denoted by (ST)

Spatial similarity is denoted by (SX)

Spatial threshold is denoted by (r): less than r pixels apart

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.

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)[33]:

$$cut(A, B) = \sum_{u \in A, v \in B} w(u, v) \quad (3.1)$$

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 :

$$N \text{ cut}(A, B) = \frac{\text{cut}(A, B)}{\text{assoc}(A, V)} + \frac{\text{cut}(A, B)}{\text{assoc}(B, V)} \quad (3.2)$$

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

3.2 Image Filtering

3.2.1 linear filter

For special type of noise such as Gaussian noise linear noise has been used.

Averaging or Gaussian filters 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[34].

3.2.2 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[35].

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[36].

3.3 Proposed Algorithm

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.

Below algorithm illustrate the proposal noise removal technique based on segmentation:

Input: noisy image

Output: free noise image

Step1: read image

Step2: add Gaussian noise to image

Step3: preprocessing steps

1- Find size of image $s \leftarrow \text{size}(\text{image})$

2- Convert 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: extract each segment and filtering it with suitable noise removal filter

Step7: reconstruct and collect the segments

Figure (3.1) shows the general flowchart of our work

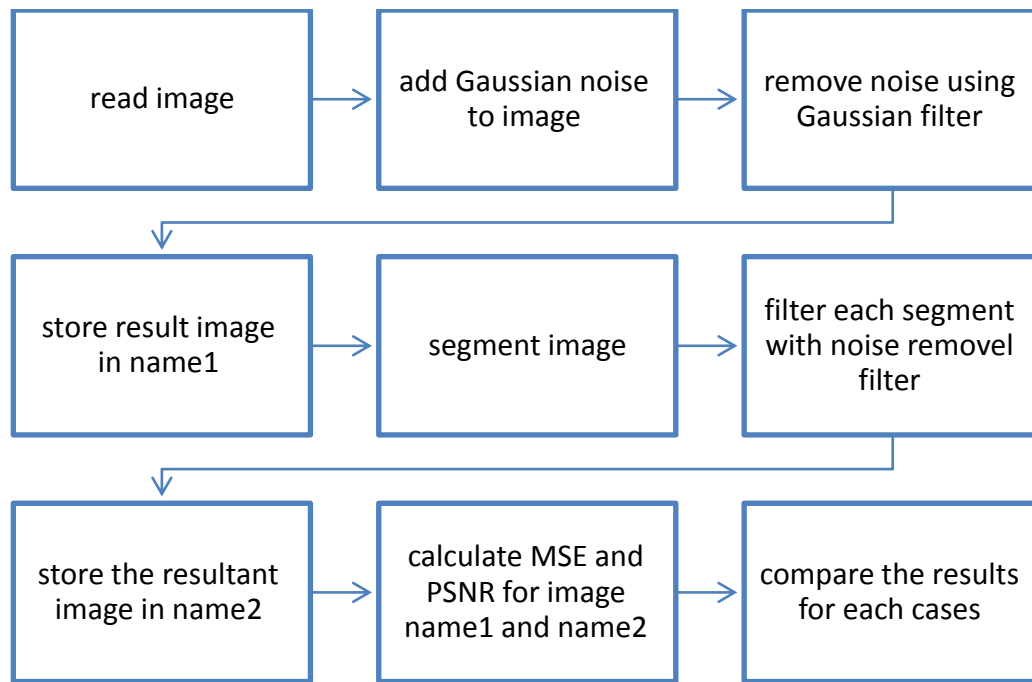


Figure (3.1): shows the proposal noise removal technique based on segmentation

Chapter Four

Results and Discussions

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

1- Simulation for segmentation using “normalized-cut”-segmentation-using-color-and-texture-information

Figures (4.1) and (4.2) show the resultant image after segmentation .



Fig.(1): first resultant segmented image

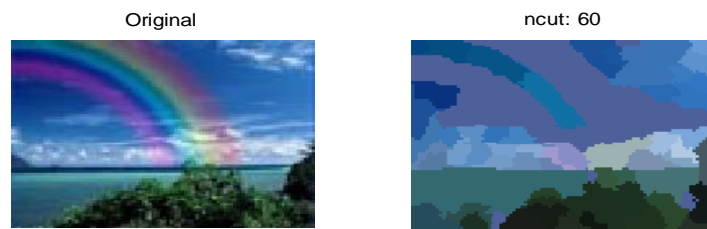


Fig.(2): second resultant segmented image

2- Simulation of noisy image and remove noise using proposed and traditional algorithm using Gaussian filter with 0.05 variance and window([2,2]).

Figures (4.3) and (4.4) show the resultant image after noise removal for image1 and image2 respectively.

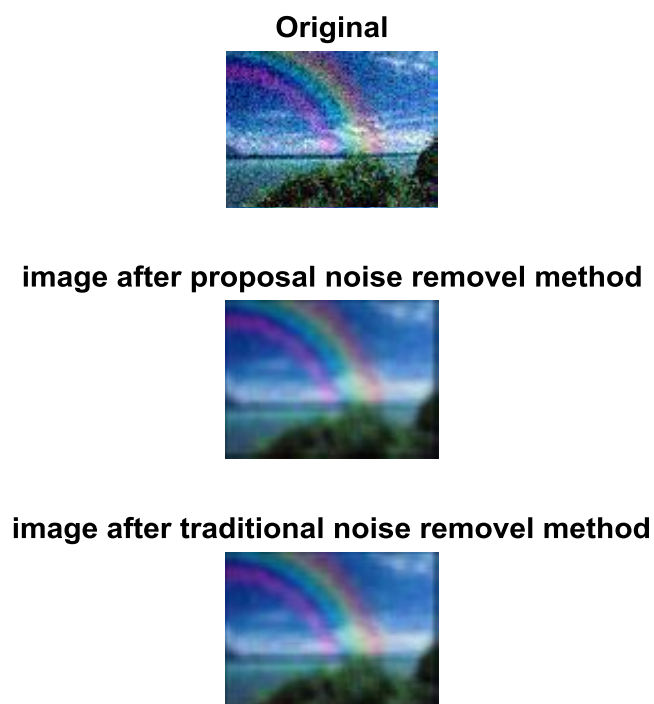


Fig.(3): show the second image after two noise removal image

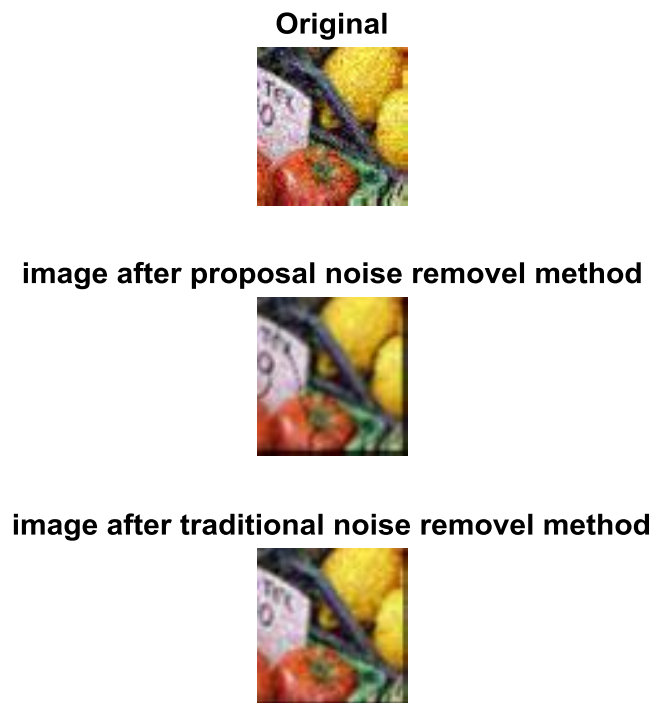


Fig.(4): show the first image after two noise removal image

It is clear from figures (3) and (4) that the resultant image using proposal method is enhance than traditional method for two testing image.

3- Mean square error (MSE) and peak SNR (PSNR) for two images above .

Table (1): MSE and PSNR for first image with two noise removal methods

method	MSE			PSNR		
	Red band	Green band	Blue band	Red band	Green band	Blue band
proposal	23.7275	18.2304	16.2564	48.4684	50.0449	50.4775
traditional	25.5830	21.0969	20.0026	48.1414	49.4107	49.5769

Table (2): MSE and PSNR for second image with two noise removal methods

method	MSE			PSNR		
	Red band	Green band	Blue band	Red band	Green band	Blue band
proposal	22.5470	22.5683	23.6400	46	46	45.5147
traditional	25.3021	25.6167	26.3495	45.4709	45.4138	45.0435

As it shown in table (1) and (2) there is difference in MSE about 3 units where the MSE is less and PSNR is high using proposal method especially for first image which has more details. So proposal segmentation based noise removal method has superior performance as compared to the traditional method.

Chapter Five

Conclusions and Suggestions

5.1 Conclusions

Noise has been defined as random signal cause impairment of color intensity of image, there are many types of noise. Mean and median filter were the most common low pass filters using as noise removal filters. Noise should be remove from image before any process of information extraction from image to avoid damage effect of noise on image. This research aims to produce new proposal noise removal method based on segmentation. A comparative study is presented on the performance analysis of traditional filters based noise removal and our proposal method in terms of MSE and PSNR. The best method is the one that gives less MSE. Numerical results showed that there is about (3 units) MSE difference between our proposed method and other traditional method so the proposal method in this research is the best since it gives less MSE and high PSNR.

5.2 Suggestions for Further Studies

- 1- Using wavelet and DCT transform as noise removal filter
- 2- Produce comparative study for the best filter and method of noise removal with the same idea of our proposal method in this research in the terms of MSE and PSNR.
- 3- Produce comparative study for the best image segmentation method with the same idea of our proposal method in this research in the terms of MSE and PSNR.
- 4- Using the idea of proposal method in image compression.

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تحليل أداء تقنية إزالة الضوضاء القائمة على التجزئة

بدر

مقدمة الى مجلس كلية علوم الحاسوب وتكنولوجيا المعلومات في جامعة
القادسية كجزء من متطلبات درجة البكالوريوس في علوم الحاسوب

من قبل

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