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Application of Different Filters for Noise Removal in Digital Images

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***Abstract*—Digital Image Processing (DIP) alludes to the processing of digital images by utilizing digital PC. In the process of transmission, the noise will get added to the image which can be removed by suitable filters. Since image quality determines the accuracy of the result, noise reduction is important. The work enforces on reducing the noise using different filters with different noises being applied on common digital images. The subjective and additionally quantitative examination of channel exhibitions on the distinctive commotions is finished. For the quantitative investigation, the parameters utilized are MSE, PSNR, CoC and MAE. For quality analysis, resultant images are used using the MATLAB 14b is used for simulation.**

***Index Terms*— PSNR, MSE, CoC, MAE, Filters, Noise, Harmonic mean, Heron mean, Centroidal mean, Contra and Inverse Contra Harmonic mean filters.**

I. INTRODUCTION

Most of the images are affected by some form of noise. The disturbance in the image intensity may be created in any unacceptable image. Filtering the noise in images may inherently be required for visual interpretation and is also used as a prerequisite for further digital processing. The important image processing task is “Image de-noising”. There are many de-noising methods in the literature. One of the image de-noising properties is “complete removal of noise and preserve edges”. The linear and non-linear are the two types of models found in literature. Several noises are introduced in the experiments. Bhateja et al.[10] removes *Speckle noise* present within ultrasound images (US) which was a genuine limitation prompting false helpful basic leadership in PC supported finding.

In the fourth century A.D, the notable means are introduced by Pappus of Alexandria in his book which is the main contribution of the ancient Greeks. In Pythagorean School, on the premise of extent, ten Greek means

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are characterized out of which 6 are named and 4 are un-named of which "Arithmetic mean = $A(a,b) = \frac{a+b}{2}$, Geometric mean= $G(a,b) = \sqrt{ab}$, Harmonic mean= $H(a,b) = \frac{2ab}{a+b}$ and Contra harmonic mean $C(a,b) = \frac{a^2+b^2}{a+b}$" have their own importance in literature [1-6].

The Heron mean $= H_e(a,b) = \frac{a+\sqrt{ab}+b}{3}$, and the α- Centroidal mean $= CT(a,b;\alpha) = \alpha H(a,b) + (1-\alpha)C(a,b)$ related results were found in [4-6]

We recall some of the basic definitions essential for this paper.

Definition 1: [3] A mean is characterized as, "A function $M: R^2 \to R^+$ which has the property $a \wedge b \leq \mathrm{M}(a,b) \leq a \vee b, \forall a,b \geq 0$, where $a \wedge b = \min(a,b)$ and $a \vee b = \max(a,b)$".

Definition 2: In [3], "A function $f: I \subseteq R \to R$ is said to be convex if $f(\lambda x + (1-\lambda)y) \leq \lambda f(x) + (1-\lambda)f(y)$, $\forall x,y \in I$ and $\lambda \in [0,1]$". For example, Heron mean $H_e(a,b) = \frac{2}{3}(AM) + \frac{1}{3}(GM)$.

Definition 3: In [3], "A mean N is called complementary into M with respect to P is called P-complementary to M if it verifies $(M,N) = P$ ". The G complementary mean is called inverse. The inverse of the contra harmonic mean is denoted and given by $C^{(G)} = \frac{ab(a+b)}{a^2+b^2}$. This motivates to design and analyze different filters for noise reduction.

II. Steps for Image Denoising

The flow chart in figure (1), gives the steps followed in image de-noising process.

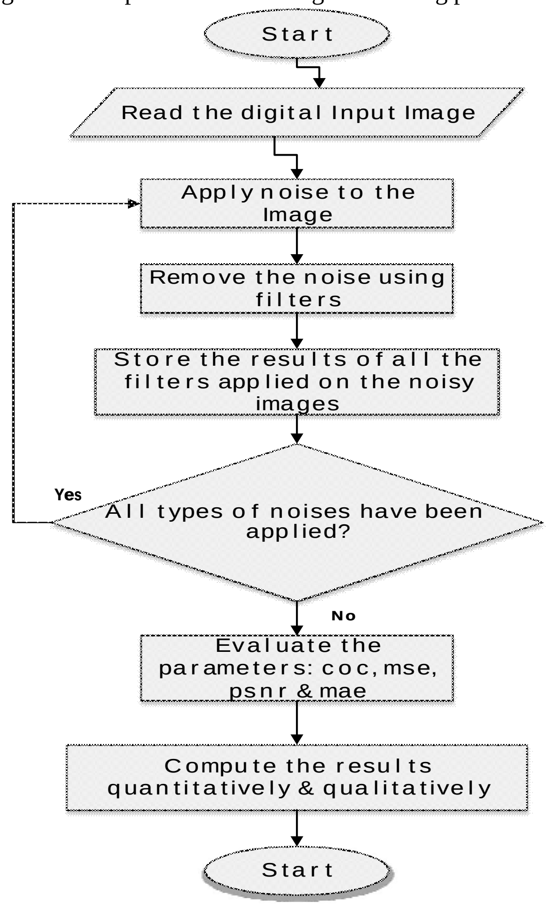

Figure 1: Flow chart showing the steps for image de-noising

III. Image Noise

It is an undesirable outcome of image capture, which gives the shading data in pictures, delivered by the sensor, scanner hardware or computerized camera. The different types of noises are as follows:

A. Amplifier noise (Gaussian noise)

It is additive, independent in each pixel and its signal intensity.

B. Poisson noise (Shot noise)

It is one of the sorts of electronic noise which is due to discrete particles of electric charge.

C. Speckle noise

It is a granular noise characteristically show in advanced images, which corrupts the nature of images. It can be communicated as " J = I + n*I ", where *J* is the spot clamour circulation images, *I* is the input picture and *n* is the uniform noise images.

D. Salt-and-pepper noise

The salt-and-pepper noise images will have "dark pixels in bright regions and bright pixels in dark regions". It is caused by dead pixels, ADC errors, transmission bit errors, etc. It can be removed by using dark frame subtraction.

IV. Various Kinds of Filters

This section provides the discussions of noise reduction by different types of filters [9] taken for this work.

A. Filter of Contra harmonic Mean

The Contra harmonic Mean filter is given by the function, "$\hat{f}(x,y) = \frac{\sum_{(s,t)\in s_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in s_{xy}} g(s,t)^{Q}}$ is the filter for the" [9].

where Q is Order of the filter

Q = 0 for Arithmetic mean filter

Q= -1 for Harmonic mean filter

The salt noise is reduced by the negative values of Q and the pepper noise is reduced by the positive values for Q.

B. Filter of Harmonic mean

The Harmonic mean filter [9] is given by the function, " $\hat{f}(x,y) = \frac{mn}{\sum_{(s,t)\in s_{xy}} \frac{1}{g(s,t)}}$ "

C. Filter of Centroidal mean

The Centroidal mean filter is given by the function, "$\hat{f}(x,y) = \frac{mn}{\sum_{(s,t)\in s_{xy}} \frac{1}{g(s,t)}} + \frac{\sum_{(s,t)\in s_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in s_{xy}} g(s,t)^{Q}}$".

D. Filter of Heron mean

The Heron mean filter is given by the function, " $(x,y) = \frac{1}{mn} \sum_{(s,t)\in s_{xy}} g(s,t) + \left(\prod_{(s,t)\in s_{xy}} g(s,t)\right)^{\frac{1}{mn}}$ ".

E. Inverse Contra harmonic Mean Filter

The Inverse Contra harmonic Mean Filter is given by the function, "$f(x,y) = \left(\prod_{(s,t)\in s_{xy}} g(s,t)\right)^{\frac{1}{mn}} * \left(\frac{\sum_{(s,t)\in s_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in s_{xy}} g(s,t)^{Q}}\right)$ ".

V. Parametric Description

A. Correlation Coefficient

The Relationship Coefficient is a factual measure used to conceive the progressions to the estimation of one variable when estimation of another variable is changed.

The term "r" is utilized to quantify the heading and quality of a linear relationship including two factors. "r" can be ascertained utilizing the equation $r = \frac{\sum x_i y_i}{\sqrt{\sum x_i^2 \sum y_i^2}}$.

Where $x_i = X_i - mean(X_i)$ and $y_i = Y_i - mean(Y_i)$

The images X and Y are to be investigated.

The estimate of 'r' lies between -1 and 1. The '+'sign indicate the positive correlation and '-'sign indicates the negative correlation. In positive correlation, the value of both *a* and *b* increase. In negative correlation value of *a* increases and the value of *b* decreases, In non correlation, there is a nonlinear relationship between *a* and *b*. Correlation relies upon SNR of the images.

B. MSE

It is the average of squares of the errors, the distinction between the estimator and really what is evaluated. It is due to randomness. The expression of MSE is given by $MSE = \frac{1}{xy} \sum_{a=0}^{x-1} \sum_{b=0}^{y-1} [I(a,b) - J(a,b)]^2$.

Where I(x, y) = noise free image and J(x, y) = noisy approximation

C. PSNR

An important parameter which justifies the image quality is "Peak Signal to Noise Ratio". It is measured between most extreme achievable power of a signal and corrupting noise's power which influences its portrayal. The reconstituted image quality is said to be good when PSNR is high. The expression for PSNR is given by the equation $PSNR = 10 \log_{10} \frac{R^2}{\sqrt{MSE}}$ (dB).

Where R = Maximum value of pixel present in an image

MSE = Mean Square Error between original and de-noised image with M*N size.

D. MAE

Mean Absolute Error measures how far predicted values are away from observed values. It is given by the expression $MAE = \frac{1}{N} \sum_{I=1}^{N} \left| x_{prod} - x_{obs} \right|$.

Where $\sum_{I=1}^{N} \left| x_{prod} - x_{obs} \right|$ = summation of absolute value of the residual and N = Number of observations.

VI. Simulation Results

The objectives of the studies are

- To measure the performance of different filters on various noise types and images.
- Suitable filters for reduction of different noise types are to be identified.
- To study the role of various image parameters.

The noises, Gaussian[12], Poisson, Speckle and Salt and Pepper noise are used for corrupting the images and these four kinds of noise are removed by five types of filters namely Centroidal mean filter, Contra-Harmonic mean Filter, Inverse Contra-Harmonic mean Filter, Harmonic mean Filter and Heron mean Filter.

The steps followed in this procedure are given in the figure 1. The Original Image is cameraman image, including four sorts of noise (Poisson noise, Gaussian noise, Speckle noise and Salt and Pepper noise). Including the noise and De-noising it utilizing Centroidal mean filter, Contra-Harmonic mean filter, Inverse Contra-Harmonic mean filter, Harmonic mean filter and Heron filter and comparing the performance values such as PSNR, MSE, CoC, MAE [10] among them. The figure 2 shows the application of Centroidal mean filter to different noises with order of the filter Q = +2 and Q = -2. The figure 3 shows the application of Contra Harmonic mean filter (Q = + 2 and Q = -2), Harmonic mean filter, Heron filter, Inverse Contra Harmonic mean filter (Q = + 2 and Q = -2) respectively.

The Quantitative analysis of the denoised images is performed by measuring various image parameters like PSNR, MSE, CoC and MAE. The parameter values PSNR, MSE, CoC and MAE for Centroidal mean filter, Contra harmonic mean filter, Inverse Contra harmonic mean filter for different noises given the order of the

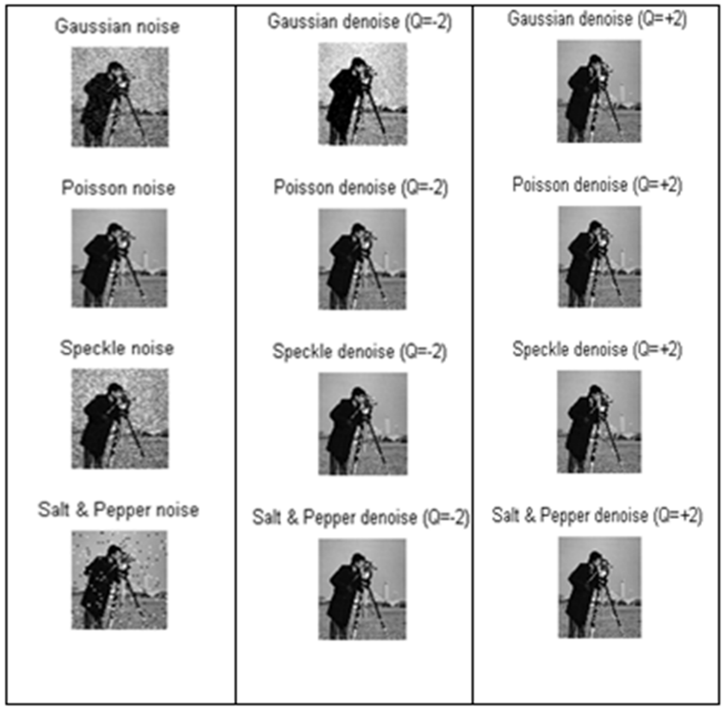

Figure 2: Application of Centroidal mean filter to different noises with order of the filter Q = +2 and Q = -2

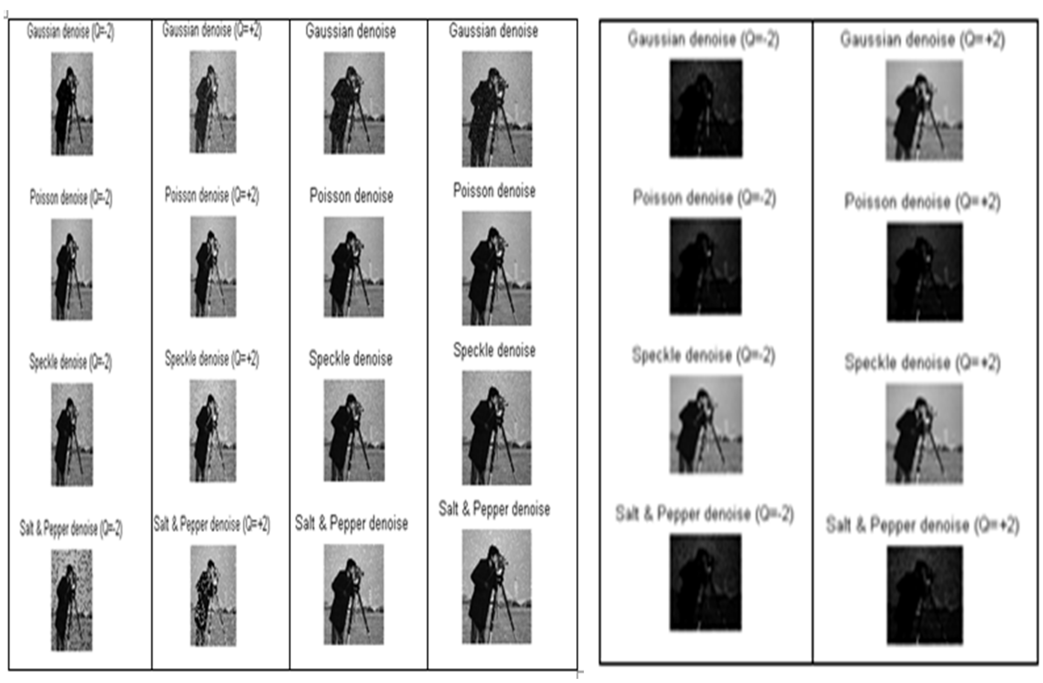

Figure 3: Application of Contra Harmonic mean filter (Q =+2 and Q = -2), Harmonic mean filter, Heron filter and Inverse Contra Harmonic mean filter respectively to different noises

filter Q = -1 and Q = +1 are listed in the Table-1and Table-2 respectively. The parameter values PSNR, MSE, CoC and MAE using Harmonic mean filter, Heron mean filter for different noises are listed in the Table – 3

TABLE I: PSNR, MSE, COC AND MAE FOR CENTROIDAL MEAN FILTER WITH RESPECT TO FOUR DIFFERENT NOISES IN THE DIGITAL IMAGE (CAMERAMAN.TIF)

Type of Noise	PSNR	MSE	CoC	MAE
Gaussian Noise	10.3730 (Q=-ve)	0.0262 (Q= -ve)	0.8938	0.1267
	14.9115 (Q= +ve)	0.0092 (Q= +ve)	0.9276	0.0759
Poisson Noise	21.5744 (Q=-ve)	0.0019 (Q= -ve)	0.9841	0.0326
	21.5356 (Q= +ve)	0.0020 (Q= +ve)	0.9840	0.0327
Speckle Noise	12.7064 (Q=-ve)	0.0154 (Q= -ve)	0.8829	0.0252
	12.7121 (Q= +ve)	0.0154 (Q=+ve)	0.8830	0.0252
Salt and Pepper Noise	14.1724 (Q=-ve)	0.0110 (Q= -ve)	0.9188	0.0803
	14.1306 (Q=+ve)	0.0111 (Q= +ve)	0.9180	0.0805

TABLE II. PSNR, MSE, COC AND MAE FOR CONTRA HARMONIC AND INVERSE CONTRA HARMONIC MEAN FILTERS WITH RESPECT TO FOUR DIFFERENT NOISES IN THE DIGITAL IMAGE

Type of Noise	Contra-Harmonic mean filter				Inverse Contra-Harmonic mean filter			
	PSNR	MSE	CoC	MAE	PSNR	MSE	CoC	MAE
Gaussian Noise	12.2916 (Q= -ve)	0.0169 (Q=-ve)	0.8931	0.0862	14.1537 (Q= -ve)	0.0110 (Q= -ve)	0.9193	0.0801
	12.5257 (Q= +ve)	0.0160 (Q=+ve)	0.8841	0.0872	14.1537 (Q= +ve)	0.0110 (Q=+ve)	0.9193	0.0801
Poisson Noise	15.0585 (Q= -ve)	0.0087 (Q=-ve)	0.9340	0.0483	1.5111 (Q= -ve)	0.1964 (Q= -ve)	0.7342	0.3962
	15.2899 (Q= +ve)	0.0082 (Q= +ve)	0.9334	0.0483	1.5593 (Q= +ve)	0.1942 (Q=+ve)	0.7392	0.3942
Speckle Noise	12.3198 (Q= -ve)	0.0168 (Q= -ve)	0.8875	0.0849	15.4829 (Q=-ve)	0.2038 (Q=-ve)	0.6909	0.4005
	12.3911 (Q= +ve)	0.0166 (Q= +ve)	0.8889	0.0861	15.0040 (Q=+ve)	0.0091 (Q=+ve)	0.9285	0.0755
Salt and Pepper Noise	9.07054 (Q= -ve)	0.0357 (Q=-ve)	0.7775	0.0742	1.4198 (Q= -ve)	0.2079 (Q= -ve)	0.6685	0.4001
	9.4230 (Q= +ve)	0.0329 (Q=+ve)	0.7713	0.0708	1.4829 (Q= +ve)	0.2049 (Q=+ve)	0.6709	0.3972

TABLE III. PSNR, MSE, COC AND MAE FOR HARMONIC AND HERON MEAN FILTER WITH RESPECT TO THE VARIOUS NOISES IN THE DIGITAL IMAGE

Type of Noise	Harmonic mean filter				Heron mean filter			
	PSNR	MSE	CoC	MAE	PSNR	MSE	CoC	MAE
Gaussian Noise	12.8889	0.0147	0.8848	0.0895	12.3944	0.0165	0.9199	0.1005
Poisson Noise	16.1653	0.0067	0.9471	0.0478	14.1024	0.0108	0.9613	0.0805
Speckle Noise	12.7034	0.0154	0.8915	0.0877	12.0720	0.0178	0.9151	0.0962
Salt and Pepper Noise	11.1069	0.0223	0.8337	0.0615	11.2617	0.0215	0.8876	0.1017

VII. CONCLUSION

Noises such as (Poisson, Salt and Pepper, & Gaussian) were introduced to the image used in this paper. The quantitative examination of the parameters utilized for the assessment of the images is CoC, MSE, PSNR, and MAE. The quality of resultant images is also analysed. Simulation experiments with various noises are performed using MATLAB tool.

Centriodal mean filters work very well for removal of “Salt and pepper noise”. An inverse Contra Harmonic mean filter works very well for removal of Speckle noise. The Contra Harmonic, Harmonic and Heron mean filters work very well for removal of Poisson noise.

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