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Analytical Comparison Of Image Imperfections And Image Filtering Model In The Context Of Guassian And Non-Guassian Noise Approach

Nishant Tripathi and Utkarsh Pandey

Department of Electronics & Communication Engineering

PSIT College of Engineering Kanpur

E-mail: findnm@gmail.com utkarsh.pandey08@gmail.com

ABSTRACT

This paper addresses to collect different types of noises and imperfections within a digital image, scanned image, aerial image, and satellite image. This paper will also include different types of filtering and algorithmic techniques to remove those noise and imperfections from the images. There would be a comparative study between all types of imperfection or noises and PSNR associated with them. The second section of the paper would contain the comparative analogy between different imperfection filtering or noise removing schemes/algorithms from the image.

Keywords: *Image, PSNR, De-Noising, Imperfection, filtering*

1. INTRODUCTION

I. Details of Different types of Noise/Imperfection Model present in a digital Imaging system

1. **Uniform noise**: It is quantization noise caused by quantizing the pixels of images to a distinct number of levels having almost uniform distributions. Uniform noise can be utilized to provide many different varieties of noise distribution. It provides essentially the most predictive neutral and unbiased imperfection within a digital image.[1],[2],[3]

2. **Gaussian Noise (Amplifier Noise)** : the imperfection or the noise with the probability distribution function of normal/Gaussian distribution providing a huge portion in reading imperfection with an image sensor having a constant noise level in the darkish section of any image. Since the Gaussian noise is evenly distributed over the entire signal and the explanation for each pixel in the imperfect image is the total of true value of pixel and random normal distribution of noise over the whole image spectrum.[3],[5],[6]

3. **Salt and pepper noise (Imperfection)**: The most impulsive type of imperfection present within an image. This type of noise or imperfection is due to the sudden changes of any part of digital signal during the transmission phase causing spikes or sharp changes in the amplitudes of the signal levels. [2],[5],[8].A number of components having faults that causes heat or the dust particles in the image acquisition phase may also cause this kind of imperfection or noise. Salt pepper noise have two distinct levels of values x and y with the probability for each is precisely less than or equal to 0.1 and if the level is crossed then the noise will be swamping out the whole digital image. The typical 8-bit or 16 bit image will be having a imperfection levels of salt noise is in order of 2^8 and 2^{16} and that for pepper noise is 0.

4. **Gamma Noise**: Gamma noise is normally visualised in the Laser system based images or signals. This particular imperfection exhibits gamma distribution function. [9],[10]

$$X(n) = \frac{p^a q^{b-1} r^{-pq}}{(b-1)!} \quad for\ q \geq 0$$
$$X(n) = 0 \quad for\ q < 0$$

where mean = b/a and Variance = b/a^2

5. **Rayleigh Noise** : Rayleigh Noise represents the imperfection in the RADAR range images [10]

$$X(n) = \frac{2}{b}(n-a)e^{\frac{-(n-a)^2}{b}} \quad for\ n \geq a$$
$$X(n) = 0 \quad for\ n < a$$

where mean = a + √πa/4 and
Variance = b(4-π)/4

6. **Photon Noise**: This is also termed as Poisson Noise. This type of noise exhibit Poisson distribution function and arises in a digital image or signal due to the variation in the photonic movement per unit time within the statistical nature of electromagnetic waves such as x-rays, visible lights and gamma rays predominately when these rays are injected in the body of the patient from the source in medical x-rays and gamma rays imaging systems. Normally all these sources have random fluctuations of photonic movements providing a spatial and temporal randomness in the resultant image which is also said to be quantum or shot noise.[10],[11],[12]

7. **Brownian Noise**: it is also called as Fractal imperfection or pink noise and even some time also called as 1/f noise. In the fractal imperfection, the PSD is proportional to the square of the frequency over an octave i.e., its power falls on quarter the part

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of overall spectrum of the signals/image.[10],[12] Brownian motion is visualised due to the random motion of the suspended particles within the fluid and it can also be originated by the white noise. But in general characteristics this kind of image imperfection have non stationary stochastic process and have normal distribution. The mathematical equation provides Fractal noise almost singular everywhere.

$$X_H (0) = 0$$

and the expected value is

$$E \{|X_H (t) - X_H (t-d)|^2\} = \alpha^2|d|^{2H}$$

8. **Periodic Noise**: The noise or the imperfection generated typically due to the electronic interferences during the analysis of image acquisitions of the power signals having the noise with the prominent characteristics such as spatially dependency with the sinusoidal natures of tuples of the critical frequency. [12], [13], [14] This type of noise is filtered out by using notch filter with sharp cut offs.

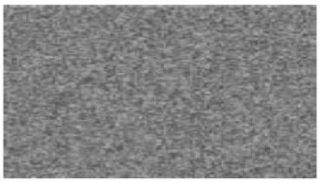
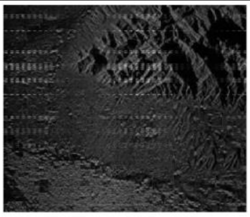
9. **Quantization Noise**: The noise that is present in any kind of analog to digital conversion process as an inherent part in the amplitude quantization process. In this imperfection model, the SNR is limited by minimum and maximum pixel value:

$$SNR_{db} = 20 \log_{10} (A_{max} - A_{min})/\sigma_n$$

σ_n = standard deviation of noise

$$SNR = 6n + 1.76 \text{ Db}$$

10. **Speckle Noise** seen in the coherent imaging system which is LASER, RADAR and acoustic systems. Speckle noise has similar existence as of Gaussian imperfections within an image and has similar PDF as of gamma distribution.[1],[2],[15],[16]

S.No	Types of Noise Model	PDF Sketch Noisy Sketches PDF Equation	Characteristics statements/Remarks
1	**Speckle Noise**	 $F(g) = \frac{g^{\alpha-1} e^{\frac{-g}{a}}}{\alpha-1! a^{\alpha}}$	• Occurs in almost all coherent imaging • Introduced in channel • Removal is tough • Heavily damage the PSNR
2	**Structured Noise**	 Structured Noise (when noise is periodic and non stationary) $Y_{(n)} = x_{(n,m)} + v_{(n)}$ $Y_{(n)} = H_{(n.m)} * \theta_{(m)} + s_{(n,t)} * \phi_{(t)} + v_{(n)}$	• Full rank measurement space in physical system • Low rank noise • Removal requires lots of computational steps • Introduces lining due to noise • PSNR is moderately disturbed

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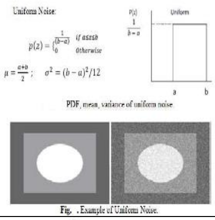
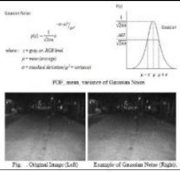
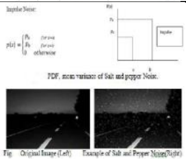
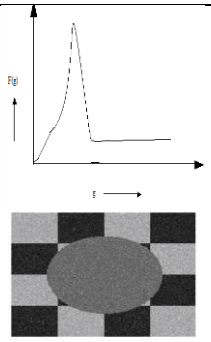
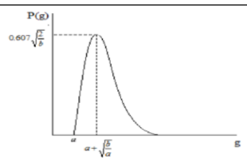
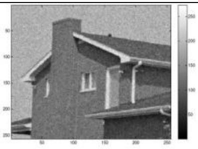
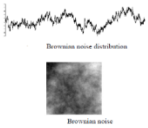
S.No	Types of Noise Model	PDF Sketch Noisy Sketches PDF Equation	Characteristics statements/Remarks
3	**Uniform Noise/Imperfection Model**		• Guassian approach • Predictive noise model • Uniform PDF • Removal is easier • Reduces intensity and sharpness of image edges
4	**Guassian Noise**		• Noise is spread all over the image • Bell shape of PDF • Removal is easy • Corruption of image is definite
5	**Salt and Pepper Noise**		• Produced due to imperfect camera sensor • Improper pixel elements • Faulty location • Generated in transmission channel • Indefinite noise
6	**Gamma Noise**		• Specific to LASER/MASER • Second order disturbance • Non regular inclusion • Removal is easier than other noise formats • Introduces mainly in pure electronic microwave transmitters
7	**Rayleigh Noise**		• Non-Guassian Noise Removal is tough • Second order disturbance • Computational cost is high Computational process is complex • Introduced in channel
8	**Photon Noise**	 $P(f_{(pi)}=k) = \frac{\lambda_i^k e^{-\lambda}}{k!}$	• Source noise, PSNR is heavily disturbed • Spatial and temporal randomness, Mainly in biomedical instruments • Removal require lots of computational steps
9	**Brownian Noise**		• Non stationary stochastic • Non Guassian model • Removal is tough • Pixels are heavily distorted

Table 1 : Types of Noises with PDF/Equation and characteristics

II. Noise removing models associated with the Image Acquisition and de-noising techniques

(a) **Mean filtering process**: In this scheme, a sliding window spatial filter is used to substitute central pixel value of the window with the total values obtained as an average within the window. The effective size of the given sample window provides level of contrast of the image and depending upon the incremental size of the window the blurriness also increases of the image.[18],[19]

(b) **Median Filtering scheme**: Normally termed as non linear sliding window spatial filter that can change the centre of the pixel by the median. A technique used more widely to preserve the image edges while removing the noises or imperfection from the image. [18],[19]

(c) **Wiener filtering scheme**: A linear adaptive filtering scheme that calculate the local variance of the image for the smoothening of the image.

(d) **Non local means of filtering scheme**: this particular model takes an assumption that the redundant pixels can be utilised to extract the noise out of the image. Several notions of the pixels within the adjacent community of the pixels can be used to provide the de-noised pixel contents. This model substitutes a given pixel by the average of the adjacent communities in the sample image and can be utilised as a most suitable de-noising model for natural images. [20],[21]

(e) **Tikhnov model scheme of filtering**: In this model the overall fluctuation of the image can be diminished by total variation denoising. This method is utilised if the components of the given sample image are extremely distorted. In this approach the filtered model of image outcome have sharp edges and lower proportions of noise.[20],[21]

(f) **ROF Model of filtering scheme**: This model is quite similar to the previous given model with a moderate change in the regularization which has been modified to the total variation from quadratic form.[20]

(g) **Histogram equalization scheme**: A common technique to improve the visibility of appearance of the images. A histogram can skew towards the lower end of the grey scale and all the image parameters is compressed into the dark end of histogram.[2],[3],[18],[21]

(h) **Wavelet transform domain scheme**: This model allows the multi resolution analysis by retrieving the frequency and time constant of the given sample signal. These methods is decomposed into two steps as fragment corrupted image by noise using wavelet transform and then follow it up by calculating threshold in wavelet domain and apply the same to imperfection coefficient. [1],[2],[18],[20]

(i) **BSS-ICA Scheme**: Recently, blind source separation by Independent Component Analysis (ICA) has received attention because of its potential applications in signal processing such as in speech recognition systems, telecommunications and medical signal processing. The goal of ICA is to recover independent sources given only sensor observations that are unknown linear mixtures of the unobserved independent source signals. In contrast to correlation-based transformations such as Principal Component Analysis (PCA), ICA not only de-correlates the signals (2nd-order statistics) but also reduces higher-order statistical dependencies, attempting to make the signals as independent as possible.[20],[21],[22]processed to identify crucial users for disseminating critical information about these natural disasters. Given that twitter is a real-time, highly distributed, decentralized technology, the work discovered that local and federal agencies could leverage this resource more effectively. Another conclusion suggests social network analysis approaches to find key twitter users through their user-resources network.

S.No	Image de-noising techniques	Approximated PSNR achieved after filtering	Methodology/impacts on noise/edges/blurriness/smoothness
1	**Mean filtering**	In between 65-75%	• Linear method • Reduces Intensity • Increases Smoothening • Reduces Edges impact • Increases Blurriness
2	**Median Filtering**	In between 65-75%	• Non-Linear Method • Edges impact are conserved • Reduces Intensity • Increases Smoothening • Increases Blurriness
3	**Weiner Filtering**	In between 70-80%	• Non Linear Method • Works fine if sample signal is smooth by itself • Implements the spatial smoothening • Less blur outcomes • Intensity is moderate
4	**Wavelet Filtering**	In between 80-87%	• Linear and non-linear both • In Linear, noise is Guassian, the MSE is uniform, and outcome is more blurred than the original noisy image. • Intra scale filtering is allowed
5	**Wavelet coefficient model**	In between 85-90%	• Utilizes multiresolution properties of Wavelet transform • Computationally complex and expensive • It could be deterministic/ statistical • Produces highly resolute outcome
6	**Marginal probabilistic model**	In between 80-90%	• Local probability model for images in wavelet domain • Wavelet coefficient are highly kurtosis having marked peak at zero and heavy tails • GMM and GGD are used to model wavelet coefficient • Lengthy analysis, outcome is moderate • PSNR is 80-85% of original
7	**Joint Probabilistic model**	In between 80-90%	• HMM is Efficient in computing inter scale dependencies • De-noised signal is predicted from imperfect observation using MAP estimator • Each wavelet coefficient is given by GSM • Computational complex process model • Good outcome with high PSNR
8	**Data Adaptive Transforms**	In between 85-92%	• BSS-ICA is used • Successfully de-noised non Guassian data • Easily implemented • high PSNR • Less complex • Computational cost is high due to sliding window modeling

Table: 2 : Noise model PSNR:Comparative Analysis

CONCLUSION

As per going through different noise corrupting the digital image and the types of different noise removing model there is a clear cut visibility that if only Guassian noise is assumed removal of noise is easy, less complex, less costly but the end result may loose the intensity, resolution and will not achieve

good PSNR.
But while going through non Guassian approach we can have better de-noised PSNR after filtering having slight complexity in the implementation of the model zig-zag cost with some model having higher cost and some with moderate cost of implementation. Probabilistic models may have certain limitations in terms of computational complexity but the best of a lot is the modern day data adaptive transform models with less computational complexity and easier algorithmic approach but with slightly higher cost than all of the previous noise filtering models.

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ABOUT THE AUTHORS:

1. **Nishant Tripathi**, M.Tech (2013) in Digital Communication from Rajasthan Technical University having nearly 09 years of teaching experience in

Engineering domain, currently working as an Assistant Professor in ECE department at PSIT College of Engineering Kanpur.

2. **Utkarsh Pandey**, M.Tech from MMMUT, Gorakhpur is an Assistant Professor in the Dept. of Electronics and Communication Engineering at PSIT College of Engineering Kanpur.