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REVIEW ON VARIOUS NOISE MODELS AND IMAGE RESTORATION TECHNIQUES

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ABSTRACT

Image restoration is field of digital image processing that includes techniques used to reconstruct an original image scene from degraded quality images. Blur & noise are two main degradations by which the quality image gets ruined. The goal of this paper is to give overview of image restoration techniques to readers, who is just beginning in this field of image restoration. The task of developing restoration algorithms is quite difficult, since the information should not be destroyed during image restoration. The aim of this article is to let the readers to know various methods of digital image restoration with their pros and cons. Digital image restoration is a very broad field, contains many other approaches that have been developed from different perspectives, such as satellite imaging, optics, astronomy, and medical imaging.

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INTRODUCTION

Real time pictures evidence some amount of degradation depending on the type of camera and settings used to capture the images of scene, external environment, and the relative motion amount between camera and object, are the other factors for degradation. Restoration algorithms are used to nullify undesired distortions like blur or noise from the distorted image. Image restoration techniques tries to reconstruct or recover an image that has been distorted by using a priori knowledge of the degradation principle. Thus, restoration techniques focus on identifying the degradation and applying the inverse model in order to recover a de-noised image. A fundamental method in the filtering theory used commonly for image restoration is the Wiener filter.This method's objective is to restore image as close as possible to the original one. This is, indeed, a method of least squares estimation in which we consider that the images are realizations of a stationary and ergodic random process. The drawback of this method is the need for a prior knowledge of the degradation model, which is nothing but the degradation function of the imaging system, i.e. point spread function (PSF), the blurred image and the statistical properties of the noise process. To restore distorted image and improve Wiener filtering without prior knowledge of the degradation model, several authors propose to estimate the Point Spread Function using the description of the imaging system or ground characters in the acquired images. Then a suitable method is selected to restore the images with the estimated PSF (Lihong Yang *et al.*, 2011; Feng Qing Qin, 2012). Digital image restoration/denoising is being applied in many fields such as, Astronomical Imaging, Medical Imaging, Restoration of aging and deteriorated films, Defense & investigation and printing applications.

The degradation process of an image can be modelled as a matrix vector formulation given by,

$$g(x,y) = k * f(x,y) + \eta$$

Where g(x, y) is the original image & f(x, y) is observed image, both expressed in vector form, K is the blurring/convolution operator represented in matrix form, which is supposed to be known and ɳ is noise vector having distribution independent and identically with mean noise and standard deviation σ. Blur and noise are the two main degradations by which the quality of image gets ruined. Noise such as Gaussian noise, multiplicative noise, Poisson noise and impulse noise affects the image and leads to loss of information. On the other hand various blur models such as atmospheric blur, uniform blur, motion blur and Gaussian blur are also alter the image information. Presence of noise and blur results in original information of image gets disturbed. In field of medical imaging the diagnosis process is merely rely on the information present in image, presence of noise and blur has severe effect and should be eliminated. This gives rise to various denoising and deblurring techniques. In the preceding sections we will discuss about various noise and blur models and their effects on images.

NOISE MODELS

Gaussian noise: It is statistical noise, which has a probability density function (PDF) similar to that of the Normal distribution. It is also known as the Gaussian distribution (Tudor Barbu, 2013). The probability density function P of a Gaussian random variable X is given by:

$$PG(Z) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(Z-\mu)^2}{2\sigma^2}}$$

Where x represents the grey level, μ the mean value of distribution and, σ the standard deviation (Philippe Cattin, 2013). Example of special type of Gaussian noise is white Gaussian noise, in which the values at any instant of times are identically distributed and statistically independent. Major sources of Gaussian noise in digital images arise at the time of acquisition like sensor noise caused by poor lightning condition or high temperature, and transmission e.g. electronic circuit noise (Philippe Cattin, 2013). Spatial filters can be used to reduce the effect of Gaussian noise in digital image processing, though at the time of smoothing an image, an undesirable effect may results in the blurring of image edges and details because these components are belongs to high frequencies which are filtered out during smoothing process.

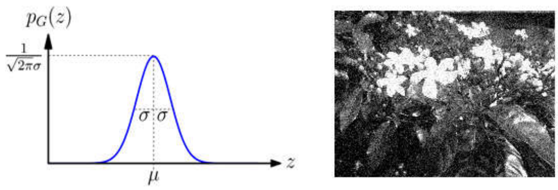

Fig. 1. (a) Gaussian probability density function $PG(z)$ (b) Image with Gaussian Noise

Rayleigh Noise: The Rayleigh distribution is a continuous probability distribution for positive valued random variables. It is often observed when the magnitude of a vector is related to its directional components (Philippe Cattin, 2013).

The PDF of Rayleigh noise is defined by

$$PR(Z) = \frac{2}{b}(Z-a)e^{\frac{-(Z-a)^2}{b}} \qquad \text{For } Z \geq a$$

$$PR(Z) = 0 \qquad \text{Otherwise}$$

The Mean & Variance of distribution is given by

$$\mu = a + \sqrt{\pi b/4}$$
$$\sigma^2 = b(4-\pi)/4$$

The Rayleigh density function is useful for approximating skewed histograms.

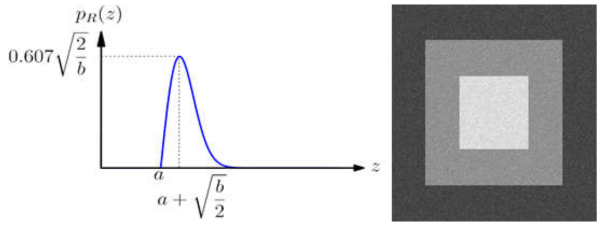

Fig. 2. (a) Rayleigh probability density function $PR(Z)$ (b) Image with Rayleigh Noise

Erlang Noise

The Erlang probability distribution is a two parameter distributions with support $x \in (0, \infty)$.

The two parameters are:

- A positive integer representing 'shape' k.
- A positive real representing 'rate' $\boldsymbol{\lambda}$; sometimes the μ, is use to represent the inverse of the rate.

The Erlang distribution with shape k tends to 1 looks identical to the exponential distribution. It is a special case of the Gamma distribution. It is the distribution of a sum of k independent exponential variables with mean $1/\lambda$ each (Philippe Cattin, 2013).

The PDF of the Erlang noise is given by

$$PE(Z) = \frac{a^b Z^{(b-1)}}{(b-1)!} e^{-aZ} \quad for\ Z \geq 0$$

$$PE(Z) = 0 \quad Otherwise$$

Where, $a > 0, b$ is a positive integer. The mean and variance are then given by

$$\mu = b/a$$

$$\sigma^2 = b/a^2$$

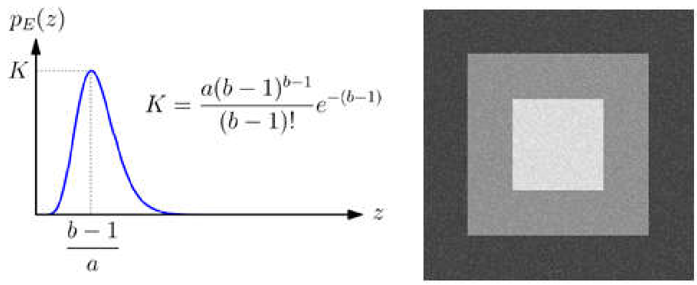

Fig. 3. (a) Erlang probability density function (b) Image with Erlang Noise

Exponential Noise

The exponential distribution is the probability distribution that describes the time relation between events in a Poisson process. It is a particular case of the gamma distribution (Philippe Cattin, 2013).

The PDF of the exponential noise is given by

$Pexp(Z) = ae^{-aZ}\, for\ Z \geq 0$
$Pexp(Z) = 0\ otherwise$

Where $a > 0$. The mean and variance of the density function are

$\mu = {}^{1}/_{a}$
$\sigma^2 = {}^{1}/_{a^2}$

In exponential noise model when b=1 it tends to be Erlang noise model.

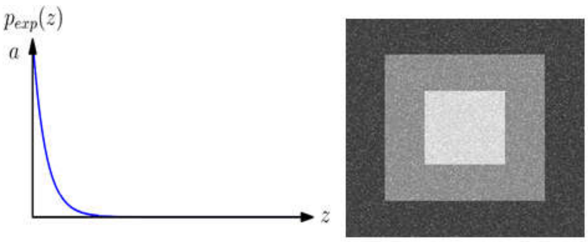

Fig. 4. (a) Probability density function $Pexp(Z)$ of exponential noise. (b) Image with exponential Noise.

Uniform Noise: The noise cause by quantizing the pixels of image to a number of distinct levels is known as quantization noise. It has distribution approximated to uniform distribution. In the uniform noise the noise are uniformly distributed across a specified range (Versha Rani, 2013).

The PDF of the uniform noise is given by:

$PU(Z) = {}^{1}/_{(b-a)}\ for\ a \leq Z \leq b$
$PU(Z) = 0\ for\ Otherwise$

The mean and variance of the density function are given by:

$\mu = {}^{(a+b)}/_{2}$
$\sigma^2 = \frac{(b-a)^2}{12}$

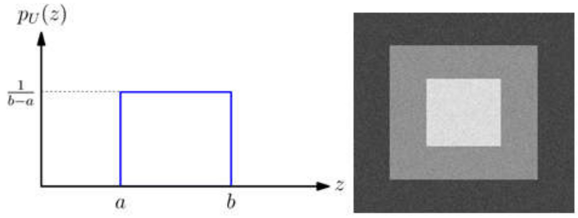

Fig. 5. (a) Probability density function $PU(Z)$ of uniform noise (b) Image with Uniform Noise

Impulse Noise: It is also known as salt & pepper noise. This is caused due to sharp & sudden disturbances in the image gray values. Its appearance is randomly scattered white or Black pixel over the image.

The PDF of bipolar impulse noise model is given by:

$PI(Z) = Pa\ for\ Z = a$
$PI(Z) = Pb\ for\ Z = b$
$PI(Z) = 0\ Otherwise$

If $b > a$, grey-level b appears as a light dot in the image like salt. Conversely, a will appear as dark dot looks like pepper. If either Pa, Pb is zero, the PDF is called unipolar. Because impulse corruption is generally large compared to the signal strength, the assumption is usually that a and b are digitized as saturated values thus black and white.

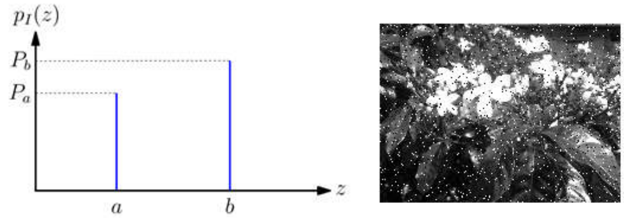

Fig. 6. (a) Probability density function $PI(Z)$ of the bipolar impulse noise model (b) Image with Salt & Pepper Noise

Literature Survey on Restoration Techniques

Chuan he *et al.* (2014) proposed Alternate Direction Method of Multiplier calculation to settle the obliged add up to variation regularization issue in reclamation of obscured pictures. They have isolated issue in triple. To begin with, their essential point is to concentrate on compelled issue and to discover ideal regularization parameter (λ) adaptively without meddling physically. Second, they propose a strategy to take care of compelled issue without internal emphasis called compacter. At long last, the meeting evidence in light of arched investigation is given. The outcome investigation demonstrates that technique requires less calculation cost and takes speedier speed.

Amin Kheradmand *et al.* (2014), proposed technique for picture deblurring in view of bit similitude by presenting novel versatile target work. They additionally exhibit the uncommon instances of the proposed philosophy that can be utilized for denoising and Sharpening of picture. The new cost work for picture rebuilding in light of new meaning of standardized chart Laplacian was proposed by creators. Amine Laghrib *et al.* (2016) in their paper proposed system for expanding robustness of the super determination strategies. They proposed a novel enhanced methodology of SR reproduction indicated at somewhat twisted low determination pictures to evade misregistration mistakes and irritating ancient rarities, for example, obscure, rugged edges, and ringing relics.

Qibin Fan *et al.* (2015) recommended a multi parameter regularization display for picture reclamation in view of aggregate variation and wavelet outline. The contrast between their calculation and different plans is that, the picture under thought is right off the bat part into two sections, then two regularization things implemented on to the staying two sections while their calculation does not have to part the picture, rather than which, add up to variety and framelets are specifically connected all in all picture in Total Variant casing. Numerically, they embrace the option course technique for multiplier to build up a quick and stable calculation and merging investigation is built up.

Primal double part system is proposed by Chuan He *et al*. (2016) to cover both the Primal Dual Splitting technique and the Parallel Linearized Alternating Direction Method of Multipliers. The proposed strategy forces diverse weights onto each direct administrator and a casual stride is connected, technique accomplishes quicker merging. Zouhair Mbarki *et al*. (2016), in their paper proposed two phase calculation. The first step comprises of regularized de-convolution in the Fourier space by the parametric Wiener filter whose reason for existing is to balance to some degree the Point Spread Function and diminish degradation's. The second step comprises in disintegration of coming about picture, which still contains a clamor part, into wave molecule change and recreate it in the wake of setting the edge to the coefficients. Benxin Zhang *et al*. take care of aggregate variation minimization issue by a straightforward primal–dual technique proposed in (2016). In their calculations they utilized a predictor–corrector plan to the double factor. In examination part they demonstrated the joining rate of iterative plan is O (1/N) in the ergodic sense, where N means the quantity of iterations.

Yidan Teng *et al*. (2016), recommended show for recouping Hyperspectral picture from blended commotion corruption in remote sensing. A novel hyper ghastly reclamation framework was produced by them. To save the spatial structure in better way it consolidates the efficient filtering techniques with the versatile SE (ASE) containing the nearby morphological subtle elements. They additionally introduced a technique for ASE era. By proposing the ASE rather than settled veil the execution of most filters will be enhanced, by overlooking unimportant pixels the nearby points of interest can be ensured. Neural system based picture inpainting approach for picture reclamation is proposed by Vahid K. Alilou *et al*. in their paper (2015). By performing relapse examination on the picture information the missing areas of picture are resolved. As per the span of missing areas, locales are isolated and sorted. To repair the harmed pixel the calculation continues with applying a GRNN system to every district. The fundamental promotion vantage of this approach is its straightforwardness and e□ciency.

A visually impaired picture reclamation strategy for the detached millimeter-wave pictures is ace postured by Tingting Liu *et al*. (2016) in their review. The point spread capacity (PSF) and rebuilding picture is all the while settled by utilizing proposed system. In light of suspicion of Gaussian commotion the information fidelity thing is built and as the hyper-Laplace work the regularization thing is developed. The laplacian capacity is fitted as indicated by the high-determination aloof millimeter wave pictures. To choose the locales that are useful for evaluating the exact PSF an information chose framework is professional postured. The determination of PMWW pictures enhanced by this strategy. The box compelled TV regularization issue with programmed regularization parameter estimation was unraveled by Chuan He *et al*. by their proposed strategy in (Chuan, 2014). The case compelled TV regularization issue is disintegrated into a grouping of sub issues by embracing the variable part procedure that are simpler to understand. At that point exchange course strategy is utilized to tackle these sub issues, in which versatile updation of regularization parameter is done outcomes in quicker union. System of close loop rebuilding proposed by Saqib Yousaf *et al*. (2015), in which a successful criticism streamlining is outlined described by its capable capacity to balance out the conduct reaction and conquer outer aggravations. The quality metric in light of obscure evaluation of de-convolved patches is proposed by creators to recognize the best PSF and figuring its relative quality. A block based compressive detecting picture reclamation model is proposed by Nasser Eslahi *et al*. (2016), in light of iterative curvelet thresholding. In this model regularization term and discrete curvelet change is considered as sparsifying change. A versatile curvelet thresholding is utilized to defeat the downside of direct rot thresholding basis, which is non versatile and delicate to commotion. Haibin Duan *et al*. (2016), proposed neurodynamic approach for picture reclamation. They embraced Echo State Network to assess the first picture. Pigeon-motivated advancement system is utilized to get sought parameters the in the preparation procedure of the ESN. Orthogonal outline procedure is utilized to enhance assorted qualities in the initialization of Pigeon Inspired Optimization.

Total Variant based picture reclamation model is examined by Dongwei Ren *et al*. (2015). They built up a novel subordinate space-based reformulation consolidating with an efficient subsidiary substituting bearing technique for multipliers (DADMM) calculation. Initial, an express correspondence limitations on the slopes was presented by them by breaking down the associations of picture space and subordinate space, and the likewise propose a novel subsidiary space based reformulation of TVIR. At that point, exchanging course technique for multipliers is presented by them for taking care of the compelled advancement issue. Khalid Youssef *et al*. (2015), in their article titled "Feature Preserving Noise Removal". In this technique every pixel of a picture is de-noised utilizing nonlinear channel that operates along information piece which comprise of fix neighborhood of pixel and numerous duplicates of a similar picture. In view of multilayer perceptron's (MLP) this nonlinear channel was planned by them, which have been appeared to be all inclusive capacity approximators. The reason for working along patches is to represent conceivable spatial relationships in the irregular field of the picture.

On the premise of low-rank grid recuperation (LRMR) a HIS based picture reclamation strategy proposed by Hongyan Zhang *et al*. in their paper (2014), which can evacuate Gaussian commotion, motivation clamor, dead pixels or lines, and stripes at the same time from uproarious picture. The investigation of the HSI low-rank property and the use of LRMR to the HSI rebuilding procedure is the primary concentration of this paper. To fathom the proposed rebuilding model enlarged Lagrange multiplier (ALM) numerical advancement calculations are utilized. An iterative HSI reclamation technique was displayed by Yuan Xie *et al*. (2016), for blend commotion evacuation in light of low rank network guess, where the low rank regularization is initiated by a non-curved rank limitation to be specific weighted Schatten p-standard (WSN). The system is separated in three stages. In the principal stage by utilizing powerful PCA the low-rank property of HSI information is investigated with expressly Gaussian commotion displaying. In Second stage, an amazing failure rank regularizer WSN is brought into LRMA. Third, the proposed strategy is incorporated into an iterative regularization mapping, in which the clamor level is assessed and refreshed consequently, prompting a self-balanced reclamation system for HSI information.

Milad Niknejad *et al*. (2015), applied idea of Gaussian Mixture Model to nearby patches in order to restore grayscale images which leads to a linear estimator with Neighborhood patch Clustering (LINC). They proposed a model that uses multivariate Gaussian Probability distribution for similar image patches in a neighborhood to get improved image segmentation results. Another approach for reclamation of pictures in light of an arrangement of limitation setsand projections of sub-slope was proposed by Moacir Ponti *et al*. in their paper (Ponti, 2016). The curiosity of this paper depends essentially on the depiction of the Richardson-Lucy emphases as an angle cycle that enables imperatives to be authorized amid the iterative procedure of reclamation.

Vardan Papyan *et al*. (2016), proposed to additionally broaden and enhance the expected patch log likelihood (EPLL) by considering a multiscale earlier. Their calculation forces the extremely same earlier on various scale patches separated from the objective picture. The multiscale EPLL for the assignment of tackling three distinctive reverse issues: denoising, deblurring and super-determination. Correlations with EPLL demonstrate clear favorable position to the proposed worldview over all assignments, and particularly so when the issue is extremely not well postured. Xiaoyong Shen *et al*. (2015), proposed a system in view of novel scale outline construction. Structure inconsistency between pictures is caught by scale guide and it additionally has clear measurable and numerical importance.

They had configuration capacities to frame an ideal scale delineate versatile smoothing, edge conservation and direction quality control. A viable and quick solver was created by them through cutting edge powerful capacity estimate and issue deterioration. Sakthidasan *et al*. (2016), exhibited another picture denoising and reclamation system that utilizations cross breed channel and delicate processing strategy. The half and half filter is outlined by joining two filters to expel the clamor from the information pictures. To accomplish an abnormal state commotion free picture, the yield values from the mixture filter and uproarious information pictures values must be given to the SVM for preparing. The SVM is very much prepared utilizing a few information pictures and it acquires the boisterous free picture as the yield. The subsequent pixel values from the SVM deliver a commotion free yield, however these pictures have a couple obscuring impacts. Along these lines, there is a need to reestablish pictures with high caliber. To reestablish clamor free pictures, a versatile hereditary calculation (AGA) will be used to sparkle the picture pixel values.

A higher requested aggregate variety minimization model was considered by Jin-Jin Mei *et al*. (2016), which is use to expel undesired antiquities for reestablishing foggy and boisterous pictures. To take care of the high-arrange minimization issue a primal-dual part calculation is produced by creators. In light of a scientific foundation and the current e□cient anisotropic function Tebini *et al*. (2016), in their paper proposed another numerical anisotropic diffusion work. To defeat the disadvantages of the conventional procedure, for example, the points of interest misfortune and the picture obscure this model is utilized. For a versatile smoothing another diffusivity capacity is proposed by them. Another conduction capacity was produced by creators, in the homogeneous areas it favors picture smoothing with little gradient and stop the dispersion crosswise over edges at or around.

Conclusion

In the field of digital image processing Restoration of noisy image is important task. In this paper, different type of noises are discussed that are induced in images during the process of image acquisition or transmission. Various causes of these noises and their major sources are also discussed. In the literature section detailed review is presented of the various noise removal techniques that can be applied to de-noise and de-blur the images. From the literature review presented in previous section we conclude that combining the state of art method with Machine Learning techniques gives better outcome. Accuracy and efficiency of traditional restoration algorithms improved by using machine learning techniques such as Genetic Algorithm, Neural network and Support vector machine. Adaptive methods for variation of regularization parameters in the restoration process gives faster convergence rate which helps to reduce computation cost & time.

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