Proc. of Int. Conf. on Emerging Trends in Engineering & Technology, IETET

A Study of Image Denoising Technique using Bilateral Filtering Method

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***Abstract*—Most of the image processing techniques such as edge detection, segmentation, object tracking, pattern recognition etc. do not perform well in the presence of noise. Thus, image restoration as a preprocessing step is performed before applying the image to any of the above mentioned techniques. The sources of noise in images arise during image acquisition, digitization or transmission. Now study for removing fixed impulse noise (salt & pepper) is carried out for noise from color images. Impulse noise is caused by errors in the data transmission generated in noisy sensors or communication channels, or by errors during the data capture from digital cameras. Noise is usually quantified by the percentage of pixels which are corrupted. Corrupted pixels are either set to the maximum value or have single bits flipped over. In some cases, single pixels are set alternatively to zero or to the maximum value. This is the most common form of impulse noise and is called salt and pepper noise.**

***Index Terms*— Image Processing, Denoising, Impulse Noise, Bilateral Filter.**

I. INTRODUCTION

Noise reduction in digital images, despite many years active research, still remains a challenging problem. The rapid proliferation of portable image capturing devices, combined with the miniaturization of the imaging sensors and increasing data throughput capacity of communication channels, results in the need to create novel fast and efficient denoising algorithms. Color images are very often corrupted by impulsive noise, which is introduced into the image by faulty pixels in the camera sensors, transmission errors in noisy channels, poor lighting conditions and aging of the storage material. The suppression of the disturbances introduced by the impulsive noise is indispensable for the success of further stages of the image processing pipeline. This image contains 8 bits/pixel data, which means it can have up to 256 (0-255) different brightness levels. A 0'represents black and '255' denotes white. In between values from 1 to 254 represent the different gray levels. As they contain the intensity information, they are also referred to as intensity images. Colour images are considered as three band monochrome images, where each band is of a different colour. Each band provides the brightness information of the corresponding spectral band. Typical colour images are red, green and blue images and are also referred to as RGB images. This is a 24 bits/pixel image.[4]

Grenze ID: 02.IETET.2016.5.12

A. Noise in Image

During the capture, transmission, processing or acquisition of an Image it can have many kind of variations in its original form, this variation is usually random and has no particular pattern. In many cases, it reduces image quality. This random variation in image is called noise. Generally noise gives an image an undesirable appearance, the most significant factor that noise can cover and reduce is the visibility of certain features within the image. The noise present in image can be either in additive form or in multiplicative form. These both forms can be represented as below:[2]

Additive noise equation –

$$w(x,y) = s(x,y) + n(x, y) \quad (1)$$

Multiplicative noise equation –

$$w(x, y) = s(x, y) \times n(x, y) \quad (2)$$

In the above equations s(x, y) represents the original signal, n(x, y) is the noise introduced in signal, w(x, y) is the image corrupted by noise and (x, y) is the pixel location. There are different sources of noise in a digital image, depending upon sources noise can be: Dark current noise, Shot noise, Amplifier noise and Quantization noise, usually following types of noises are most common in image processing:

Gaussian noise, Impulse noise, Speckle noise

- Gaussian Noise:

Gaussian noise is a noise which has Gaussian distribution, which has a bell shaped probability distribution function. This noise is evenly distributed over the signal. This means that in the noisy image each pixel has a value which is the sum of the true pixel value and a random Gaussian distributed noise value. The probability distribution function of Gaussian noise is given by:

$$F(g) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(g-m)^2/2\sigma^2} \quad (3)$$

In the above equation g represents the gray level, m is the mean or average, and σ is the standard deviation of the noise. The following graph shows the distribution:

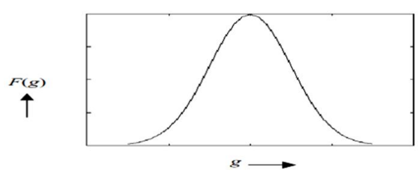

Fig.1. Probability Density Function for Gaussian noise

- Impulse (Salt-and-Pepper) Noise Model:

The PDF of (bipolar) impulse noise is given by

$$p(z) = \begin{cases} p_a & for\ z = a \\ p_b & for\ z = b \\ 0 & otherwise \end{cases} \quad (4)$$

If $b > a$, gray level b will appear as a light dot in image. Conversely, level a will appear like a dark dot. If either P_a or P_b is zero, the impulse noise is called unipolar. Impulse noise is found in situations where quick transients, such as faulty switching take place during imaging. Four impulse noise models are reported in recent papers.

- Impulse Noise Model 1

Noise is modeled as salt-and-pepper impulse noise. Pixels are randomly corrupted by two fixed extremal values, 0 and 255 (for 8-bit monochrome image), generated with the same probability. That is, for each image pixel at location (i, j) with intensity value $s_{i,j}$, the corresponding pixel of the noisy image will be $x_{i,j}$, in which the probability density function of $x_{i,j}$ is

$$f(x) = \begin{cases} \frac{p}{2} & for \ \ x = 0 \\ 1 - p & for \ \ x = s_{i,j} \\ \frac{p}{2} & for \ \ x = 255 \end{cases} \tag{5}$$

Where p is the noise density.

- Impulse Noise Model 2

For the Model 2, it is similar to Model 1, except that each pixel might be corrupted by either "pepper" noise (i.e., 0) or "salt" noise with unequal probabilities. That is

$$f(x) = \begin{cases} p_1 & for \ x = 0 \\ 1 - p & for \ x = s_{i,j} \\ p_2 & for \ x = 255 \end{cases} \tag{6}$$

Where $p = p_1 + p_2$ is the noise density and $p_1 \neq p_2$.

Impulse noise is found in situations where quick transients, such as faulty switching take place during imaging.

- Impulse noise model 3

Instead of two fixed values, impulse noise could be more realistically modeled by two fixed ranges that appear at both ends with a length of m each, respectively. For example, if m is 10, noise will equal likely be any values in the range of either [0, 9] or [246, 255]. The mathematical model showing this type of impulse noise model is shown next.[5]

$$f(x) = \begin{cases} \frac{p}{2m} & for \ 0 \leq x \leq m \\ 1 - p & for \ x = s_{i,j} \\ \frac{p}{2m} & for \ 255 - m \leq x \leq 255 \end{cases} \tag{7}$$

Where p is the noise density.

- *Impulse Noise Model 4*

Model 4 is similar to Model 3, except that the densities of low-intensity impulse noise and high-intensity impulse noise are unequal. That is

$$f(x) = \begin{cases} \frac{p_1}{m} & for \ \ 0 \leq x \leq m \\ 1 - p & for \ \ x = s_{i,j} \\ \frac{p_2}{m} & for \ \ 255 - m \leq x \leq 255 \end{cases} \tag{8}$$

Where $p = p_1 + p_2$ is the noise density and $p_1 \neq p_2$.

- Speckle Noise

Speckle noise is a multiplicative noise. This type of noise occurs in almost all coherent imaging systems such as laser, acoustics and SAR (Synthetic Aperture Radar) images. The source of this noise is the random interference between the coherent returns. Fully developed speckle noise has the characteristic of multiplicative noise. Speckle noise follows a gamma distribution and is given as:

$$F(g) = \frac{g^{a-1}}{(a-1)!a^{a}} e^{\frac{-g}{a}} \quad (9)$$

In the above equation variance is $a^2 a$ and g is the gray level.

The gamma distribution for the speckle noise is shown as following in Fig.2.

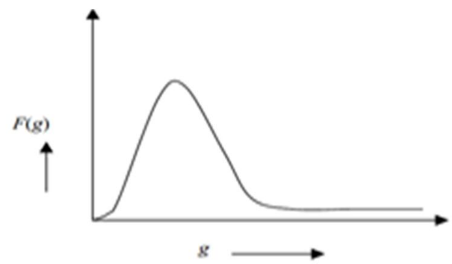

Fig.2 Gamma Distribution for Speckle noise

II. BILATERAL FILTER

Bilateral Filter is a nonlinear, non-iterative technique, which uses both range filtering and domain filtering instead of only domain filtering used by the conventional techniques. Bilateral filter is capable of smoothing the image and preserving edges as well. The bilateral filter can also be defined as a weighted average of nearby pixels, in a manner very similar to Gaussian convolution. The difference is that the bilateral filter takes into account the difference in value with the neighbors to preserve edges while smoothing. The key idea of the bilateral filter is that for a pixel to influence another pixel, it should not only occupy a nearby location but also have a similar value. Bilateral filter overcomes the limitations of Gaussian low pass filtering and anisotropic diffusion techniques of image smoothing. As bilateral filtering is the combination of both range and domain filtering.

III. LITERATURE REVIEW

S. Esakkirajan et al. and others purposed a Modified Decision Based Un-symmetrical Trimmed Median Filter (MDBUTMF) in May 2011 for the removal of high density salt and pepper noise from images. This filter is based on a simple algorithm as stepwise processing of image is done in this technique. MDBUTMF uses the fact that salt and pepper noise can be removed by working only on noisy pixels and leaving all other pixels unaffected. In this algorithm the noise is detected and then a 3x3 window is selected for the processing.

Mahdi Nooshyar et al. and other purposed algorithm use the weighted window with variable sizes and apply median filtering on them. Simulation results, with various images and noise intensities, show that the proposed algorithm has better performance compared with state of the art methods and increases the PSNR value (of there constructed image) up to 4dBs Proposed algorithm for noise detecting and removing, the whole of the image is scanned and processed pixel by pixel. If the current pixel has the maximum value (255) or minimum value (0) then the pixel is considered as noisy pixel. To current the value of a noisy pixel, a two-dimensional window centered in that pixel is created. The size of the window is varied according to the number of noise free pixel in the neighborhood of the current pixel.

Mr.N.Krishna Chaitanya et al. and other purposed a novel approach for removal of salt and pepper noise from the high density salt & pepper noisy images, using Iterative Modified Decision based Unsymmetric Trimmed Median Filter. The existing MDBUTMF is unable to restore the original image from the noisy one if noise density is more than 70%. The performance of the proposed method is analyzed by using various qualities of metrics, such as Mean Square Error (MSE) and Peak Signal to Noise ratio (PSNR). Simulation results clearly show that the proposed method is out performs both in qualitative as well quantitative fidelity criteria, when it is compared with MDBUTMF.

Dr.T. Santhanam et al. and other purposed for the removal of Salt and Pepper noise from a gray scale images. The proposed algorithm replaces the noisy pixel by trimmed median value of uncorrupted pixels which are having minimum Euclidian distance between processing pixel and surrounding pixels. When all the pixels are 0's and 255's then the noisy pixel is replaced by mean value. The performance of the proposed algorithm is compared with the MDBUTMF using PSNR (Peak Signal to Noise Ratio) .The proposed filter is experimented with different noise density in Lena image, Left iris image, Right iris image and Plant image in JPG/JPEG (Joint Photographic Experts Group format. The results of the proposed algorithm shows a significant improvement in comparison with MDBUTMF filter even if noise density in very high with better PSNR values.

Zhang and orher purposed et al. which is an extension of the Bilateral Filter given by Tomasi and Manduchi. ABF can sharpen the image by increasing slope of the edges without producing overshoot and undershoot. The Bilateral Filter can do only smoothing of image and preserve edges but it cannot increase the slope of edges. For ABF two modifications are done.[7]

IV. RESEARCH METHODOLOGY

A. Scope of Research- There are various kind of noises and denoising techniques in image processing and my main concentration is on denoising of salt and pepper noise by using Bilateral Filtering technique. Various advancements in the field of Bilateral Filtering and impulse noise removal have been studied and then a new filter for the denoising of impulse noise and edge preserving is purposed by using Switching Bilateral Filter and Trimmed Mean of noisy image.

B. Efficient Removal of Noise- The bilateral filter is very efficient in removing the salt and pepper noise from images almost at any densities value especially the high density noises The given technique provides better results than existing techniques for impulse noise removal and can be very effective in image processing applications.

C. Edge preserving in images- Bilateral filter is known as an edge preserving filter, because it not only removes the noise from images but also at the same time saves the important features of image. It is the most efficient technique in edge preservation. The other techniques of high density impulse noise removal cannot do this.

D. Adaptability- Performance of proposed filter can be improved by optimizing its parameters like domain parameter σ_d and predefined parameter α.Hence the technique can be used more efficiently by using proper values of these parameters.

V. CONCLUSION AND FUTURE SCOPE

In this paper we are presenting a novel approach for removal of salt and pepper noise from the high density salt & pepper noisy images, In future this filter can be further improved by adding more advanced impulse noise detection schemes to it. By using efficient noise detection technique the thin lines and texture can also be classified differently along with edges in image hence the information contained by thin lines and texture can also be preserved as edges are preserved in this method.

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