NOISE REDUCTION TECHNIQUE USING BILATERAL BASED FILTER

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Abstract - *proposed noise removal approach using spatial gradient based bilateral filter and minimum mean square error filtering. This method consist two-steps process. In first step, they generate a reference image from the given noisy image, by extracting 3*3 size patches from it and then applies this spatial gradient based bilateral filter on each of these patches. To reduce the mean square error, in second step they apply minimum mean square error MSE, PSNR. IEF filter on the reference image. Generally all the noise removal approaches change the natural appearance of the restored image, while this method restores the image without affecting its natural appearance.*

Key Words: **Digital Noise, SMF, PSNR,MSE,IEF,VMF**

1. INTRODUCTION

Digital images provide important information that on one hand is used in most real-world applications such as remote sensing, defense medical imaging processing for diagnosis of diseases, face recognition for security purposes, satellite images used for weather updates and so on. Hence it is very important that images should be noise free for various processing in image sector. On the other hand, users of these applications suffer from quality degradation issues caused during image transmissions over the networks. Nature of the problem depends on the type of noise added to the image. Extracting useful information from corrupted images without having the knowledge about the noise type from which they are polluted has been an issue in real world applications. The noises that may wipe out image textures include Gaussian, speckle, and salt and pepper noise. Various techniques have been developed to suppress noise and boost image quality such as linear filters, nonlinear filters and wavelet threshold-based techniques. Almost all the techniques developed so far do not attempt to diminish the effects of multiple noises. Hence, numerous hybrid techniques have been proposed to increase visual quality of a received image by removing multiple noises [1] [2].

1.1.1Impulsive Noise:

Impulsive noise can be caused by malfunctioning camera photo sensors, optic imperfections, electronic instability of the image signalof the storage objects, faulty memory locations in hardware or communication errors due to natural or man-made processes.

Common sources of impulsive noise include also lightning, strong electromagnetic interferences caused by faulty or dusty insulations of high-voltage power lines, car starters, and unprotected electric switches. These noise sources generate short time duration, high-energy pulses which upset the regular signal, resulting in the acquisition of color image samples differing significantly from their local region in the image domain [6].

Images are often corrupted by impulse noise in acquisition and transmission. Two common types of impulse noise are:

a. Salt and Pepper noise
b. Random Valued noise

For images corrupted by salt-and-pepper noise, the noise pixels can take only the maximum and the minimum values in the dynamic range and images corrupted by random-valued noise, the noise pixels can take any random value in the dynamic range.

In the past two decades, a variety of median filters have been proposed for restoration of images contaminated by impulse noise. Standard median filter (SMF) was used widely because of its simplicity and capability of preserving image edges. However, it operates equally across images and thus tends to modify both noise and noise-free pixels. To avoid the damage to noise-free pixels, adaptive median filter (AMF) and switching median filter have been existing. These filters first identify likely noise pixels and restore them by median filter while leaving uncorrupted pixels unchanged. Most of subsequent impulse noise removal filters take over this idea. However, these filters and some other recently proposed algorithms restore noise pixels by median filter or its variants and without taking into account local features such as promising presence of edges. Hence, details and edges are not recovered satisfactorily, especially when the noise level is high [3].

Consequently, since impulsive noise can be seen as an unusual or unexpected value, methods based on the theory of robust statistics, such as the median filter (MF), or its generalization to the multichannel case, the vector median filter (VMF), have been widely used to reduce impulsive noise. Vector processing has proved suitable for processing color images since it takes into account correlation between color channels in the image. Given that the filtering operation in classic filters is performed on each pixel of the image regardless of whether it is noisy or not, the resulting images usually suffer blurred edges and loss of detail; so that the overall quality is significantly degraded. An intuitive idea to solve this problem is proposed that enables switching between applying a pixel filter or not – depending on whether noise is detected or not. This approach preserves the noise-free structures of the image [4].

1.1.2 Salt and Pepper Noise:

Salt and pepper noise is also identified as impulse noise. Sharp and sudden disturbances in the image signal cause this noise. Its look is randomly scattered white or black (or both) pixel over the image. A special type of noise called impulse noise can have various origins. Faulty memory locations, timing errors in A-D conversions and transmission errors are the key reasons for images to be corrupted by impulse noise. The noise is scattered through the image in such a way that pixels can acquire only the minimum and maximum value (0-255) in the dynamic range; it may leads to corrupted image. Many algorithms have been proposed to eliminate the impulse (salt and pepper) noise. Linear filters are used to eliminate noise. These are mathematically simple and are favored due to the existence of unifying linear system theory. Most of these filters minimizes the mean square errors (MSE) criterion & provides optimum performance. However, linear filtering method has drawback i.e. if the noise is non-additive, it can’t remove the impulse noise successfully. These disadvantages can be reduced with the help of non-linear filters like Median filters, standard median filters, adaptive median filter, Tolerance based selective arithmetic mean filter, Decision based algorithm, DBAUTMF etc [5].

1.1.3 Gaussian Noise:

Majority of noise added to images can be modeled by Gaussian noise. Gaussian noise is statistical noise following Gaussian probability density and brings in the image at the time of acquiring of image. As this noise follows Gaussian distribution and hence in common it can be removed by locally averaging operation. Common choice for removing Gaussian noise is classic linear filter such as Gaussian filter, this is accepted method to remove Gaussian noise, however this filter has a tendency to blur edges which may cause information loss in some visually important areas [4].

The edge-sharpening is also an significant topic in image processing, which enhances the visual quality of images. One of the classical edge improvement methods is to use the “unsharpening filter”, where an image is low pass filtered and subtracted from the original and remained with high band signal that contain the edges. The high band signal is then amplified and added to the low pass filtered image, which is the edge-sharpened product. When the Gaussian filter is used for the low pass filtering, its subtraction from the original is the Laplacian of Gaussian, and thus the sub band images so shaped are called the Laplacian Pyramids. In this process, since the noise in the high band can also be amplified, it is necessary to denoise all the sub band images in the Laplacian pyramid [6].

Total variation (TV) regularization was introduced by Rudin, Osher, and Fatemi in and has become accepted in recent years. Recently, the variety of application of TV-based methods has been successfully extended to inpainting, blind deconvolution, and processing of vector-valued images. The success of TV regularization relies on a good balance between the ability to describe piecewise flat images and the complexity of the resulting algorithms [7].

Mathematical Representation of Noise:

Some of the mathematical representation of Noise can be defined as:

a. A corrupted gray-level image with an additive noise is formulated as follows:

$$f = f_0 + \text{additive noise}$$

where $f : \Omega \to R$ is a noisy image and $f0 : \Omega \to R$ is an original image. Both are defined in a closed region Ω. $X = (x, y)$ indicates image coordinates.

b. Impulsive noise has the following statistical model:

$$P_X(x) = \begin{cases} probability_w, & x = \text{a near white value} \\ probability_b, & x = \text{a near black value} \\ 0, & \text{otherwise} \end{cases}$$

where X is a random variable.

c. Gaussian noise has the probability distribution function (PDF) shown as below:

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

where σ^2 is the noise variance and μ is the mean value of Gaussian noise [6].

II. Nonlinear Filters:

Over the last several years, a huge amount of fuzzy-based noise reduction methods were developed, e.g., the histogram adaptive fuzzy filter (HAF), the fuzzy impulse noise detection and reduction method (FIDRM), the adaptive fuzzy switching filter (AFSF), the fuzzy similarity-based filter (FSB), the fuzzy random impulse noise reduction method (FRINRM), and so on. These fuzzy filters are mainly developed for images corrupted with fat-tailed noise like impulse noise. They outperform rank-order filter schemes (such as the median filter). Although these filters are especially developed for grayscale images, they can be used to filter color images by applying them on each color component separately. This approach generally introduces many color artifacts mainly on edge and texture elements. To overcome these problems, several nonlinear vector-based approaches were successfully introduced. One of the most important families of nonlinear filters, which take advantage of the theory of robust statistics, is based on the ordering of vectors in a predefined sliding window. This ordering is realized by a distance or similarity measure where the lowest ranked vector corresponds to that vector which is closest to all the other vectors in a predefined window in terms of the used measure [9].

The nonlinear filters applied to images are required to preserve edges, corners and other image details, and to remove different types of noise. One of the most important families of nonlinear 2lters is based on order statistics [10].

a. Hybrid Bilateral Filter: The bilateral filter takes a weighted sum of pixels in a local neighborhood. The weights are depending on spatial distance and color intensity distance. In this way, edges are preserved while noise is removed [8].

2.1 Median Filters:

Median filter having the good denoising power has been the most popular filter. Its variations have been proposed in multistate median filter, median filter based on homogeneity information decision based trimmed median filters to get better its performance [11].

Various types of median filter can be defined as:

a.Vector Median filter: One of the most popular methods based on reduced ordering, used in many filtering designs, is the Vector Median Filter (VMF). The VMF output is the pixel from W for which the sum of cumulated distances to other samples is minimized. It is always one of the pixels of the filtering window, which is profitable as the filter does not introduce any new colors to the processed image. However, when all pixels of W are affected, for example by additional Gaussian noise, the output is also noisy. Numerous solutions devoted to the elimination of this undesired behavior were introduced, resulting in significantly better filtering performance. To increase the VMF efficiency, weights are assigned to the distances between pixels, which privilege the central pixel of the filtering window, thus diminishing the number of unnecessarily altered pixels [20].

In the digital color images, the vector median filtering has been extensively used to remove impulse noise which normally occurs because of faulty sensor or during the transmission. The objective of a filtering system is to suppress the noise without affecting the high frequency components and detail information. Although the median filter is good to preserve the edges, it also changes the values of the pixels which are not affected by the noise. The gets elevated with increasing the size of the filtering mask. To effectively eliminate this problem many variants of median filter have been proposed such as the switching median filter, center weighted median filter (CWM), multi state median filter (MSM), conditional signal adaptive median (CASM) filter and adaptive two–pass rank order filter (ATPMF). Basically the task is to decide when to alter the pixel using the median value and when to keep it unchanged [12].

b.Standard Median Filter: The standard median filter (SMF) is the most typical one due to its good denoising power and computational efficiency. However, this method operates uniformly across the image and tends to modify all the pixels without distinguishing noisy pixels from noise-free pixels, thus some details and edges are smeared when the noise level is over 50% [13].

c.Adaptive Median Filters: The adaptive median filter (AMF) adopts adaptive window size and performs well at low noise density, but the filter window size has to be expanded when the noise density increases which may lead to blurring the image. To avoid the damages of noise-free pixels, the switching median filtersare introduced where impulse detection algorithms are employed before filtering and the detection results are used to control whether a pixel should be modified [13].

III.Proposed Method

Removing or reducing impulse noise is a very active research area in image processing. 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. Nevertheless other types of impulse noise are possible as well.

If $W_G(s,t)$ is the domain filter, $\widetilde{W}_{TMSR}(s,t)$is range filter and $f(x+s,y+t)$ is the neighborhood of $f(x,y)$ in the selected $(N \times N)$ window then output $\hat{u}(x,y)$ is given as follows:

$$\hat{u}(x,y) = \frac{\sum_{s=-N}^{N}\sum_{t=-N}^{N} W_G(s,t)\widetilde{W}_{TMSR}(s,t)f(x+s,y+t)}{\sum_{s=-N}^{N}\sum_{t=-N}^{N} W_G(s,t)\widetilde{W}_{TMSR}(s,t)}$$

Eq.(3.1)

Where,

$$W_G(s,t) = \exp\left(-\frac{(x-s)^2+(y-t)^2}{2\sigma_d^2}\right) \quad \text{Eq.(3.2)}$$

and

$$\widetilde{W}_{TMSR}(s,t) = \exp\left(-\frac{\alpha\sigma_d(TM-f(x+s,y+t))^2}{n^2}\right)$$

Eq.(3.3)

The domain filter$W_G(s,t)$ weights in this are calculated in same manner as in conventional bilateral filter as given in Eq. (3.2). The range filter of Trimmed Mean Adaptive Bilateral filter $\widetilde{W}_{TMSR}(s,t)$ is calculated as given in Eq. (4.3), Where TM is the trimmed mean value and α is a predefined parameter whose value is empirically set to .003.

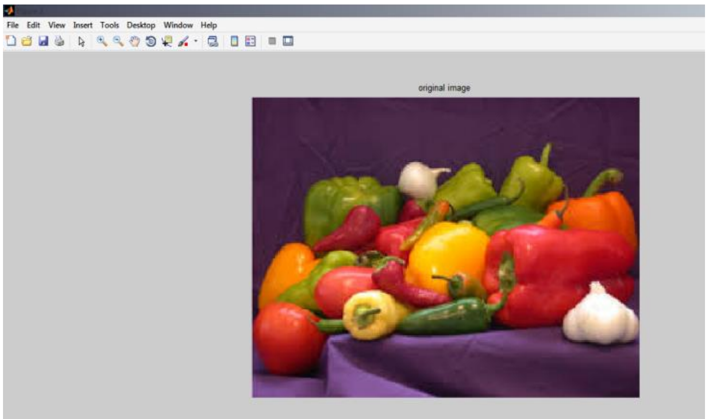
UNTMF uses trimmed mean of noisy image for the calculation of range filter weights$\widetilde{W}_{TMSR}(s,t)$ hence only noise free pixels are processed during the range filter calculation. Due to which the computational time of proposed UBTMF algorithm is less as compared to SBF method because SBF requires the processing of all noisy and noise free pixels to calculate range filter $W_{SR}(s,t)$

IV .Simulation Result

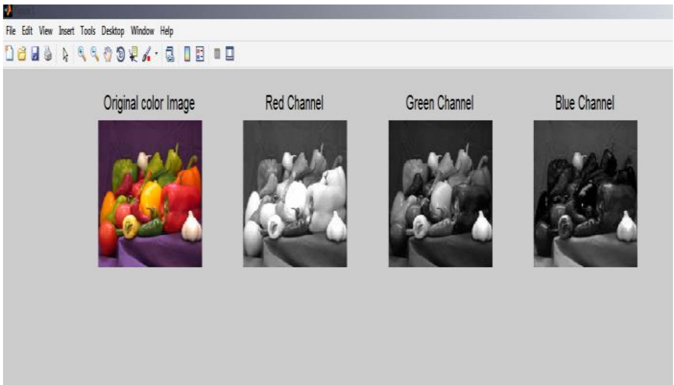
Load the Original and Distorted Images

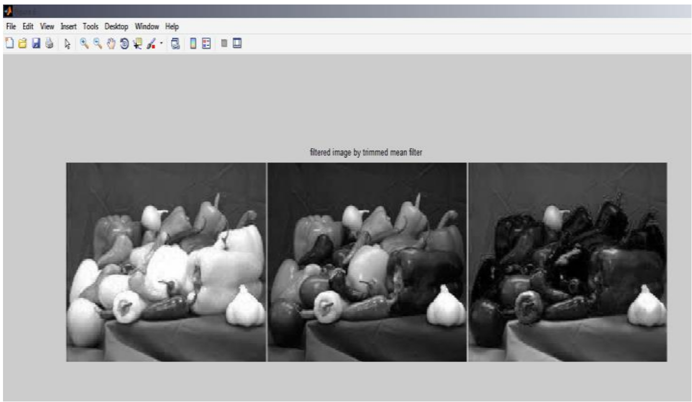
Firstly we load the original and distorted images to analyse the quality of distorted images by taking original images as reference. The images used are as follows:

Step1 Load the original color image of Leena



Step-2 Separate the three plane of color of color image i.e. red-green-blue plane.





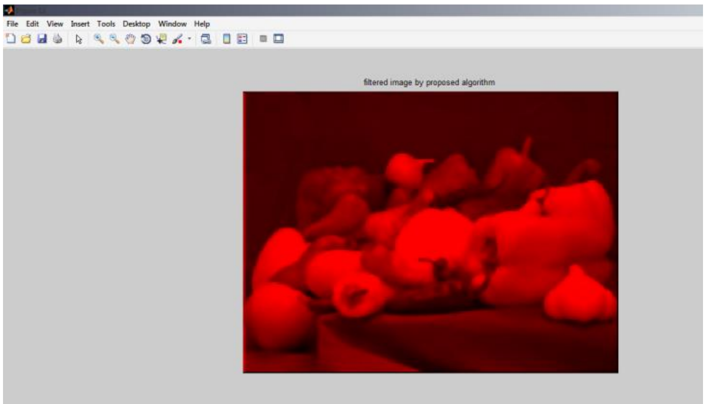


Table No-4.1 Comparative analysis of Image Metric parameter(PSNR) using different filter

Density level	PSNR by conventional filter	PSNR by Trimmed filter	PSNR by Purposed
0.9	**7.6482**	**15.9714**	**17.5548**
0.8	**9.1413**	**20.2127**	**22.331**
0.7	**11.0225**	**24.6628**	**26.8838**
0.6	**13.2709**	**27.7758**	**30.2495**

As shown in Table 4.1, PSNR value of different algorithms is compared with the proposed algorithm as a function of noise density for color Lena image. Table shows that the proposed algorithm (UBTMF) outperforms the existing algorithms for noise densities from 0.6 to 0.9 A plot of PSNR values has been presented in Fig.4.1

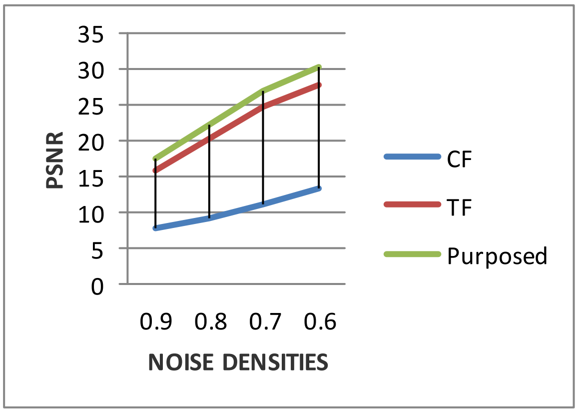


Fig. 4.1 PSNR By Different Filter

Table No-4.2 Comparative analysis of Image Metric parameter(IEF) using different filter

Density level	IEF by conventional filter	IEF by Trimmed filter	IEF by Purposed Filter
0.9	**1.4984**	**10.0868**	**14.5030**
0.8	**1.8704**	**23.9377**	**38.9864**
0.7	**2.5268**	**58.4271**	**97.4340**
0.6	**3.642**	**129.5202**	**181.8449**

Table 4.2 shows comparison of Image Enhancement factor of different algorithms for color image at different noise densities (0.6 to 0.9). In comparison with the existing algorithms, the proposed algorithms shows substantial growth in IEF values even at high noise density. From Fig.4.2 it is clear that, at low noise density, this algorithm outperforms the existing ones having high IEF Values.

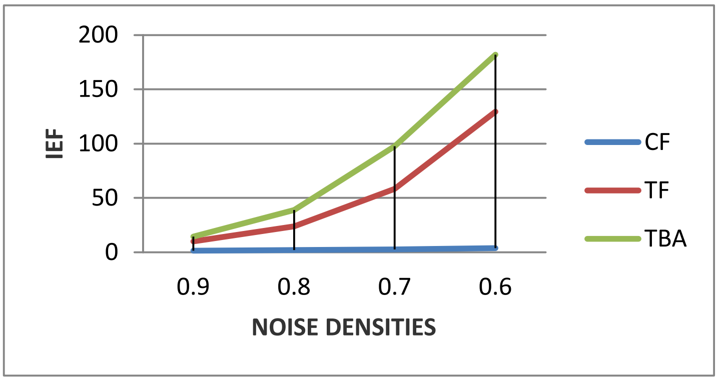


Fig. 4.2 IEF By Different Filter.

Table No-4.3Comparative analysis of Image Metric parameter (MSE)using different filter

Density level	MSE by conventional filter	MSE by Trimmed filter	MSE by Tradition Based Filter
0.9	**0.1713**	**0.0255**	**0.0177**
0.8	**0.1219**	**0.0095**	**0.0058**
0.7	**0.0790**	**0.0034**	**0.0020**
0.6	**0.0471**	**0.0013**	**9.4417**

Table 4.3 shows the mean square error comparison of different algorithms as a function of noise density for leena image. Here as the noise density varied from 0.6 to 0.9 i.e. even at high noise density the proposed algorithm shows minimum MSE values in comparison with the existing algorithms, showing the effectiveness of proposed algorithm.

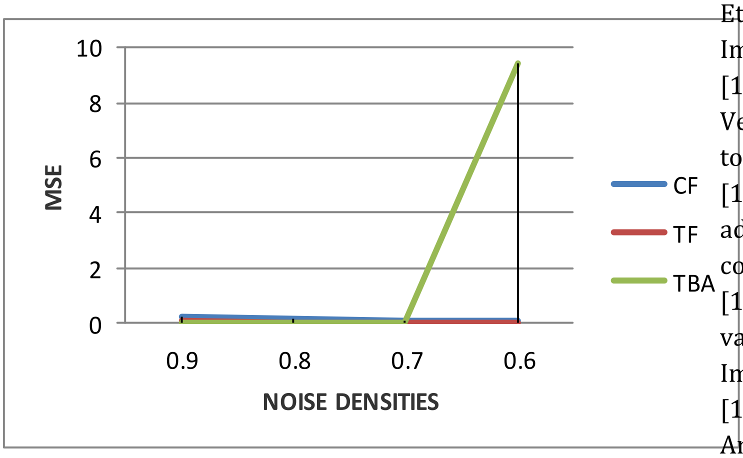


Fig. 4.3 MSE By Different Filter

V. Conclusion and Future Scope

The performance of the algorithm has been tested at low, medium and high noise densities on color images. Even at high noise density levels the purposed gives better results in comparison with other algorithms. Both visual and quantitative results are demonstrated. This algorithm is effective for salt and pepper noise removal in images at high noise densities

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