

Techniques to Remove High Density Salt and Pepper Noise Form Images

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Abstract

In the field of image processing corruption of images by Impulse noise due to different reasons is common. Impulse noise can degrade the visibility of image up to a great extent hence proper denoising technique for this kind of noise should be there. There are various type of filters used for the removal of impulse noise but every filter has its own limitations. It is observed that the techniques used for removing impulse noise have a problem that they cannot preserve the image details like edges at the high noise densities hence such techniques damage the important information of image during denoising. This problem can be solved by introducing a new approach of impulse noise removal which has the capability of edge preservation. The proposed filter is basically a combination of two different approaches which are bilateral filter and trimmed median filter.

Keywords: Image Processing, salt and pepper noise, Image enhancement, PSNR, MSE, Bilateral filter

I. INTRODUCTION

One of the first applications of digital images was in the newspaper industry [1], when pictures were first sent by submarine cable between London and New York. Introduction of the Bartlane cable picture transmission system in the early 1920s reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours. Specialized printing equipment coded pictures for cable transmission and then reconstructed them at the receiving end. Some of the initial problems in improving the visual quality of these early digital pictures were related to the selection of printing procedures and the distribution of intensity levels. Although the methods just cited involve digital images, they are not considered digital image processing results in the context of our definition because computers were not involved in their creation. Thus, the history of digital image processing is intimately tied to the development of the digital computer.

However, the basis for what is called a modern digital computer dates back to only the 1940s with the introduction by John Von Neumann of two key concepts: (1) a memory to hold a stored program and data, and (2) conditional branching. These two ideas are the foundation of a central processing unit (CPU), which is at the heart of computers today. Starting with von Neumann, there were a series of key advances that led to computers powerful enough to be used for digital image processing. Briefly, these advances may be summarized as follows: (1) the invention of the transistor by Bell Laboratories in 1948; (2) the development in the 1950s and 1960s of the high-level programming languages COBOL (Common Business-Oriented Language) and FORTRAN (Formula Translator); (3) the invention of the integrated circuit (IC) at Texas Instruments in 1958; (4) the development of operating systems in the early 1960s; (5) the development of the microprocessor (a single chip consisting of the central processing unit, memory, and input and output controls) by Intel in the early 1970s; (6) introduction by IBM of the personal computer in 1981; and (7) progressive miniaturization of components, starting with large scale integration (LSI) in the late 1970s, then very large scale integration (VLSI) in the 1980s, to the present use of ultra large scale integration (ULSI). Concurrent with these advances were developments in the areas of mass storage and display systems, both of which are fundamental requirements for digital image processing.

A. Problems in Image Processing

There are six classes of problems in image processing as follows-

- Image representation and modeling
- Image enhancement
- Image restoration
- Image analysis
- Image reconstruction
- Image data compression

B. Image Representation and Modeling

In Image representation one is concerned with the characterization of the quantity that each picture element represents. An image could represent luminance of objects in a scene, the absorption characteristics of the body tissue, the radar cross section of the target, the temperature profile of the region or the gravitational field in an area. In general, any two dimensional function that

bears information can be considered as an image. An important consideration in image representation is the fidelity or intelligibility criteria for measuring the quality of an image or the Performance of processing technique.

C. Image Enhancement

In image enhancement, the goal is to accentuate certain image features for subsequent analysis or for image display. Examples include contrast and edge enhancement, pseudo coloring, noise filtering, sharpening and magnifying [1]. Image enhancement is useful in feature extraction, image analysis and visual information display. The enhancement process itself does not increase the inherent information display in the data. It simply emphasizes certain specified image characteristics. Enhancement algorithms are generally interactive and application dependent.

D. Image Restoration

It refers to removal or minimization of known degradations in an image. This includes deblurring of images degraded by the limitations of a sensor or its environment, noise filtering and correction of geometric distortion or non-linearities due to sensors [1]. A fundamental result in filtering theory used commonly for image restoration is called Weiner filter. This filter gives the best linear mean square estimate of the object from the observation. It can be implemented in frequency domain via the fast unitary transform, in spatial domain by two dimensional recursive techniques similar to Kalman filtering or by FIR non-recursive filters.

E. Image Analysis

Image analysis techniques require extraction of certain features that aid in the identification of an object [1]. It is concerned with making quantitative measurements from an image to produce a description of it. In simplest form, this task is reading a label on a grocery item, sorting different parts on an assembly line or measuring the size and orientation of blood cells in a medical image.

F. Image Reconstruction from Projections

It is special class of image restoration problems where two dimensional objects are reconstructed from several one dimensional projections. Each projection is obtained by projecting a parallel X-ray beam through the object. Planar projections are thus obtained by viewing the object from many different angles. Reconstruction algorithms derive an image of a thin axial slice of the object giving an inside view otherwise unobtainable without performing extensive surgery.

G. Image Data Compression

The amount of data associated with visual information is so large that its storage would require enormous storage capability [1]. Although the capacities of several storage media are substantial, their access speeds are usually inversely proportional to their capacities. Typical television images data rates exceeding ten million bytes per second. There are other image sources that generate even higher data rates. Storage and transmission of such data requires large capacity or bandwidth could be very expensive. Image data compression techniques are concerned with reduction of the number of bits required to store or transmit images without any appreciable loss of information.

1) Median Filter

The low pass filtering methods like averaging filter do blurring of image, hence it also blurs the edges of image with the noise. Low pass filtering methods works well for Gaussian noise but they cannot remove salt and pepper noise from the image, Hence for the removal of salt and pepper noise from image a non-linear filter called Median Filter (MF) (2) is used, which replaces the gray level of each pixel by the median of the gray levels of all the pixels in the neighborhood.

2) Trimmed Median Filter (TMF)

Trimmed Median Filter (TMF) [3] is a decision based unsymmetrical filter. TMF is a two stage filter. First it detects the noisy pixels and then restores them. TMF considers all saturated pixels (0 or 255) as noisy pixels. If a pixel value lies within the dynamic range then it is considered a noise free pixel. Noise free pixels are left unchanged in the restoration stage. For each noisy pixel, the neighboring pixels within the 3X3 window are analyzed in the restoration stage. If all the pixels of the selected 3X3 window are deemed to be noisy, then the center pixel is replaced by the mean of the 3X3 window in the restored image. If the selected 3X3 window contains both the noisy pixels and noise free pixels, then the center pixel is replaced by the median of the noise free pixels in the 3X3 window.

3) Bilateral Filter:

The bilateral filter proposed by Tomasi and Manduchi[4] is the combination of range and domain filtering. 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.

If $f(x, y)$ be the center pixel, and $f(x + s, y + t)$ be the neighboring pixels of window $(2N + 1) \times (2N + 1)$. where (x, y) and $(x + s, y + t)$ are the locations of $f(x, y)$ and $f(x + s, y + t)$ respectively, then the output of bilateral filter $\hat{f}(x, y)$ can be defined as follows:

$$\hat{f}(x, y) = \frac{\sum_{s=-N}^N \sum_{t=-N}^N W_G(s, t) W_R(s, t) f(x + s, y + t)}{\sum_{s=-N}^N \sum_{t=-N}^N W_G(s, t) W_R(s, t)}$$

where

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

and

$$W_R(s, t) = \exp\left(-\frac{(f(x, y) - f(x+s, y+t))^2}{2\sigma_r^2}\right)$$

Here $W_G(s, t)$ is the domain filter and $W_R(s, t)$ is the range filter. σ_d and σ_r are the standard deviations of domain filter and range filter respectively.

The results of bilateral filter show that it reduces the noise significantly but does not sharpen the edges. Hence in order to enhance the sharpness we need to modify the bilateral filter and therefore an attempt is made in this paper to improve the results of bilateral filter

II. PERFORMANCE ANALYSIS

The proposed filter is tested with Lena and Cameraman images. Images are corrupted by Salt and Pepper noise at various noise densities and performance are quantitatively measured by Peak signal to noise ratio (PSNR), Mean Square Error (MSE), Image Enhancement factor (IEF).

A. Mean Squared Error (MSE)

One obvious way of measuring the similarity between two images is to compute an error signal by subtracting the test signal from the reference, and then computing the average energy of the error signal. The mean-squared-error (MSE) is the simplest, and the most widely used, full-reference image quality measurement.

This metric is frequently used in signal processing and is defined in [5].

$$MSE = \frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N (x(i, j) - y(i, j))^2$$

B. Peak Signal to Noise Ratio (PSNR)

It is inversely proportional to the MSE; its units are in decibels (dB) and are formally defined by [6]:

$$PSNR = 10 \log_{10} \frac{(2^n - 1)^2}{\sqrt{MSE}}$$

Where 255 is the maximum pixel value for an 8 bit/pixel gray-scale image.

Table – 1

Comparison of PSNR Values of different algorithm for LENA Image at different noise densities.

Noise Density	MF	TMF	BBTMF
0.6	13.3076	28.7685	30.2568
0.7	11.0225	24.6628	26.8838
0.8	9.1413	20.2127	22.3311
0.9	7.6482	15.9714	17.5548

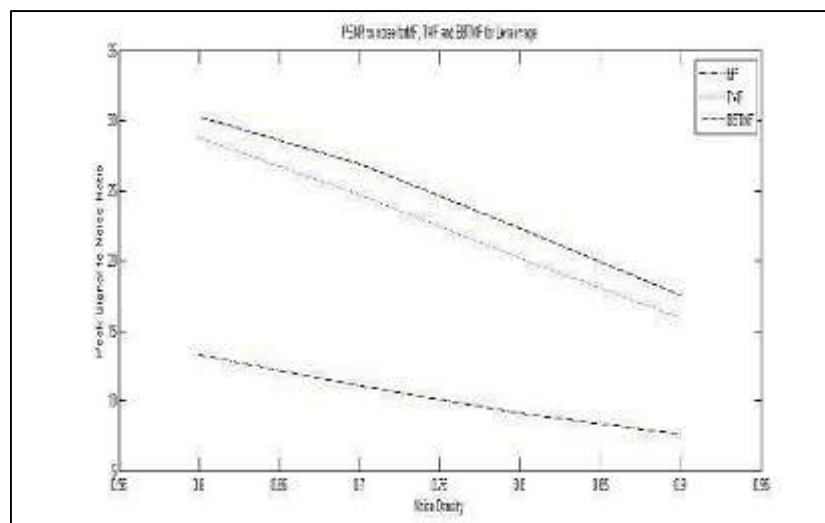


Fig. 1: Noise Density versus PSNR for LENA Image

Table – 2
Comparison of MSE Values of different algorithm for LENA Image at different noise densities.

NOISE DENSITY	MF	TMF	BBTMF
0.6	0.0467	0.0013	9.42E-04
0.7	0.079	0.0034	0.002
0.8	0.1219	0.0095	0.0058
0.9	0.1719	0.0253	0.0176

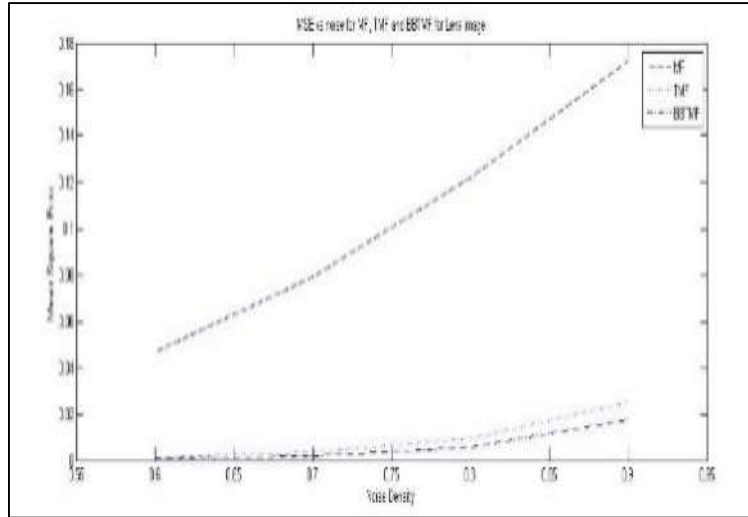


Fig. 2: Noise Density versus MSE for LENA Image

Table – 3
Comparison of IEF Values of different algorithm for LENA Image at different noise densities

NOISE DENSITY	MF	TMF	BBTMF
0.6	3.6669	128.9427	181.6449
0.7	2.5268	58.4271	97.434
0.8	1.8704	23.9377	38.9864
0.9	1.4924	10.1437	14.6061

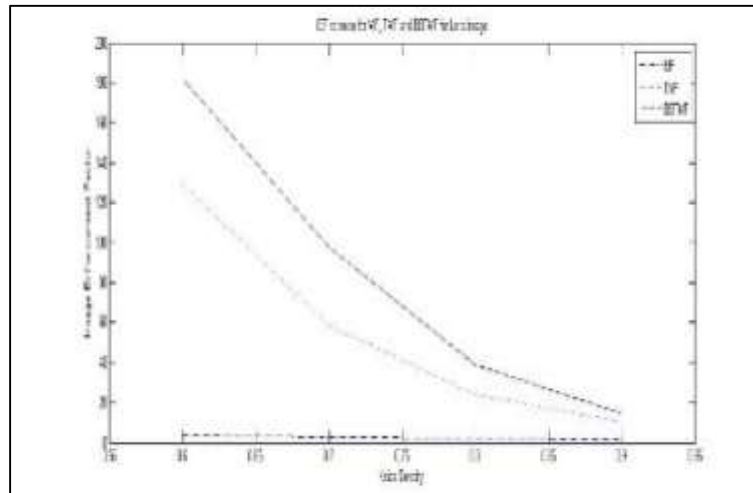


Fig. 3: Noise Density versus IEF for LENA Image

Table – 4
Comparison of PSNR Values of different algorithm for CAMERAMAN Image at different noise densities.

NOISE DENSITY	MF	TMF	BBTMF
0.6	12.9613	27.6758	29.0653
0.7	10.6378	23.4974	25.1833
0.8	8.748	18.7711	20.2793
0.9	7.2391	14.5328	15.6377

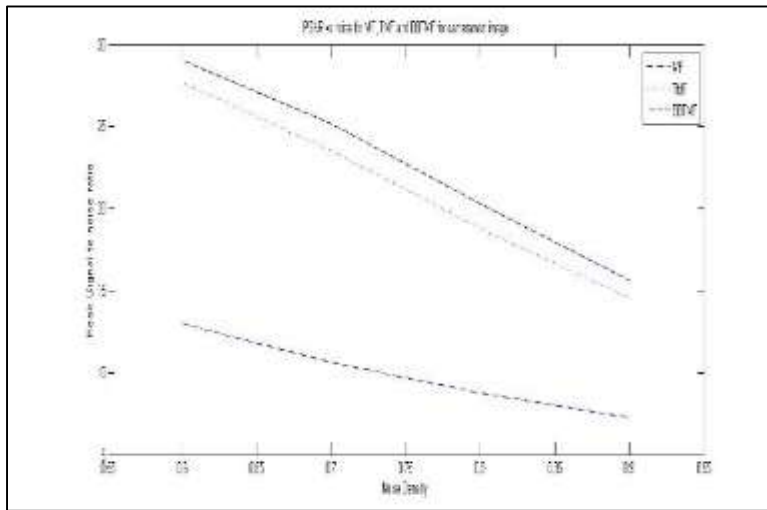


Fig. 4: Noise Density versus PSNR for CAMERAMAN Image

Table – 5

Comparison of IEF Values of different algorithm for CAMERAMAN Image at different noise densities

NOISE DENSITY	MF	TMF	BBTMF
0.6	3.694	109.3828	150.6268
0.7	2.5185	48.6527	71.7303
0.8	1.8611	18.7107	26.4791
0.9	1.4773	7.9224	10.2174

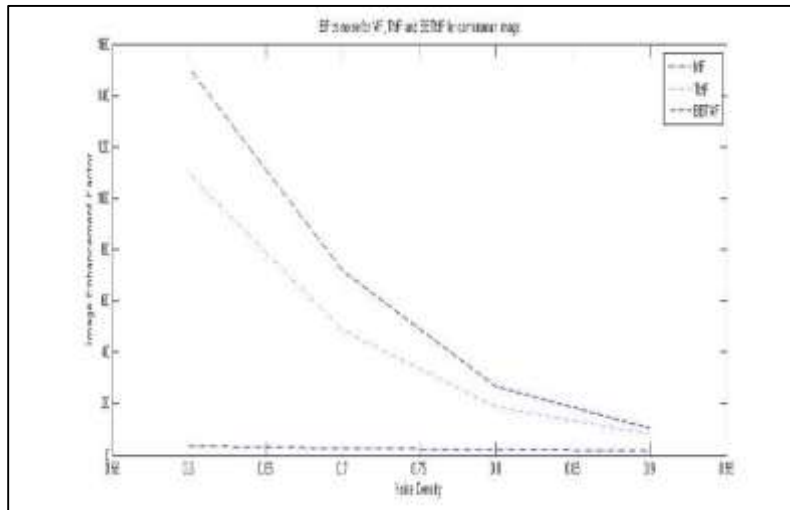


Fig. 5: Noise Density versus IEF for CAMERAMAN Image

Table – 6

Comparison of MSE Values of different algorithm for CAMERAMAN Image at different noise densities

NOISE DENSITY	MF	TMF	BBTMF
0.6	0.0506	0.0017	0.0012
0.7	0.0863	0.0045	0.003
0.8	0.1334	0.0133	0.0094
0.9	0.1888	0.0352	0.0273

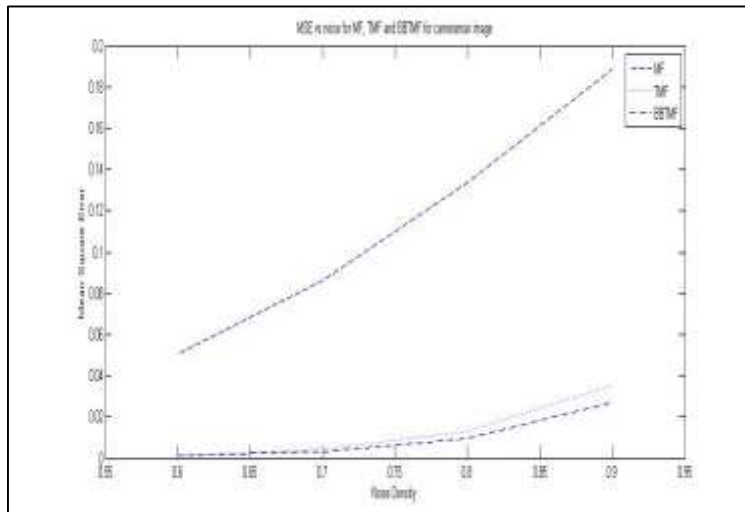
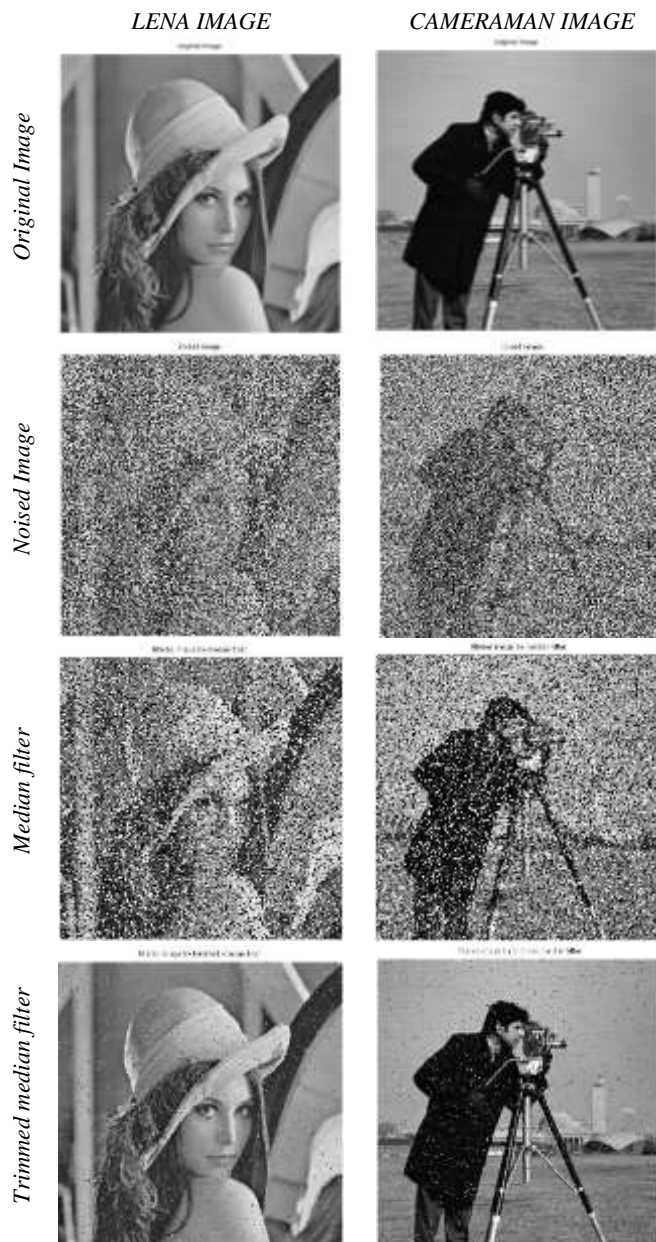


Fig. 6: Noise Density versus MSE for Cameraman Image





III. CONCLUSION

In this paper a new algorithm (BBTMF) is proposed which gives better performance in comparison with MF AND TMF in terms of PSNR, MSE and IEF. The performance of the algorithm has been tested at medium and high noise densities on gray-scale images. Even at high noise densities levels the BBTMF gives better result in comparison with other existing algorithm. The proposed algorithm is effective for salt and pepper noise removal in images at high noise densities.

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