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REMOVAL OF SALT AND PEPPER NOISE USING MODIFIED TOLERANCE BASED SELECTIVE ARITHMETIC MEAN FILTERING TECHNIQUE

Ms. Piyusha H. Sangave, Solapur University, Solapur,

Abstract

In proposed filter technique, first stage min-max strategy is used to detect the effected pixels followed by second stage Modified Tolerance based selective mean filter to restore the effected pixels. Extensive experimental results demonstrate that proposed filter performs significantly better than many existing, well accepted and recently proposed median, decision based filters for gray scale images corrupted up to 70% of salt and pepper noise.

Keywords: image restoration, impulse noise, decision based filters, Min-max noise detection, Tolerance Based Selective Arithmetic Mean Filtering Technique (TSAMFT).

1. Introduction

Noise is any undesired information that contaminates an image. Impulse noise is a special type of noise, which have many different origins. The Salt and Pepper type impulse noise is typically caused by malfunctioning of the pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process. For the images corrupted by Salt and Pepper noise, the noisy pixels can take only the maximum or the minimum values in the dynamic range.

An important non linear filter that will preserve the edges and remove impulse noise is standard median filter Median (SMF) [3]. It replaces every pixel by its median value from its neighborhood and often removes desirable details in the image. Some of decision based algorithms, such as Adaptive Median filter (AMF) [4]; these algorithms first detect the noisy pixels and remove it by applying either standard median filter or its variants. Specialized median filter such as weighted median filter (WMF) [5] were proposed to improve the performance of median filter by giving more weight to some selected pixel in the filtering window. These filters are effective in removing low to medium density impulse noise only. But they still implemented uniformly across the images without considering the current pixel whether is noisy or noise free. Therefore, a noise-detection process to discriminate between uncorrupted pixels and corrupted pixels is highly desirable.

The outline of the paper is as follows.
Tolerance Based Selective Arithmetic Mean Filtering Technique (TSAMFT) scheme is reviewed in Section 2. Our denoising scheme is presented in Section 3. Experimental results and conclusions are presented in Sections 4 and 5, respectively.

2. Tolerance Based Selective Arithmetic Mean Filtering Technique (TSAMFT)

Salt and Pepper noise is considered as the extreme case among all types of noises. To restore the images affected by this noise, a technique is developed called TSAMFT [2]. In this technique the main concern is to use the Arithmetic Mean Filtering Technique efficiently to recover from Salt and Pepper noise. We know that for Salt and Pepper noise the pixel value of the noisy image is converted to 0 and 255. When we use Arithmetic Mean Filtering Technique we take 3×3 window and find out the Arithmetic Mean and in this case all the 9 pixels of this 3×3 window are used to calculate the Arithmetic Mean.

But while calculating the mean using the extreme values, we get erroneous results. To avoid this effect we ignored the pixels of value 0 and 255 while calculating the mean. But it may be the case that the pixels of the 3×3 window represent a black or white object. Hence the pixels are not affected by the noise rather the original values 0 and 255. To deal with this situation, one pixel and a sub window of size 3×3 around that pixel is considered. Arithmetic Mean from the pixels of the sub window is obtained by ignoring the pixels with the maximum (255) and minimum (0) value. If the number of pixels is less than 1/3 rd of $m\times n$ (window size $m\times n$) adjacent pixels, the traditional Arithmetic Mean Filtering Technique is used. Otherwise the calculated mean found by this technique is used.

This technique uses a threshold called Tolerance. If the difference between the calculated Arithmetic Mean (excluding the pixels with gray level 0 or 255) and the intensity of the considered pixel is greater than the Tolerance, then intensity of the considered pixel is replaced by the Arithmetic mean. Otherwise the intensity of the considered pixel is left unchanged.

A. Algorithm of TSAMFT

1. For each pixel p in the image do
i. Take a sub window of size m×n around that pixel.
ii. Find out the Arithmetic Mean (AM) from the pixels of the sub window ignoring the pixels with the maximum (255) and minimum value (0).
iii. If the number of pixels obtained after ignoring pixels of minimum and maximum value is greater than or equal to 1/3 rd of m×n then calculate the Arithmetic Mean value with the selected pixels. Otherwise calculate Arithmetic Mean Value with all the pixels in the m×n sub window.
iv. Compute Diff = Difference between Arithmetic Mean and the intensity of p.
a) If Diff ≥ Tolerance, then replace intensity of p by AM
b) Otherwise leave the pixel value unchanged.

3. Proposed Algorithm (PA)

The modified filter is non iterative, non linear decision based filter based on the order statistics to remove impulse noise from an image. It operates in two stages. First stage is a detection strategy using min-max filter [1] which compute the minimum and maximum of current working window excluding the centre pixel, and compare these values against the centre pixel to check whether centre pixel lies in between the maximum and minimum value, if so declare it as "uncorrupted" otherwise declare it as "corrupted". In this way a noise flag map is prepared.

In second stage the corrupted pixels are replaced by the median of the uncorrupted pixels within the working window based on satisfying a particular Tolerance condition with the help of a modified Tolerance based selective mean filter [2].

The steps of modified algorithm are:
Step 1) Estimate the noise density of the corrupted image by comparing every pixel with two extreme values '0' and '255' and counting the number corrupted pixels.

Step 2) Working window is decided based on the estimated noise density adaptively as given in Table 1 below.

TABLE 1: Suggested Window size for the estimated noise density

Noise density P	Working window W × W
$P < 30\%$	3 × 3
$30\% \le P \le 70\%$	5 × 5
$P > 70\%$	7 × 7

Step 3) For a W × W working window centered at a test pixel D9, for example a 3 × 3 window is shown as below

D_1	D_2	D_3
D_4	D_9	D_5
D_6	D_7	D_8

Step 4) If $D9 \ge \max(Di)$ or $D9 \le \min(Di)$ where $1 \le i \le 8$, then D9 is a noisy pixel and must be estimated, otherwise Y= D9 i.e. centre pixel is left unchanged.

Step 5) Step1 and step2 are repeated for each and every pixel of a noisy image and a noise flag map B (i, j) is prepared.

Step 6) Now count the number of uncorrupted pixels C, within the working window:

if $C \ge (\frac{w\ x\ w}{3})$ then
M1= median of uncorrupted pixels within the current window.
Otherwise
M1 = median of full window.

Step 7) Compute Diff = Difference between M1 and the intensity of centre pixel p.
a) If Diff ≥ Tolerance then replace Intensity of p by median of uncorrupted pixel.
b) Otherwise leave the pixel value unchanged.

Step 8) If the number of uncorrupted pixels within the working window is zero then leave the centre pixel as it is.

The Significance of the Tolerance Value

For Salt and Pepper noise the value of the distorted pixel is 0 or 255. So we find a significant difference between the median of uncorrupted pixel and the value of the corrupted pixel. Replacing only the effected pixel will provide us with better result than replacing all the pixels. Our Tolerance value ensures that only the effected pixels are replaced.

If we take small Tolerance value, then not only the distorted pixels but also the other pixels are replaced. If we in-

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crease the Tolerance value then the quality of restored image also increases. If we take a very large Tolerance value (like 65 or greater than 65), few Pepper noise pixels are not replaced at all, and quality of restored image decreases.

From our experiments this technique is found to produce very good results for Salt and Pepper noise when the Tolerance value is 35.

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4. Results & Simulation

Among the commonly tested 512x512 8-bit grayscale Lena image, will be selected for our simulations. In the simulations, images will be corrupted by "salt" (with value 255) and "pepper" (with value 0) noise with equal probability. Also a wide range of noise levels varied from 10% to 70% with increments of 10% will be tested. Restoration performances are quantitatively measured by the peak signal-to-noise ratio (PSNR) and the mean absolute error (MAE).

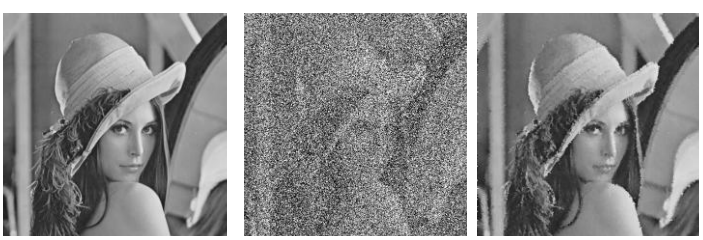
$$\text{PSNR}=10\log_{10}\frac{255^2}{\frac{1}{MN}\sum_{i,j}(r_{i,j}-x_{i,j})^2} \quad (1)$$

$$\text{MAE}=\frac{1}{MN}\sum_{i,j}|r_{i,j}-x_{i,j}| \quad (2)$$

Where ri,j and xi,j denote the pixel values of the restored image and the original image, respectively.

4.1 Denoising Performance

The denoising performance of proposed algorithm and other standard methods are tested for grayscale Lena image. The visual quality results are presented in tables below for different noise densities of salt and pepper noise ranging from 10% to 70%.



(a) (b) (c)
Fig. 1 a) Original Lena image b) Noisy image with 70% Noise Density & PSNR of 6.99 c) DBA with PSNR of 25.69

(d) (e)
Fig. 1 d) IDBA with PSNR of 24.46 e) PA with PSNR of 29.41.

The quantitative performances in terms of PSNR and MAE for all the algorithms are given in Table 2, 3 below. The same is shown in fig. 1 and plotted in fig. 2 and 3. For lower noise density up to 30% almost all algorithms performs equally well in removing the salt and pepper noise completely with edge preservation as shown in Table 2 and 3. For the case of noise density 40% and above the standard algorithms such as SMF fails to remove the salt and pepper noise completely. But the DBA, IDBA and proposed algorithms completely remove noise.

TABLE 2
Peak Signal to Noise Ratio of "Lena" Test image for different noise removal techniques

ND	SMF	DBA	IDBA	PA
10%	33.12	41.58	41.39	40.97
20%	28.76	37.44	37.32	38.31
30%	23.64	34.69	34.5	35.12
40%	19.08	32.18	32.22	33.47
50%	15.29	30.18	29.72	32.01
60%	12.35	27.92	27.18	30.78
70%	10	25.69	24.46	29.41

TABLE 3
Mean Absolute Error of "Lena" Test image for different noise removal techniques

ND	SMF	DBA	IDBA	PA
10%	2.79	0.4	0.4	0.4
20%	3.57	0.86	0.88	0.8
30%	5.32	1.43	1.44	1.38
40%	9.21	2.1	2.12	1.93

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50%	16.81	2.92	3.08	2.5
60%	29.77	4.03	4.48	3.13
70%	47.27	5.56	6.75	3.9

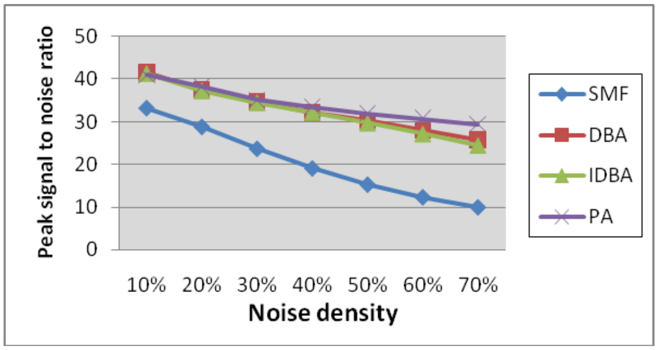

Fig. 2 Peak Signal to Noise Ratio Vs. Noise density of Lena Gray Image

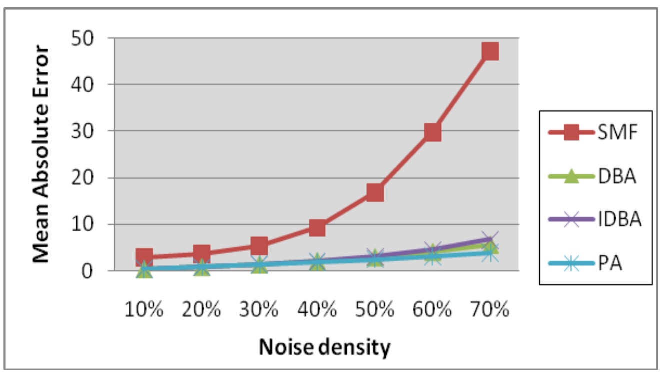

Fig. 3 Mean Absolute Error Vs. Noise Density of Lena Gray Image

In the case of high noise density such as 70% of salt and pepper noise the standard methods are very poor in noise cleaning and details preservation for the case of 70% of noise density. AMF is slightly less than that of proposed filter in terms of noise removal and edge preservation. The maximum window size of 17x17 is selected for AMF to give better at high noise density level. The visual quality, PSNR and MAE results clearly show that the proposed filter out performs the many of standard and recently proposed filters.

4.2 Computational time:

The CPU time of proposed algorithms is compared with standard filters in the Table 4, for Lena grayscale image. For the case of comparison Lena grayscale image is corrupted with salt and pepper noise of density 70% and applied to all filters. All the algorithms are implemented in MATLAB 7.1 on a PC equipped with AMD Athlon 64x2 Dual core processor of 2.71 GHZ Capacity and 1.75 GHZ RAM memory. The computation time of proposed filter is slightly higher than the decision based algorithms since the proposed algorithms uses adaptive filtering window instead of fixed window as in case of DBA [6].

TABLE 4
Computational Time in Seconds for Denoising 70% Salt & Pepper Noise Corrupted LENA (512x512 Grayscale) Image for Different Denoising Techniques

FILTER	TIME (in sec.)
Standard Median Filter	0.08
Decision Based Filter	2.83
Improved Decision Based Filter	3.08
Proposed Algorithm	76.82

5. Conclusions

In this paper an efficient decision based filter is proposed to remove low to high value of salt and pepper noise with edge preservation. The proposed decision based filter performs well for gray scale image with different noise model of salt and pepper noise. In proposed algorithm a min-max filter [1] is used to detect the effected pixels followed by modified Tolerance based selective mean filter [2] to restore the effected pixels.

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Biographies

PIYUSHA H. SANGAVE received the B.E. degree in Electronics Engineering from the Shivaji University, Kolhapur, Maharashtra, India, in 2003, the M.E. degree in Electronics Engineering from the Solapur University, Solapur, Maharashtra, in 2013, respectively. Currently, she is an Assistant Professor in Electronics & Telecommunication Engineering department in Walchand Institute of Technology, Solapur. Her areas of interests include electromagnetic engineering and radiating systems, basic electronics and electronic system design. She has published two papers in the area of image processing in International Journal.