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High Density Impulse noise removal from Digital Images by Fast and Enhanced Tolerance based Selective Arithmetic Mean Filtering Technique

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***Abstract* — As we all know digital images holds detailed information which play very important role in various applications. Due to environmental effects, errors while transmission, while acquiring image by sensors their might be noise interference in the image and to get expected or detailed information from noise interfaced image we need to apply effective denoising algorithm or technique to get back effective information associated with that image. As we know today there are superior techniques which are associated with technology. Even though denoising concept is challenging role for researchers. As we know for less salt and pepper noise median filters works well and enhanced techniques associated with median filters and mean filters gives impact results. Tolerance based Selective Arithmetic Mean Filtering is among one which work good for certain level of high noise density to restore image information. In this paper fast and enhanced Tolerance based Selective Arithmetic Mean Filtering Technique is proposed for effective denoising concept. Simulated results show that proposed technique performs effectively for highly corrupted salt and pepper noise.**

***Index Terms*—Tolerance based Selective Arithmetic Mean Filtering Technique (TSAMFT), Peak Signal to Noise Ratio, Image Enhancement Factor (IEF), Noise density, Salt and Pepper Noise.**

I. INTRODUCTION

The basic problem associated with image processing is the image enhancement and the image restoration in the noisy environment. To enhance the quality of images we should use various filtering techniques which are available in image processing. Noise is considered to be undesired information that contaminates the image. Among various types of noises, salt and pepper noise typically causes error in 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 and the minimum values in the dynamic range (0, 255) [1].

There are various filters available which can remove the noise from images and preserve or restore image details and finally to enhance the quality of looking image. Salt & Pepper noise is the one type of noise which occurs due to the dead pixels or analog to digital conversion of images. To remove this impulse noise we have filters like Min. filter, Max. filter,

MinMax. Filter, Mean filter, Median filter. Impulse noise corruption is very common in digital images. Impulse noise is always independent and uncorrelated to the image pixels and is randomly distributed over the image [2].

The image which has salt-and-pepper noise present in image will show dark pixels in the bright regions and bright pixels in the dark regions [3]. Median filters have been widely applied in impulse noise reduction. To preserve more details of original images, the topological median filter (TMF) was introduced in [4]. Since uncorrupted pixels are also processed, the quality of image filtering is degraded. Thus, noise detection is necessary before image filtering. A switching-based median filter was presented in [5]. However, the result of noise detection is not satisfactory.

Many algorithms have been proposed for the removal of salt and pepper noise from the image over the past two decades and some of the decision based algorithms, such as Centre Weighted Median Filter [7], Tri-State Median Filter (TSMF) [8], Adaptive Median Filter [9], Modified Decision Based Unsymmetric Median Filter (MDBUTMF) [10], Modified Decision Based Partially Trimmed Global Mean Filter (MDBPTGMF) [11], Impulse detector for switching median filters [12], Recursive Weighted Median Filter (RWMF) [13], Multi-State Median Filter (MSMF) [14], Progressive Switching Median filter [15], Noise adaptive fuzzy switching median filter (NAFSMF) [16], have been studied.

Chan et al. [17] presented an interesting work which proposes the removal of salt and pepper noise by using a two-phase scheme. At the first phase an adaptive median filter is used in order to identify pixels that can be considered as noise. In the second phase, the image is restored by a regularization method which eliminates noise and preserves edges by minimizing a functional which consists of a data fidelity term

as well as a regularization term that preserves edges and this concept requires more time for computation.
One of the most important issues in the image restoration is not only to remove noise associated with image but also to preserve the edge and texture details that image contains.
In this paper, Salt and Pepper Noise removal by Tolerance based Selective Arithmetic Mean Filtering Technique and Improved Tolerance based Selective Arithmetic Mean filtering technique is presented [18-19]. Mean while for fast and immediate high density noise removal approach has been analyzed. This paper is organized in the following way. In section II Image Processing Terminologies and Image Quality Measures; section III Algorithm of TSAMFT; section IV Level-1 and Level-2 ITSAMFT Algorithm; section V Applied or Proposed Method enhanced steps, section VI Presents the Experimental Results and Discussions; finally in section VII Conclusions are made.

II. Terminologies And Image Quality Measures

Image processing terminologies and image quality measure are given below and these are most commonly used objective quality measures.

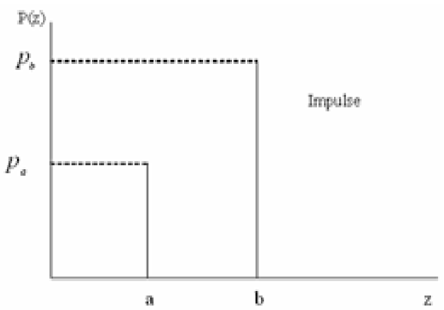
A. Probability Density Function (PDF):

Bipolar impulse noise is also known as salt and pepper noise. Its characteristic Probability Distribution Function (PDF) is shown in Figure.
The PDF of Salt and Pepper noise is given by

$$p(z) = \begin{cases} P_a & for\ z = a \\ P_b & for\ z = b \\ 0 & otherwise \end{cases}$$

As shown below in affected salt and pepper noise image, if a>b, gray-level **a** appears as a light dot in the image.
Conversely, level **b** appears like a dark dot. If either P_a or P_b is zero, the impulse noise is called unipolar.

Figure 1 a) Image affected by Salt and Pepper Noise



b) PDF of the Impulse noise

Fig.1 Image with Salt and Pepper Noise and PDF We can elaborate concept associated with noise impulse, the can be negative or positive. We use to assume or our main assumption is that a and b are saturated values in the digital images. As a result, negative impulses appear as black (Pepper) points in an image. For the same reason positive impulses appear as white (Salt) noises. For an 8 bit image this means that a=0 (black) and b=255 (white) [18,20].

B. Mean Square Error (MSE): Mean square error is collective difference between the compressed image and original image.

$$MSE = \frac{1}{MN}\sum_{ij}(y_{ij} - x_{ij})^2$$

C. *Peak Signal to Noise Ratio (PSNR):* Peak signal to noise ration van be calculated by ration between power of a signal and the the power of distorting noise that affects the main quality in digital image processing.

$$PSNR = 10\,log_{10}\left[\frac{255^2}{MSE}\right]$$

D. Correlation (COR): Correlation Filters are optimized to produce sharp peaks in the correlation output which brings perfection in images.

$$COR = \frac{\sum_{ij}^{MN}(y_{ij} - \mu_y)(x_{ij} - \mu_x)}{\sqrt{\sum_{ij}^{MN}(y_{ij} - \mu_y)^2 \sum_{ij}^{MN}(x_{ij} - \mu_x)^2}}$$

E. Image Enhancement Factor (IEF): Image enhancement factor will improve the interpretability or perception of information in images for human viewers.

$$IEF = \frac{\sum_i \sum_j(\eta_{ij} - x_{ij})^2}{\sqrt{\sum_i \sum_j(y_{ij} - x_{ij})^2}}$$

Where y_{ij}, x_{ij} and η_{ij} represents the pixel values of the restored image, original image and the noisy image respectively. *M×N is* the size of the image. μ_x and μ_y represent the mean of the original and restored images [18-20].

III. Algorithm of TSAMFT:

The Tolerance based Selective Arithmetic Mean Filtering Algorithm given below [15].
For each pixel *p* in the image;

1. Take a sub window of size *m×n around* that pixel.
2. Find out the number of pixels in the sub window by ignoring the pixels with the maximum (255) and minimum value (0).
3. 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 (AM) with the selected pixels. Otherwise, calculate Arithmetic Mean Value for all the pixels in the *m×n* sub window.
4. Calculate the Difference between Arithmetic Mean and the intensity of *p*.
   a. If Difference ≥ Tolerance then replace Intensity of *p* by AM
   b. Otherwise leave the pixel value unchanged.

This method performance during high density noise was not reached expected mark, hence the image recovered by using TSAMF algorithm is not good.

IV. Algorithm of ITSAMFT:

The TSAMFT algorithm works very well for low noise densities. When the noise density is very high then algorithm not achieved very good results.
However, when noise density is high, say more than 80, then it is highly unlikely that there might be more than 3 number of information pixels in every 3x3 mask. Thus, for better performance some changes to the basic algorithm is suggested and the same is given below.

1. Store all pixels of noisy image in a temporary matrix.

2. For every mask of size 3x3, find if the number of information pixel is greater than or equal to n_1 (say 1 and assume tolerance to be 0 as noise density is very high). If so, do the following steps.
   i). Calculate the Arithmetic Mean Value (AM) for the information pixels.
   ii). Calculate the Difference between Arithmetic Mean and pixel *p* in the mask.
      a) If Difference ≥ Tolerance then replace Intensity of *p* by AM
      b) Otherwise leave the pixel value unchanged.
3. If not, then extend the mask around the pixel of interest to size 5x5. If all the pixels in that mask are non informative then calculate the arithmetic mean of all pixels in that mask then go to step v. Otherwise follow the steps given below.
   i). Choose the very first information pixel in that mask and set the appropriate range.
   ii). Find the number of pixels within that range and calculate the sum of those pixels.
   iii). Find the number of pixels out of range and calculate the sum of those pixels.
   iv). If the numbers of pixels within that range greater than or equal to number of pixels out of range, then find the AM of pixels within the range. Otherwise, find the arithmetic mean of pixels out of range.
   v). Then, calculate the difference between the pixel of interest and Arithmetic mean.
4. If the difference is greater than tolerance then replace that pixel by arithmetic mean, otherwise that pixel information remains unchanged.
5. Once the mask operation is carried out for the entire image. For Level-2 ITSAMFT repeat steps 2 through 4 for the temporary image [19].
   This level based performs very well but LEVEL-1 and LEVEL-2 takes more time and for immediate effective response we need to enhance this method.

V. Proposed Filtering Algorithm:

The Fast and Enhanced Tolerance based Selective Arithmetic Mean Filtering Algorithm given below.

1. Initially take a sub window of size *5×5 around* pixel p in the image.
2. Find out the number of informative pixels in the 5x5 sub window by ignoring the pixels with the maximum (255) and minimum value (0).
   i) Calculate the Arithmetic Mean Value (AM) for the information pixels.
   ii) Calculate the Difference between Arithmetic Mean and pixel *p* in the mask.
      a) If Difference ≥ Tolerance then replace Intensity of *p* by AM
      b) Otherwise leave the pixel value unchanged.
   iii) If informative pixels are not their go to step 3.
3. Extend the window size to 7x7 around pixel p in the image again find out the number of informative pixels in the 7x7 sub window by ignoring the pixels with the maximum (255) and minimum value (0).
   i) Calculate the Arithmetic Mean Value (AM) for the information pixels.
   ii) Calculate the Difference between Arithmetic Mean and pixel *p* in the mask.
      a) If Difference ≥ Tolerance then replace Intensity of *p* by AM
      b) Otherwise leave the pixel value unchanged.
   iii) If informative pixels are not their go to step 4.
4. Extend the window size to 9x9 around pixel p in the image again find out the number of informative pixels in the 9x9 sub window by ignoring the pixels with the maximum (255) and minimum value (0).
   i) Calculate the Arithmetic Mean Value (AM) for the information pixels.
   ii) Calculate the Difference between Arithmetic Mean and pixel *p* in the mask.
      a) If Difference ≥ Tolerance then replace Intensity of *p* by AM
      b) Otherwise leave the pixel value unchanged.
   iii) If informative pixels are not their go to step 5.
5. If all the pixels in that mask are non informative then calculate the arithmetic mean of all pixels in that mask then go to step 6.
6. If the difference is greater than tolerance then replace that pixel by arithmetic mean, otherwise that pixel information remains unchanged.

Finally compute the MSE, PSNR, Correlation and IEF to analyze the performance of TSAMFT, ITSAMFT Level-1 and Level-2 along with proposed algorithm FETSAMFT.

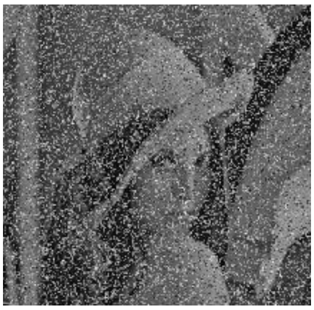
VI. Experimental Results and Discussion

The simulation is carried out in MATLAB for TSAMFT ITSAMFT LEVEL-1, ITSAMFT LEVEL-2 and FETSAMFT to analyze best performing algorithm along with computational time consideration that it akes to complete and view resultant image.

We tried out experimental results for different 8-bits/pixel images. In this we have represented with 512X512, 8-bits/pixel Lena Image. Experimental results presented in this paper shows performance analysis for noise density level 80, 90, 91, 92, 93, 94 and 95.

Fig.2 Lena Image

The results are shown in Table I-IV for different high noise density levels. And few compared resultant images for noise density level 80, 90, 91 and 92 are shown below for high density salt and pepper noise removal



(a) TSAMFT

(b) ITSAMFT Level-1

(c) ITSAMFT Level-2

(d) FETSAMFT

Fig.3 Shows computed images for noise density 80% for (a) TSAMFT (b) Level-1 ITSAMFT (c) Level-2 ITSAMFT (d) FETSAMFT

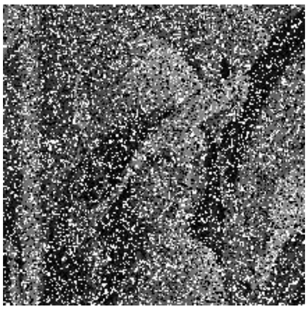
(a) TSAMFT

(b) ITSAMFT Level-1

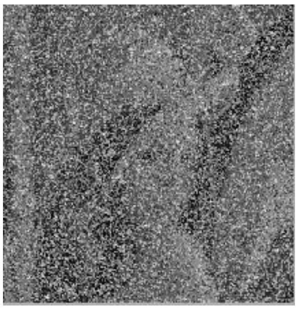
(c) ITSAMFT Level-2

(d) FETSAMFT

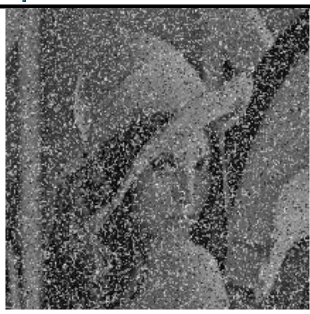
Fig.4 Shows computed images for noise density 90% for (a) TSAMFT (b) Level-1 ITSAMFT (c) Level-2 ITSAMFT (d) FETSAMFT



(a) TSAMFT



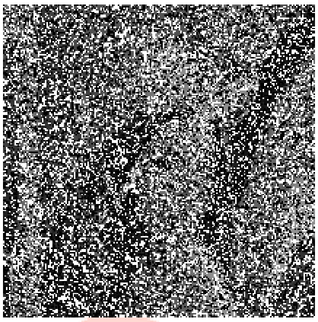
(b) ITSAMFT Level-1



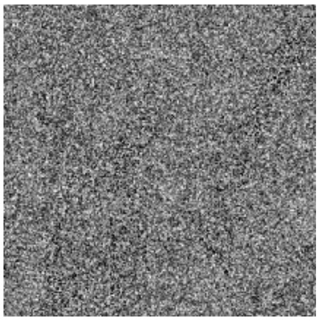
(c) ITSAMFT Level-2

(d) FETSAMFT

Fig.5 Shows computed images for noise density 91% for (a) TSAMFT (b) Level-1 ITSAMFT (c) Level-2 ITSAMFT (d) FETSAMFT



(a) TSAMFT



(b) ITSAMFT Level-1

(c) ITSAMFT Level-2

(d) FETSAMFT

Fig.6 Shows computed images for noise density 91% for (a) TSAMFT (b) Level-1 ITSAMFT (c) Level-2 ITSAMFT (d) FETSAMFT

Table I: For Lena Image Mean Square Error (MSE) Analysis:

MEAN SQUARE ERROR (MSE)				
Noise Density	**TSAMFT**	**ITSAMFT Level-1**	**ITSAMFT Level-2**	**FETSAMFT**
80%	**3186**	**162.3**	**106**	**101**
90%	**4700**	**502**	**220**	**190**
91%	**4825**	**594**	**380**	**328**
92%	**4958**	**820**	**440**	**418**
93%	**4985**	**956**	**602**	**529**
94%	**5052**	**1078**	**802**	**649**
95%	**5279**	**1570**	**1156**	**897**

Table II: Peak Signal To Noise Ratio (PSNR) Analysis:

PEAK SIGNAL TO NOISE RATIO (PSNR)				
Noise Density	**TSAMFT**	**ITSAMFT Level-1**	**ITSAMFT Level-2**	**FETSAMFT**
80%	**13.2**	**25**	**29.2**	**31.9**
90%	**7.5**	**12**	**20.8**	**24.1**
91%	**12.3**	**22.86**	**25.3**	**27.8**
92%	**11.8**	**22.1**	**23.3**	**29.3**
93%	**12.1**	**19.3**	**22.7**	**27.2**
94%	**11.56**	**17.3**	**21.2**	**23.19**
95%	**11.98**	**17.2**	**19.85**	**20.81**

Table III: Correlation (COR) Analysis:

Correlation (COR)				
Noise Density	**TSAMFT**	**ITSAMFT Level-1**	**ITSAMFT Level-2**	**FETSAMFT**
80%	**0.447**	**0.948**	**0.952**	**0.952**
90%	**0.374**	**0.852**	**0.914**	**0.928**
91%	**0.184**	**0.818**	**0.856**	**0.881**
92%	**0.188**	**0.779**	**0.823**	**0.869**
93%	**0.179**	**0.745**	**0.812**	**0.847**
94%	**0.147**	**0.632**	**0.717**	**0.768**
95%	**0.115**	**0.421**	**0.594**	**0.657**

Table IV: Image Enhancement Factor (IEF) Analysis:

Image Enhancement Factor (IEF)				
Noise Density	**TSAMFT**	**ITSAMFT Level-1**	**ITSAMFT Level-2**	**FETSAMFT**
80%	**5.1**	**109.8**	**133.7**	**189.5**
90%	**4.1**	**39.1**	**59.66**	**71.5**
91%	**4.16**	**35.5**	**50.2**	**63.89**
92%	**4.18**	**23.89**	**44.089**	**46.3**
93%	**4.2**	**19.9**	**31.4**	**39.3**
94%	**4.8**	**18.9**	**25**	**27.7**
95%	**4.5**	**11.4**	**20**	**23**

The simulated results obtained for FETSAMFT gives better results than the TSAMFT, ITSAMFT Level-1 and Level-2 and it is recommended that for images corrupted with higher noise densities.

VII. CONCLUSION

Experimental analysis in MATLAB R2020a for FETSAMFT, Level-1 and Level-2 ITSAMFT, TSAMFT at different noise densities levels shown that if the noise density is low then almost every simplified algorithm will perform action and gives better results for low density levels. Especially for high density noise where more information has to be retained we need effective algorithm with less time constraint and FETSAMFT filtering technique resulted with highest PSNR (dB), Correlation and Image Enhancement Factor. Finally it is clear that for images corrupted with higher noise densities FETSAMFT is used to filer the images to improve and extract required information.

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