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# Comparative Performance Analysis of Enhanced Salt and Pepper Noise Removal Algorithms in Image Restoration

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**ABSTRACT:** Digital images and their information contribution play a very important role in many applications in our today's life. Images should to be not affected by noise while transmitting, acquiring images by sensors or by environmental effects etc. If the image gets affected by noise then we need effective denoising methods to make or regain effective information related to particular image. Today this is very challenging role to researchers and researches are still going on with this view using several algorithms. Very well known salt and pepper noise or impulse can be normally removed with well know mean and median filters. But same cannot be applied to all noise density levels. Effective algorithm considerations are main challenge for us today because we have numerous algorithms and techniques in denoising concept in removal of impulse noise. Maximum efforts made to resolve this problem by considering and comparing the following algorithms or techniques based on tolerance level. They are Tolerance based Selective Arithmetic Mean Filtering Technique (TSAMFT), Improved Tolerance based Selective Arithmetic Mean Filtering (ITSAMFT), Effective Enhanced Tolerance based Selective Arithmetic Mean Filtering Technique for Image Restoration (EETSAMFT) and Fast and enhanced Tolerance based Selective Arithmetic Mean Filtering Technique (FETSAMFT). These are the techniques considered in our state of art comparison and explored simulated MATLAB results so that technique can be immediately applied to bring major effectiveness in impulse noisy image.

**KEYWORDS:** Tolerance based Selective Arithmetic Mean Filtering Technique (TSAMFT), Improved Tolerance based Selective Arithmetic Mean Filtering Technique (ITSAMFT), Effective Enhanced Tolerance based Selective Arithmetic Mean Filtering Technique (EETSAMFT), Fast and enhanced Tolerance based Selective Arithmetic Mean Filtering Technique (FETSAMFT), Mean Square Error (MSE), Peak Signal to Noise Ratio, Tolerance, Noise density, Density level, Salt and Pepper Noise, Arithmetic Mean Value.

## I. INTRODUCTION

Noise removal in an image is important in image processing because noise can bring a great deal amount of problems such as degraded the quality image and loss of crucial information in image. Therefore, image filtering technique has been introduced to overcome the problems. One of the common noises in image is Salt and Pepper noise [1]. The median filter was once the most popular nonlinear filter for removing impulse noise, because of its good denoising power[2] and computational efficiency[3]. Mean and Median filters most widely used but as noise density increases then performance decreases. To overcome these problems we have several denoising techniques such as Centre Weighted Median Filter[4], Adaptive Median Filter[5], Modified Decision Based Partially Trimmed Global Mean Filter (MDBPTGMF)[6], a switching-based median filter [7], Tri-State Median Filter (TSMF)[8], Modified Decision Based Unsymmetric Median Filter (MDBUTMF)[9], Noise adaptive fuzzy switching median filter (NAFSMF)[10], Multi-State Median Filter (MSMF)[11], Impulse detector for switching median filters[12], Recursive Weighted Median Filter(RWMF)[13]. 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 [14],

In this paper comparison of Salt and Pepper Noise removal by Tolerance based Selective Arithmetic Mean Filtering Technique, Improved Tolerance based Selective Arithmetic Mean filtering technique is presented [15-16], Effective Enhanced Tolerance based Selective Arithmetic Mean Filtering Technique for Image Restoration (EETSAMFT) and Fast and Enhanced Tolerance based Selective Arithmetic Mean Filtering Technique (FETSAMFT) has been compared.

Proposed paper is organized in the following manner. In section II Various Comparative Measures; section III Algorithm of TSAMFT; section IV Level-1 and Level-2 ITSAMFT Algorithm; section V Algorithm of EETSAMFT section VI FETSAMFT section VII Presents the Experimental Results and Discussions; finally in section VIII Conclusions are made.

## II. VARIOUS COMPARATIVE PARAMETERS

As we know in comparison we need various parameters to explore best technique and for that we considered following most commonly used objective quality measures as explained below.

### A. Probability Density Function (PDF):

Characteristic Probability Distribution Function (PDF) is shown in Figure 1 a). Salt and Pepper noise is also known as Bipolar impulse noise. Its

We know that PDF of Salt and Pepper noise is given by

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

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) PDF of the Impulse noise b) Image affected by Salt and Pepper Noise

Fig.1 shows PDF and Image with Salt and Pepper Noise. We can elaborate concept associated with noise impulse, this 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) [15,16].

**B) Mean Square Error (MSE):** Calculates the average of squared errors. The Low value of MSE will give a low error and hence results would be better.

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

**C) Peak Signal to Noise Ratio (PSNR):** PSNR evaluates the peak signal to noise ratio, in between the input image i.e. the original image and therefore the filtered output i.e. reconstructed image which is obtained after performing filtering on the input. Higher value of PSNR gives high filtering value so by calculating the PSNR values of different types of filters we can analyse which type of filter is best for the noise removal from an image.

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

**D) Correlation (COR):** Correlation Filters are optimized to produce sharp peaks in the correlation output and these will enhance image information which brings perfection in images.

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

**E) Image Enhancement Factor (IEF):** To show improved interpretability and perception of information in images for human viewers' image enhancement factor plays a very important role.

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

Where  $y_{ij}$ ,  $x_{ij}$  and  $\eta_{ij}$  represents the pixel values of the restored image, original image and the noisy image respectively.  $M \times N$  is the size of the image.  $\mu_x$  and  $\mu_y$  represent the mean of the original and restored images [15-16].

### III. ALGORITHM OF TSAMFT

In this comparison of various enhanced methods base paper technique Tolerance based Selective Arithmetic Mean Filtering Technique plays very important role and is explained below [15].

For each pixel  $p$  in the image;

1. Take a sub window of size  $m \times n$  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  $m \times n$  then calculate the Arithmetic Mean Value (AM) with the selected pixels. Otherwise, calculate Arithmetic Mean Value for all the pixels in the  $m \times n$  sub window.
4. Calculate the Difference between Arithmetic Mean and the intensity of  $p$ .
  - a. If Difference  $\geq$  Tolerance then replace Intensity of  $p$  by AM
  - b. Otherwise leave the pixel value unchanged.

This TSAMFT algorithm will not reach expected level for high and very high level noise densities.

### IV. ALGORITHM OF ITSAMFT

Considered base paper improved version is improved technique is Improved TSAMFT algorithm explained below [19]. Reason to consider this paper Improved TSAMFT as compared to TSAMFT is 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  $3 \times 3$  mask. Thus, to get better information some changes to the basic algorithm is suggested and ITSAMFT algorithm explained below.

1. Store all pixels of noisy image in a temporary matrix.
2. For every mask of size  $3 \times 3$ , 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  $\geq$  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  $5 \times 5$ . 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 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 [16].

This algorithm consisting of Level-1 and Level-2 makes it effective if tolerance level is very well know and also it takes more computational time to execute its levels.

#### V. ALGORITHM OF EETSAMFT

Salt and Pepper noise removal by Effective Enhanced Tolerance based Selective Arithmetic Mean Filtering Technique for Image Restoration method we explained here after considering both above algorithms

1. In the beginning start by taking a sub window of size  $3 \times 3$  around considered pixel  $p$  in the image.
  2. Calculate the number of informative pixels in the  $3 \times 3$  sub window by ignoring the pixels with the maximum (255) and minimum value (0).
    - i) Calculate the Arithmetic Mean Value for the information pixels.
    - ii) Calculate the Difference between Arithmetic Mean of the informative pixel and considered pixel  $p$  in the mask.
      - a) If  $\text{Difference} \geq \text{Tolerance}$  then replace Intensity of considered pixel  $p$  by calculated Arithmetic Mean Value.
      - b) Otherwise leave the considered pixel value unchanged.
    - iii) If informative pixels are not found in this considered sub window of size  $3 \times 3$  then go to step 3.
  3. the sub window size to  $5 \times 5$  around pixel  $p$  in the image again find out the number of informative pixels in the  $5 \times 5$  sub window by ignoring the pixels with the maximum (255) and minimum value (0).
    - i) Calculate the Arithmetic Mean Value for the information pixels.
    - ii) Calculate the Difference between Arithmetic Mean of the informative pixel and considered pixel  $p$  in the mask
      - a) If  $\text{Difference} \geq \text{Tolerance}$  then replace Intensity of considered pixel  $p$  by calculated Arithmetic Mean Value.
      - b) Otherwise leave the considered pixel value unchanged.
    - iii) If informative pixels are not found in this considered sub window of size  $5 \times 5$  then go to step 4.
  4. Extend the window size to  $7 \times 7$  around pixel  $p$  in the image again find out the number of informative pixels in the  $7 \times 7$  sub window by ignoring the pixels with the maximum (255) and minimum value (0).
    - i) Calculate the Arithmetic Mean Value for the information pixels.
    - ii) Calculate the Difference between Arithmetic Mean of the informative pixel and considered pixel  $p$  in the mask
      - a) If  $\text{Difference} \geq \text{Tolerance}$  then replace Intensity of considered  $p$  by calculated Arithmetic Mean Value.
      - b) Otherwise leave the considered pixel value unchanged.
    - iii) If informative pixels are not found in this considered sub window of size  $7 \times 7$  then go to step 5.
  5. Extend the window size to  $9 \times 9$  around pixel  $p$  in the image again find out the number of informative pixels in the  $9 \times 9$  sub window by ignoring the pixels with the maximum (255) and minimum value (0).
    - i) Calculate the Arithmetic Mean Value for the information pixels.
    - ii) Calculate the Arithmetic Mean Value of all pixels in the given mask or sub window of size  $9 \times 9$ .
    - iii) Calculate the Difference between Arithmetic Mean of the informative pixel and considered pixel  $p$  in the mask.
      - a) If  $\text{Difference} \geq \text{Tolerance}$  then replace Intensity of considered  $p$  by calculated Arithmetic Mean Value of the informative pixel.
      - b) Otherwise leave the considered pixel value unchanged.
    - iii) If informative pixels are not found in this considered sub window of size  $9 \times 9$  then replace Intensity of considered  $p$  by calculated Arithmetic Mean Value of all pixels in the considered  $9 \times 9$  sub window.
- This algorithm plays a very important role even if tolerance is not know very well but takes more time to execute when noise density level is very high

### VI. ALGORITHM OF FETSAMFT

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

1. Initially take a sub window of size  $5 \times 5$  around pixel  $p$  in the image.
2. Find out the number of informative pixels in the  $5 \times 5$  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  $\text{Difference} \geq \text{Tolerance}$  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  $7 \times 7$  around pixel  $p$  in the image again find out the number of informative pixels in the  $7 \times 7$  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  $\text{Difference} \geq \text{Tolerance}$  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  $9 \times 9$  around pixel  $p$  in the image again find out the number of informative pixels in the  $9 \times 9$  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.
    - c) If  $\text{Difference} \geq \text{Tolerance}$  then replace Intensity of  $p$  by AM
    - d) 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.

This above explained algorithm plays very important role when the noise density level is very high. Finally compute the MSE, PSNR, Correlation and IEF to analyse the performance of TSAMFT, ITSAMFT Level-1 and Level-2, EETSAMFT and FETSAMFT.

### VII. EXPERIMENTAL RESULTS

MATLAB 2020a based simulation is carried out for TSAMFT, ITSAMFT LEVEL-1, ITSAMFT LEVEL-2, EETSAMFT and FETSAMFT to know the performance of various algorithms along with time constraint and explored resultant image.

We tried out experimental results for different 8-bits/pixel images. In these experimental explanations we have suggested with  $512 \times 512$ , 8-bits/pixel Lena Image. Experimental analysis carried out in this paper shows performance analysis for noise density level 50, 60, 70, 80, 90, 91, 92, 93, 94 and 95.

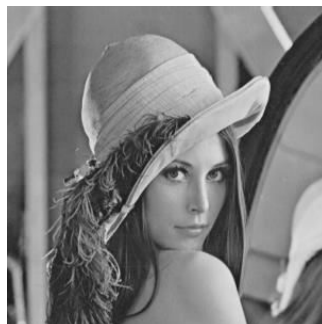


Fig.2 Lena Image



The results are shown in Table I-IV for different noise density levels. And compared resultant images for noise density level are varied from 50, 60, 70, 80, 90, 91, 92, 93, 94 and 95 are shown below.

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

MEAN SQUARE ERROR (MSE)					
Noise Density	TSAMFT	ITSAMFT Level-1	ITSAMFT Level-2	EETSAMFT	FETSAMFT
50%	2347	1734	1568	1365	3487
60%	2215	965	135	122	2651
70%	2627	174	135	117	1378
80%	3186	162.3	106	94	101
90%	4700	502	220	158	190
91%	4825	594	380	420	328
92%	4958	820	440	458	418
93%	4985	956	602	529	529
94%	5052	1078	802	568	649
95%	5279	1570	1156	1357	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	EETSAMFT	FETSAMFT
50%	19.2	22	26	27	11.58
60%	17.5	18.23	26.8	27.3	12.7
70%	11.5	15.18	26.83	27.42	17.3
80%	13.2	25	29.2	31.4	31.9
90%	7.5	12	20.8	21.7	24.1
91%	12.3	22.86	25.3	26.2	27.8
92%	11.8	22.1	23.3	24	29.3
93%	12.1	19.3	22.7	23.88	27.2
94%	11.56	17.3	21.2	21.8	23.19
95%	11.98	17.2	19.85	20.3	20.81

Table III: Correlation (COR) Analysis:

Correlation (COR)					
Noise Density	TSAMFT	ITSAMFT Level-1	ITSAMFT Level-2	EETSAMFT	FETSAMFT
50%	0.692	0.712	0.744	0.748	0.465
60%	0.577	0.874	0.898	0.916	0.598
70%	0.501	0.962	0.911	0.927	0.723
80%	0.447	0.948	0.952	0.952	0.952
90%	0.374	0.852	0.914	0.921	0.928
91%	0.184	0.818	0.856	0.865	0.881
92%	0.188	0.779	0.823	0.835	0.869
93%	0.179	0.745	0.812	0.853	0.847
94%	0.147	0.632	0.717	0.776	0.768
95%	0.115	0.421	0.594	0.682	0.657

Table IV: Image Enhancement Factor (IEF) Analysis:

Image Enhancement Factor (IEF)					
Noise Density	TSAMFT	ITSAMFT Level-1	ITSAMFT Level-2	EETSAMFT	FETSAMFT
50 %	23	29	43	47	21
60 %	27	33	41	43	26
70 %	15	67	73	81	33
80 %	5.1	109.8	133.7	143.5	189.5
90 %	4.1	39.1	59.66	61.8	71.5
91 %	4.16	35.5	50.2	56.78	63.89
92 %	4.18	23.89	44.089	48.9	46.3
93 %	4.2	19.9	31.4	32.4	39.3
94 %	4.8	18.9	25	25.7	27.7
95 %	4.5	11.4	20	22	23



Fig.3 Shows computed images for noise density level 50%



Fig.4 Shows computed images for noise density level 60%



Fig.5 Shows computed images for noise density level 70%





TSAMFT ITSAMFT Level-1 ITSAMFT Level-2 EETSAMFT FETSAMFT

Fig.6 Shows computed images for noise density level 80%



TSAMFT ITSAMFT Level-1 ITSAMFT Level-2 EETSAMFT FETSAMFT

Fig.7 Shows computed images for noise density level 90%



TSAMFT ITSAMFT Level-1 ITSAMFT Level-2 EETSAMFT FETSAMFT

Fig.8 Shows computed images for noise density level 91%



TSAMFT ITSAMFT Level-1 ITSAMFT Level-2 EETSAMFT FETSAMFT

Fig.9 Shows computed images for noise density level 92%

Comparative study from simulated results shown in table with respective noise density levels and observing from images we can conclude that tolerance based selective arithmetic mean filtering will not well as noise density level increases, similarly ITSAMFT algorithm works well only if proper tolerance level known and fails to works without proper tolerance concluded with both Level-1 and Level-2 of ITTSAMFT and also FETSAMFT will perform well only if noise density level is high or more and comparatively EETSAMFT performed well and we got better results. Hence we performed this experiment on cameramen, vegetables, coins etc. Results oriented with EETSAMFT performed really better than other algorithms.

## VIII. CONCLUSION

We have studied many different algorithms related with digital images and also with discussion and performance analysis we came to know that EETSAMFT performs best along with Level-2 ITSAMFT and Level-1 ITSAMFT but when noise density is high and tolerance not known then even these two technique performance is not up to expected mark and finally the last one FETSAMFT performs very good only for high density noise levels. We also placed time computational method where FETSAMFT makes best for high noise density level and EETASMFT takes long but results are better and In ITSAMFT especially during level-2 it takes more computational time to execute. We have applied suggested algorithm and found our EETSAMFT is better. Further analysis has to be carried to analyse different denoising techniques with parametric analysis.

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