

Median Filter for Noise Removal using Particle Swarm Optimization

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ABSTRACT

Adaptive median filter has been an efficient algorithm for salt and pepper noise removal. But, if the noise percentage are very high, adaptive median filter may still remain noise regions in result image. So a Particle swarm optimization based novel and modified adaptive median filter (PSOMF) is proposed. The Proposed filter works in two stages: Noise detection stage and noise filtering stage. Particle swarm optimization is a simple algorithm that seems to be effective for optimizing a wide range of functions. Noise Detection stage works on it. First, a test decides whether or not a given pixel is contaminated by impulse noise. If contaminated, a median filter is applied. Simulation results show that our method is significantly better than a number of existing techniques in term of image restoration and noise detection, even for noise levels as high as 90%.

General Terms

Image Restoration, Genetic Algorithms, Adaptive Median filter.

Keywords

Particle Swam Optimization, Impulse Noise, PSNR, IQI, SSIM.

1. INTRODUCTION

Noise gets introduced in image via any electrical system used for storage, transmission or processing. Random impulse noise, also known as spike noise or Salt and Pepper, occurs when a pixel takes on either the maximum or minimum value possible generating black or white pixels. It has either 0 or 255 value.

Non-linear median filter (MED) filter is often used to remove noise [1]. Median filter cannot distinguish fine detail from noise. An adaptive median filter (ASMF) preserves fine details as compare to MED filter. For low and medium noise density, the ASMF had a good performance [2]. To improve the performance for the case of high noise density, a modified ASMF filter was introduced. A universal noise removal algorithm works both on Gaussian as well as impulse noise. It gives better results than SD-ROM filter [3]. A rank-order thresholding-based and a soft-switching impulse detector were shown work well under high noise corruption but at the cost of significantly increasing computational complexity [4]. Predictive-based adaptive switching median filter (PASMf) is two stage filter consist of neural network based noise detector [5]. It takes three inputs median filter, rank-ordered logarithmic difference (ROLD), central pixel and median value generates the noise map. PASMf handles noise upto 70 percent. Its performance is degrades with highly corrupted images. In this paper, a new noise removal filter based on genetic algorithm is proposed, which exhibits better results than many other more complicated detectors. The experimental results show that the proposed filter gives

significantly better results in terms of Peak-Signal-to-Noise Ratio (PSNR), Image Quality Index (IQI) [6], Structured Similarity Index (SSIM) [7].

Proposed filter works efficiently on highly corrupted images. Experimental results show that this method produces good output, even when tested with the high level of noise.

2. NOISE MODELS

To demonstrate the superior performance of the proposed method, experiments have been conducted on two different noise models with different noise densities [8].

2.1 Noise Model 1

Noise is modelled as salt-and-pepper impulse noise, where pixels are randomly corrupted by two fixed values, 0 and 255 (for gray-level image), generated with the same probability. That is, for each image pixel at location (i, j) with intensity value $S_{i,j}$ the corresponding pixel of the noisy image will be $X_{i,j}$ in which the probability density function of $X_{i,j}$ is,

$$P(x) = \begin{cases} P/2 & \text{for } x=0 \\ P/2 & \text{for } x=255 \\ 1-P & \text{for } x=S_{i,j} \end{cases} \quad (1)$$

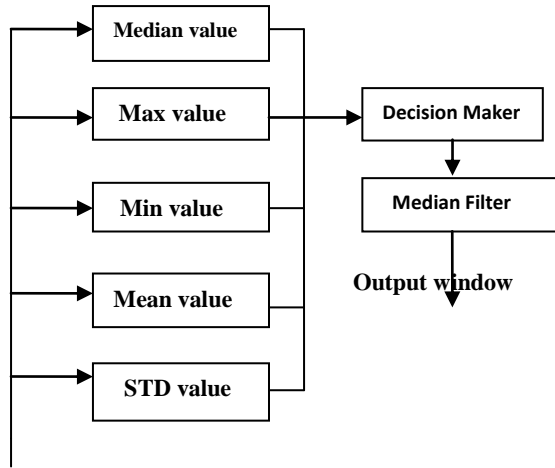
2.2 Noise Model 2

Instead of two fixed values, impulse noise could be modeled by two fixed ranges that appear at both ends with a length of m each, respectively. That is, noise will equal likely be any value in the range of either [0,m] or [255-m, 255]. The probability density function of $X_{i,j}$ will be,

$$P(x) = \begin{cases} P/2m & \text{for } 0 \leq x < m \\ P/2m & \text{for } x=(255-m) < x \leq 255 \\ 1-P & \text{for } x=S_{i,j} \end{cases} \quad (2)$$

3. PROPOSED FILTER

A novel and modified adaptive median filter, called Particle swarm optimization based median (PSOMF) filter, is proposed and discussed in this section [9,10]. A Proposed MF filter is works in two steps. First, a test decides whether or not a given pixel is contaminated by impulse noise. If contaminated, a median filter is applied.



Input window

Fig1. Block diagram of Proposed Filter

3.1 Decision Maker

In Proposed filter first step is to train the filter for generating noise map. We initialized 1000 Pixels. In which 500 Pixels are uncorrupted and 500 Pixels are corrupted. Now calculating the value of median value, maximum value, minimum value, mean value and standard deviation of 3 X 3 sliding window. These values are become pbest values of features. After 1000 Iterations pbest features taking value of gbest. For finding the corrupted Pixels, comparing the outcomes of FVT (Feature vector Table) with threshold value. If value is above the threshold means corrupted Pixel, if below then uncorrupted Pixel.

$$\text{NoiseMap}(i, j) = \begin{cases} 0 & \text{if output of FVT} < 1 \\ 1 & \text{if output of FVT} \geq 1 \end{cases} \quad (3)$$

3.2 Filtering Stage

Filter uses a 3 × 3 sliding window W, which is located on the corrupted pixel as its centre (X_{i,j}). Filter simply calculates the median of uncorrupted neighboring pixels and replaces the value of central pixel by the computed median value [11].

4. EXPERIMENTAL OUTCOMES

The performance of the filtering process is measured using Four different noise models. The PSNR, IQI (Image Quality Index) values are measured with different noise percentage.

$$\text{PSNR} = 10 \log_{10} (255^2/\text{MSE}) \quad (4)$$

Where $\text{MSE} = \sum_m \sum_n [O(m, n) - R(m, n)]^2 / (MN)$

Where O is the original image, R is the restored image, MSE is the mean squared error, M × N is the size of the image. Here Size of gray scale image is 512 × 512. This Image quality index models is a combination of three different

factors: loss of correlation, luminance distortion, and contrast distortion [6].

$$\text{IQI}_w = \text{Corr}(O_w, R_w) \times \text{Lum}(O_w, R_w) \times \text{Cont}(O_w, R_w) \quad (5)$$

The local quality index IQI_w is computed within a particular sliding window W. O_w and R_w represent the sliding window of original and restored images, respectively [8,15]. The dynamic range of IQI is [-1, 1]. The best value 1 is achieved if and only if restored image R is equal to the original image O. Black dots in Image quality map shows dissimilarity in original and restored image while white dots shows similarity. Light colour map shows excellent result.

The complete definition of similarity measures three components Luminance, contrast and Structure are combined to yield an overall similarity measure. The similarity measure to satisfy the following conditions.

- 1) Symmetry: S(x,y) = S(y,x).
- 2) Boundedness: S(x,y) ≤ 1.
- 3) Unique maximum: S(x,y) = 1 if and only if x=y.

Table 1. PSNR values with Boat Image (Noise Model 1)

NOISE %	MED [5]	AMED [5]	Kaliraj et al.[5]	PASMF [5]	Proposed MF
90	8.38	10.32	22.51	22.72	33.2169
80	12.71	15.46	24.59	25.01	33.8129
70	17.37	20.96	24.59	26.90	35.0247
60	20.43	25.03	27.83	28.25	36.3066
50	21.72	27.13	29.62	29.55	36.4634
40	22.60	28.52	30.78	30.91	38.4692
30	23.21	30.40	32.37	32.55	39.8055
20	24.06	32.21	34.53	34.91	41.5329
10	24.91	33.91	37.80	38.20	44.6177

To verify the advantage and effectiveness of our filtering algorithm, a gray-scale Lena, Boat image whose size is 512 × 512 are selected. The Canny operator is used for calculating the edge maps [12]. Edge map of original and corrupted image are shown in every case. To further check the performance of the proposed algorithm, a one-dimensional signal (200 row) of original and corrupted image has been shown in the form of a graph. Figure 2 and 3 shows the image results based on noise model 1. Figure 3 and 4 shows the image results based on model 2.

Table 2. SSIM Values Obtained For Boat Image Based On Noise Model 1

NOISE %	MED[5]	AMED[5]	Kaliraj et al.[5]	PASMF[5]	Proposed MF
90	0.167	0.316	0.909	0.913	0.9646
80	0.482	0.666	0.943	0.948	0.9704
70	0.758	0.885	0.961	0.967	0.9772
60	0.868	0.953	0.973	0.976	0.9825
50	0.899	0.970	0.980	0.982	0.9861
40	0.916	0.978	0.986	0.989	0.9920
30	0.927	0.986	0.990	0.991	0.9940
20	0.939	0.990	0.994	0.995	0.9963
10	0.949	0.993	0.997	0.999	0.9983

Table 3. IQI Values Obtained For Boat Image Based On Noise Model 1

NOISE %	MED[5]	AMED[5]	Kaliraj et al.[5]	PASMF[5]	Proposed MF
90	0.023	0.064	0.553	0.559	0.9503
80	0.104	0.258	0.691	0.699	0.9582
70	0.251	0.505	0.772	0.779	0.9658
60	0.347	0.659	0.834	0.839	0.9731
50	0.389	0.736	0.876	0.879	0.9784
40	0.406	0.788	0.907	0.911	0.9860
30	0.416	0.835	0.939	0.941	0.9896
20	0.426	0.865	0.961	0.965	0.9934
10	0.433	0.875	0.982	0.984	0.9968

Table 4. PSNR Values Obtained For Lena Image Based On Noise Model 2

NOISE %	MED[5]	AMED[5]	PASMF[5]	Proposed MF
90	08.76	10.64	26.592448	33.1224
80	13.33	16.05	29.097967	34.0440
70	18.53	21.92	31.387784	35.3951
60	22.14	27.23	32.956618	36.0677
50	23.65	30.09	34.476593	37.0928
40	24.51	31.79	36.290139	39.3405
30	25.48	33.85	38.310070	39.9616
20	27.00	35.97	40.202637	42.1757
10	28.47	38.18	44.226346	45.0307

In table 1, 2 and 3 Proposed filter was compared with standard median filter (MED), adaptive median filter (AMED), Kaliraj et al.[13] and Predictive-based adaptive switching median filter (PASMF) on PSNR, IQI, SSIM Value. In table 4, 5 and 6 proposed filter was compared with standard median filter (MED), adaptive median filter (AMED) and Predictive-based adaptive switching median filter (PASMF). In the last image of every figure image quality map of restored image is shown [14]. Black dots in Image Quality map shows dissimilarity of original image with restored image. Light Quality map shows resemblance of original and restored image.

Table 5. IQI Values Obtained For Lena Image Based On Noise Model 2

NOISE %	MED[5]	AMED[5]	PASMF[5]	PSOMF
90	0.022	0.057	0.658	0.951
80	0.123	0.271	0.779	0.960
70	0.325	0.549	0.845	0.973
60	0.463	0.703	0.888	0.978
50	0.518	0.777	0.917	0.984
40	0.538	0.827	0.942	0.990
30	0.553	0.865	0.961	0.991
20	0.5632	0.887	0.973	0.995
10	0.569	0.894	0.989	0.997

Table 6. SSIM Values Obtained For Lena Image Based On Noise Model 2

NOISE %	MED[5]	AMED[5]	PASMF[5]	PSOMF
90	0.2041	0.3432	0.94638	0.9614
80	0.5413	0.7137	0.96972	0.9687
70	0.8201	0.9132	0.98219	0.9803
60	0.9162	0.9731	0.98759	0.9843
50	0.9404	0.9863	0.99125	0.9893
40	0.9506	0.9914	0.99424	0.9938
30	0.9609	0.9946	0.99638	0.9946
20	0.9714	0.9963	0.99861	0.9974
10	0.9791	0.9988	0.99899	0.9985

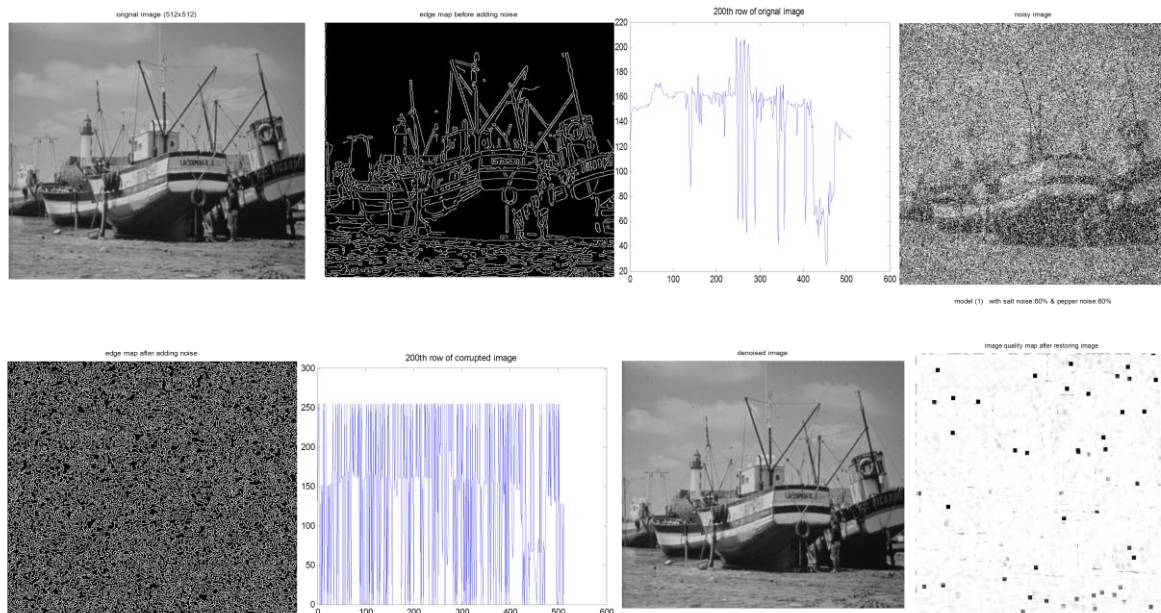


Fig 2. Boat image corrupted by 60% noise based on noise model 1

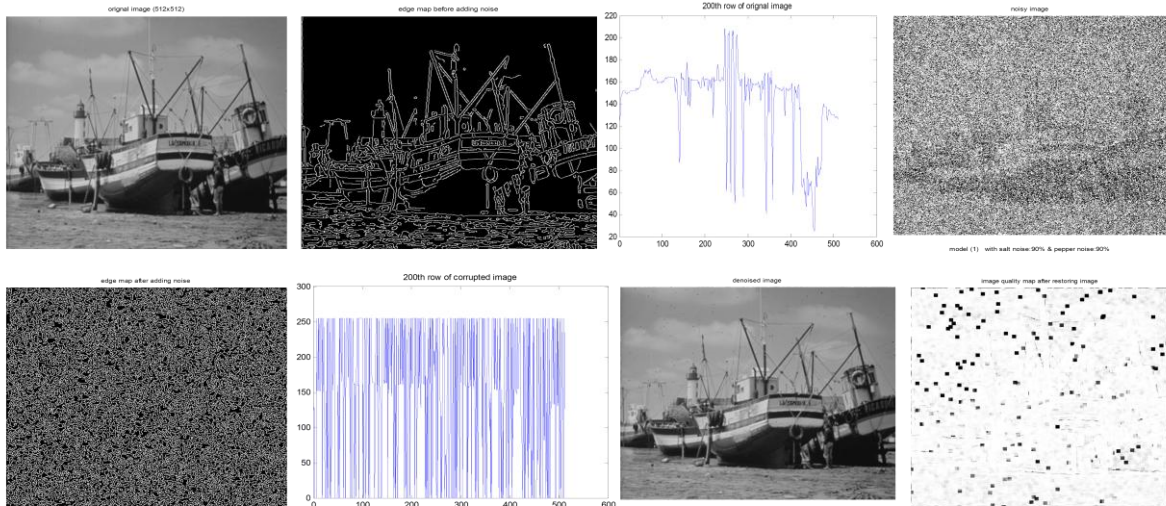


Fig 3. Boat image corrupted by 90% noise based on noise model 1

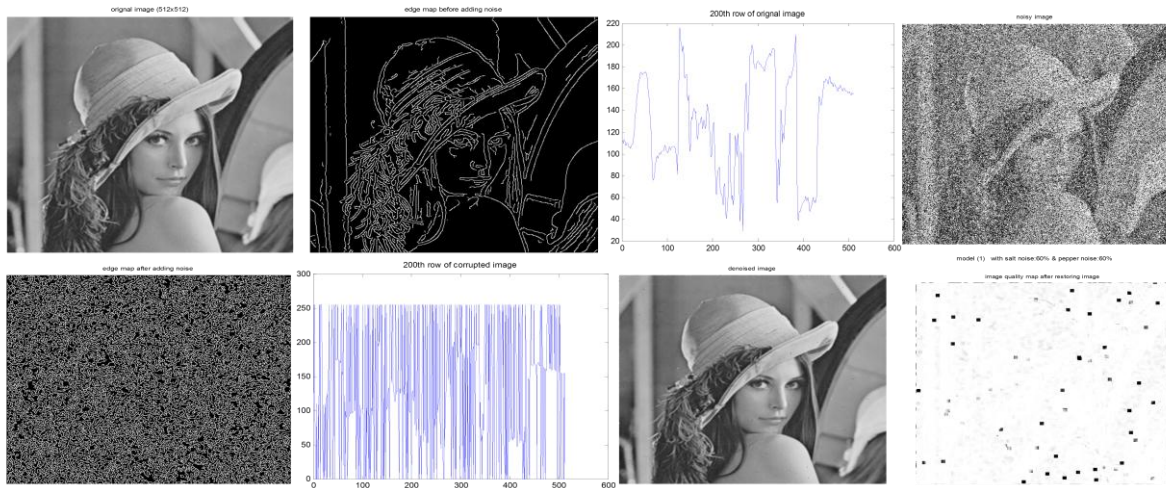


Fig 4. Lena image corrupted by 60% noise based on noise model 2

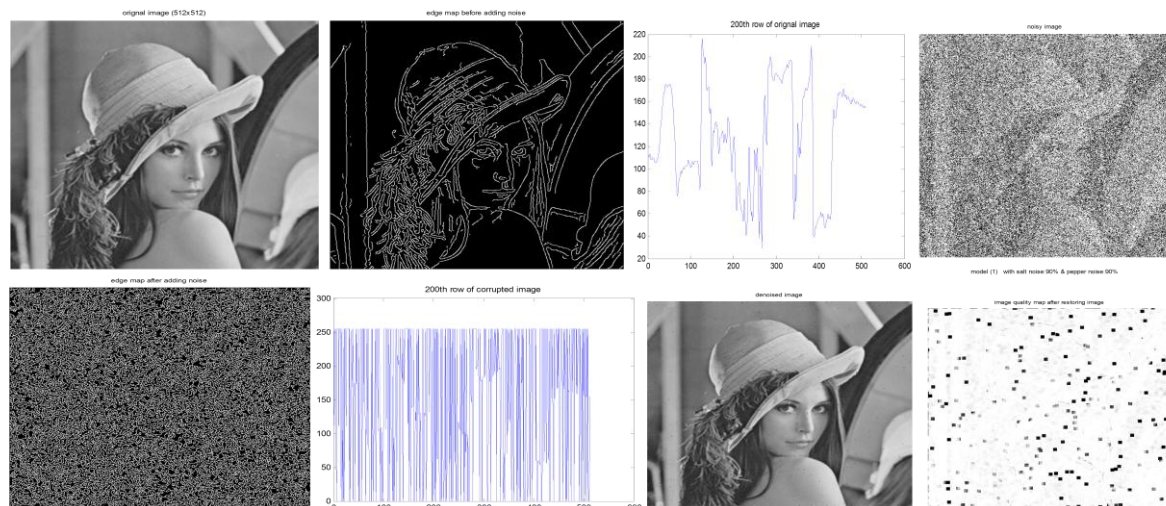


Fig 5. Lena image corrupted by 90% noise based on noise model 2

5. CONCLUSION

This paper presents a novel technique to remove salt and pepper noise from highly corrupted images. To demonstrate the superior performance of the proposed method, extensive experiments have been conducted on a variety of standard test images to compare with many other well known techniques. Experimental results show that this method always produces good output, even when tested with the high level of noise. Both the simulation and computational complexity analysis show that the proposed method is better than existing standard median filter (MED), adaptive median filter (AMED), Kaliraj et al. filter [15] and Predictive-based adaptive switching median filter (PASMf). Some points can be discussed for further research.

1. Image Enhancement Factor (IEF) is not improved in noise model 2 in comparison to PASMf filter.
2. Proposed filter Tested on gray scale images only.

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