



Two-Step Fuzzy Decision Based Median filter for removal of Impulse Noise

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Abstract— *Nonlinear and linear filters have been proposed earlier for the removal of impulse noise from color images; however the removal of impulse noise often brings about distortion of images which generally results in poor quality of colored images. Therefore the necessity to preserve the details and edges during filtering process is the main challenge faced by researchers today. This paper proposes a two-stage approach for detection and removal of salt and pepper noise. In the first stage, the noise detection is based on simple thresholding of pixels. In the second stage, these detected noise pixels will be corrected by an improved two-step fuzzy decision based filter, while these noise-free pixels are left unchanged by the filter. In term of the conflict of edge preservation and noise suppression, our proposed method uses fuzzy based reasoning to handle it. The results show that this method is quite good for image restoration and noise reduction especially in high level noisy images*

Keywords— *Thresholding, Fuzzy based reasoning, Fuzzy decision based filter, Impulse Noise, Salt and pepper noise.*

I. INTRODUCTION

Digital images and signals are valid information sources to varied fields of Digital image processing. They in the course of acquisition/ transmission have their true values in random positions impaired by corruptive values in extreme ranges called impulses. So impulse noise removal algorithms are essential for signal restoration to precede reliable digital signals/ images through varied image processing applications. The pioneer impulse filtering algorithms based on linear operations like the Mean filter smoothed image details while removing noise and so non-linear operators emerged successful to deal the non-linear characteristics of impulses [3] – [4].

The non-linear Simple Median Filter (SMF) [1] –[2] is the first in its kind which sensibly replaces every pixel of the impulse corrupted image by considering the acute range of the strength of impulses with the mid-order statistic or the median of a set of pixels in the window sliding over each pixel of the image. The results though are significant than the linear counterparts; the median filters are indecisive in that all the signals are replaced by the median to affect the reliability of the restored image. As an improvement did numerous offshoots of median filter evolved in the form of Weighted Median Filter (WMF), Center Weighted Median Filter (CWMF), Adaptive Center Weighted Median Filter (ACWMF), Adaptive Median Filter (AMF) [4] – [5] which weighed the pixels around each pixel differently according to the spatial positions of those neighboring pixels that an impulse-free pixel turns out to replace a particular pixel during the filtering operation. But these algorithms are indecisive in that the filtering function was applied with no ceil on all the true/impaired signals of the digital image irrespective of the impulse noise ratio and the statistics of the image. So filtering algorithms with switching schemes are developed to detect and identify the spatial position of impulses in a distinct impulse detection phase.

The prominent decision based impulse filter, the Progressive Switching Median Filter (PSMF) [9], though can produce results from images corrupted to slightly higher impulse ratios, its assurance that all impulses are correctly identified is meager since an optimal impulse detecting threshold suitable for a particular impulse noise ratio which varies for different window sizes could not be obtained by PSMF. Chan and Nikolova proposed a two-phase algorithm for high-density noise removal (RAMF) [11]. The main drawback of the method is that the processing time is very high because it uses a very large window of size.

In addition, the switching schemes of certain decision based filtering algorithms could not differentiate high frequency edge details of the corrupted digital image from high frequency impulses in view of the fact that they could not tune to various optimal impulse detection parameters suitable for varied impulse noise ratios and image statistics. Thus many filtering schemes are not adaptive in fixing a reliable neighborhood or other parameters to determine the correct impulsive position or an appropriate signal restorer suitable for that position of a particular impulsive environment. The Decision Based Algorithm (DBA) [13] is capable of removing impulse noise at noise densities as high as 80%. A major drawback of this algorithm is streaking at higher noise densities. Robust Estimation Algorithms (REA) [12] – [16] are effective in high-density impulse noise removal but their computational complexity is higher.

Many noise detection algorithms were proposed for impulse noise detection [16] – [23]. The Signal-Dependent Rank Ordered Mean (SD-ROM) [17] filter can remove impulse noise rather effectively, but when applied to images with Gaussian or mixed noise, it often produces a visually disappointing output similar to other median-based filters. This is

because the rank-ordered mean gets corrupted in a high noise intensity window. The Directional Weighted Median (DWM) [8] filter uses an iterative filtering approach, and the detector is based on absolute differences within the filtering window. The estimation is done using an adaptive weighted median filter. For ensuring high accuracy of detection, iterative filtering is applied, which takes a longer total processing time but removes more details with each iteration. The trilateral filter is based on Rank-Order Absolute Difference (ROAD) [20] statistics for impulse noise detection. It has been especially designed for uniform impulse and Gaussian noise removal. The ROAD value could be false under the case that half of the pixels in the processing window are corrupted. Three main types of noise exist: impulse noise, additive noise, and multiplicative noise. Impulse noise is usually characterized by some portion of image pixels that are corrupted, leaving the remaining pixels unchanged

II. DIFFERENT NOISE MODELS

Impulse noise affects random signal positions of a digital image during acquisition stage when faulty sensors are used to acquire images in poor imaging conditions or during transmission when images are transmitted through faulty radio channels. Of the various impulse noise models, the salt and pepper impulses and the random values impulses that changes the signals by replacing them with maximum and minimum values and large random values in the extreme ranges respectively, modelled through different equations are better dealt by the proposed impulse filtering algorithm. Two impulse noise models are implemented, for extensively examining the performance of our proposed filter with consideration of practical situations. Each model is described in detail as follows:-

A. FIRST NOISE MODEL

Noise is modeled as salt-and-pepper impulse noise. Pixels are randomly corrupted by two fixed extreme values, 0 and 255 (for 8-bit monochrome 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:-

$$F(x) = \begin{cases} \frac{p}{2} & \text{for } x = 0 \\ 1 - p & \text{for } x = s(i,j) \\ \frac{p}{2} & \text{for } x = 255 \end{cases}$$

where 'p' is the noise density.

B. SECOND NOISE MODEL

Random Valued Impulse Noise (RVIN) will produce impulses whose gray level value lies within a predetermined range. For example, if gray level exceeds a L_{MAX} , it is a positive impulse (L_{MAX} to 255); if gray level is less than L_{MIN} , it is a negative impulse (0 to L_{MIN}).

$$F(x) = \begin{cases} \frac{p^l}{L_{min}} & \text{for } 0 \leq x < L_{min} \\ 1 - p & \text{for } x = s(i,j) \\ \frac{p^l}{L_{max}} & \text{for } 255 - L_{max} < x \leq 255 \end{cases}$$

III. TWO-STEP FUZZY DECISION BASED MEDIAN FILTER

A. MEDIAN FILTER

Let $X_{i,j}$ which locates at (i, j), be the gray intensity of a $M \times N$ image X and $\min \max [L, L]$ be the dynamic range of X, i.e., $\min i, j \max L \leq x \leq L$ for all (i, j) which accords to the following rule:

$$(i, j) \in A \equiv \{1, \dots, M\} \times \{1, \dots, NN\}$$

In the conventional salt and pepper noise model, we assume y is the noisy image, the model is given by:-

$$Y_{i,j} = \begin{cases} L_{min}, & \text{with } \% p \\ L_{max}, & \text{with } \% q \\ x_{i,j} & \text{with } \% 1 - p - q \end{cases}$$

where $\text{rate} = p + q$ means the noise level in image. Next, we give a brief introduction of the adaptive median filter. Assuming the filtering window $W_{i,j}$ is a window of size $(2N+1) \times (2N+1)$ centered at position at (i, j), $W_{i,j}$ can be narrated as:

$$W_{i,j} = \{x_{i-N, i-N}, \dots, x_{i,j}, \dots, x_{i+N, j+N}\}$$

let $w = 2N + 1 \leq W_{max}$. The algorithm tries to improve the output image $y_{i,j}$ by the median in the window.

Algorithm (Median Filter):

1. Initialization: $w = 3$.
2. Compute the maximum, minimum and median value in window, they can be explained as $W_{i,j}^{max}$, $W_{i,j}^{min}$, $W_{i,j}^{med}$ respectively.

3. If $W_{i,j}^{\min} < W_{i,j}^{\text{med}} < W_{i,j}^{\max}$, then go to step 5. Otherwise, set $N=N+1$.
4. If $w \leq W_{\max}$, go to step 2. Otherwise, we replace $Y_{i,j}$ by $W_{i,j}^{\text{med}}$ when the window size W_{\max}
5. If $W_{i,j}^{\min} < y_{i,j} < W_{i,j}^{\max}$, then $y_{i,j}$ is noise free, else we replace $y_{i,j}$ by $W_{i,j}^{\text{med}}$

The adaptive median filter can ensure the most of the noisy pixels can be detected and the noisy free pixels left unchanged but couldn't consider about fine edge preserving performance

B. FUZZY DECISION BASED METHOD

Recently, in the literature of denoising, fuzzy switching median filter is one of the most popular methods. Usually, it is divided into two stages. The first stage is noise detection which is necessary before fuzzy switching method. Based on noise detection, we can distinguish between "suspicious noise pixels" and "noise free pixels". Then, the fuzzy switching method is employed for the cancellation module. We assume the median value W^{med} is found, the absolute luminance difference $d(i, j)$ in a window is given by:-

$$d(i+k, j+l) = |X(i+k, j+l) - X(i, j)|$$

where $(i+k, j+l) \neq (i, j)$ and $-N \leq k, l \leq N$ then the parameter $D(i, j)$ which represents the local information is defined as the maximum absolute luminance difference in the following window:-

$$D(i, j) = \max \{d(i+k, j+l)\}$$

According to $D(i, j)$, pixels in image X is divided into three classes which are "noise free pixels", "suspicious noise free pixels" and "suspicious noise pixels". The fuzzy reasoning is employed and function $f(i, j)$ is defined by:-

$$f(i, j) = \begin{cases} 0, & : D(i, j) < T_1 \\ D(i, j) - T_1 / T_2 - T_1 & : T_1 \leq D(i, j) < T_2 \\ 1, & : D(i, j) \geq T_2 \end{cases}$$

where the threshold T_1 and T_2 are normally set to 10 and 30

Finally the output image $y_{i,j}$ can be restored by a linear combination between original pixel $X_{i,j}$ and median pixel $W_{i,j}^{\text{med}}$. This correction term is also be adopted by our proposed method:-

$$y_{i,j} = (1 - f(i, j))X_{i,j} + f(i, j)W_{i,j}^{\text{med}}$$

where $f(i, j)$ means a weight on the median pixel $w_{i,j}$

IV. THE PROPOSED METHOD

The proposed method is a combination of adaptive median filter with fuzzy switching median method. It is divided into noise detection module and noise cancellation module. In order to implement our proposed algorithm we need three arrays with the same size as image X and they are original image X , output image y and the calibration array α to mark the noise pixels.

A. NOISE DETECTION STAGE

In this stage, we can mark the noise pixels with 0 and mark others with 1 in calibration array α , and also approximate the noisy level in the image:-

$$\alpha(i, j) = \begin{cases} 1: X(i, j) = L - 1 \\ 1: X(i, j) = 0 \\ 0: otherwise \end{cases}$$

according to [8] we suppose that the maximum and the minimum in the dynamic range (i.e. 0 and $L-1$) is the pixels corrupted by salt and pepper noise where value 1 means corresponding pixels is "suspicious noise free" or "suspicious noise" and the value 0 means corresponding pixels is "noise free". The number of noise free pixels S is given by (9)

$$S = \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \alpha(i, j)$$

Using the value of S we can achieve the number of suspicious noise free pixels and suspicious noise pixels that are used to calculate the noisy level δ in the image with equation

$$\delta = MN - \frac{S}{MN} \quad 0 \leq \alpha \leq 1$$

In the following adaptive algorithm, based on different noisy level, we need a adaptive initialization of filtering window size w . According to parameter δ , the initialization $w_{initialization}$ can be calculated as:

$$W_{initialization} = \sqrt{9/1 - \alpha}$$

B. NOISE CANCELLATION STAGE

In this stage, filter [8] similarly weights median value $m(x,y)$ 0 or 1. This method has not take a fine considering about the suspicious noise free pixels between threshold $T1$ and $T2$, however, it is classified to noise pixels directly. In our proposed method, the output value is defined as:

$$W_{i,j}^{med} = med\{X(i - N, j - N), \dots X(i, j), \dots X(i + N, j + N)\}$$

$$y_{i,j} = (1 - f(i,j))X_{i,j} + f(i,j)W_{i,j}^{med}$$

where $f(i,j)$ is defined in equation (1), it is a real number between 0 and 1.

We use the improved adaptive median method to determine $W_{i,j}$. The proposed method will remove the maximum and minimum in the filtering window, then to calculate the median value $W_{i,j}$ is given by:-

$$W_{i,j}^{med} = \sum_{k=-N}^N \sum_{l=-N}^N \frac{X(i - k, j - l)}{num} \\ X(i - k, j - l) \neq L_{max} \text{ or } L_{min}$$

To maximum L_{max} or minimum L_{min} of filtering window

V. RESULTS AND DISCUSSIONS

Various images are used to test the performance of the algorithm with dynamic range of values (0, 255). Images will be corrupted by salt-and-pepper noise at different noise densities, such as low noise (30%), medium noise (60%) and high noise (90%).

Images	10%	20%	30%	50%	60%	70%	80%
Lena	42.65	40.85	38.89	34.31	32.74	30.39	27.87
Peppers	43.96	39.95	36.69	33.32	31.65	28.67	28.91
Cameraman	35.50	38.86	30.13	27.67	28.64	24.78	22.77
Baboon	32.61	30.86	27.45	25.68	25.67	23.67	21.33

Table 1: Performance comparison of different images corrupted with various noise levels.

Various Filters	10%	30%	50%	70%
Standard Median Filter	41.67	45.21	34.61	15.64
Adaptive Median Filter	38.21	23.34	32.45	22.39
Contrast Enhancement Filter	30.12	34.45	40.32	24.70
Proposed method	39.06	38.89	31.63	10.65

Table 2: Performance comparison of different methods corrupted with various noise levels



Figure 1: a) Original "Peppers" Image

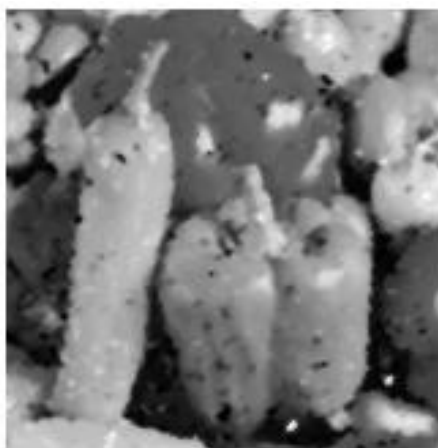


Figure 1: b) “Decision based median Filtered Image” for “peppers” Image after introducing 70% of salt and pepper noise

VI. CONCLUSIONS

In this paper, we propose a novel algorithm for eliminate salt and pepper denoising. The method is actually a combination of adaptive median filter and fuzzy reasoning method. The advantages of this proposed method are the fuzzy initialization of filtering window size and the precision of median value. Thus, no training or tuning is required. Extensive simulation results reveal that our filter consistently outperforms the existing filters by attaining much higher PSNR across a wide range of noise densities, from 10% to 90%. The key success of such performance delivery is mainly due to highly accurate noise detection accomplished by the noise detection algorithm having high noise detection ratio and our proposed method performs better than the median filter and other conventional edge preserving method, even at a high noise level. The PSNR is high, MAE and Processing time is low. This proposed method is a fast method in the algorithm of removing salt and pepper noise

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