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An Efficient Approach of Removing the High Density Salt & Pepper Noise Using Stationary Wavelet Transform

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Abstract - Images are often corrupted by impulse noise, also known as salt and pepper noise. Salt and pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level. Amongst these standard median filter has been established as reliable - method to remove the salt and pepper noise without harming the edge details. However, the major problem of standard Median Filter (MF) is that the filter is effective only at low noise densities. When the noise level is over 50% the edge details of the original image will not be preserved by standard median filter. Adaptive Median Filter (AMF) performs well at low noise densities. In our proposed method, first we apply the Stationary Wavelet Transform (SWT) for noise added image. It will separate into four bands like LL, LH, HL and HH. Further, we calculate the window size 3x3 for LL band image by Reading the pixels from the window, computing the minimum, maximum and median values from inside the window. Then we find out the noise and noise free pixels inside the window by applying our algorithm which replaces the noise pixels. The higher bands are smoothing by soft thresholding method. Then all the coefficients are decomposed by inverse stationary wavelet transform. The performance of the proposed algorithm is tested for various levels of noise corruption and compared with standard filters namely standard median filter (SMF), weighted median filter (WMF). Our proposed method performs well in removing low to medium density impulse noise with detail preservation up to a noise density of 70% and it gives better Peak Signal-to-Noise Ratio (PSNR) and Mean square error (MSE) values.

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AN EFFICIENT APPROACH OF REMOVING THE HIGH DENSITY SALT PEPPER NOISE USING STATIONARY WAVELET TRANSFORM

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Abstract - Images are often corrupted by impulse noise, also known as salt and pepper noise. Salt and pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level. Amongst these standard median filter has been established as reliable - method to remove the salt and pepper noise without harming the edge details. However, the major problem of standard Median Filter (MF) is that the filter is effective only at low noise densities. When the noise level is over 50% the edge details of the original image will not be preserved by standard median filter. Adaptive Median Filter (AMF) performs well at low noise densities. In our proposed method, first we apply the Stationary Wavelet Transform (SWT) for noise added image. It will separate into four bands like LL, LH, HL and HH. Further, we calculate the window size 3x3 for LL band image by Reading the pixels from the window, computing the minimum, maximum and median values from inside the window. Then we find out the noise and noise free pixels inside the window by applying our algorithm which replaces the noise pixels. The higher bands are smoothing by soft thresholding method. Then all the coefficients are decomposed by inverse stationary wavelet transform. The performance of the proposed algorithm is tested for various levels of noise corruption and compared with standard filters namely standard median filter (SMF), weighted median filter (WMF). Our proposed method performs well in removing low to medium density impulse noise with detail preservation up to a noise density of 70% and it gives better Peak Signal-to-Noise Ratio (PSNR) and Mean square error (MSE) values.

I. Introduction

Impulse noise may often corrupt the images, which is known as salt and pepper noise..A standard signal processing requirement is to remove randomly occurring impulses without disturbing the edges. It is well known that linear filtering techniques fail when the noise is non-additive and are not effective in removing impulse noise. This lead researchers to make use of the nonlinear signal processing techniques. Based on two types of image models corrupted by impulse noise, two new algorithms for adaptive median filters are presented in Ref. [1]. these have variable window size for removal of impulses while preserving sharpness. The first one, called the ranked-order based adaptive median filter (RAMF), is based on a test for the presence of impulses in the center pixel itself followed by the test for the presence of residual impulses in the median filter output. The second one, called the impulse size based adaptive median filter (SAMF), is based on the detection of the size of the impulse noise.

A new impulse noise detection technique for switching median filters was described in Ref. [2], which is based on the minimum absolute value of four convolutions obtained using one-dimensional Laplacian operators. Extensive simulations show that the proposed filter provides better performance than many of the existing switching median filters with comparable computational complexity.

Srinivasan et al. [3], proposed a new decision-based algorithm for the restoration of images that are highly corrupted by impulse noise. They reported significantly better image quality than a standard median filter (SMF), adaptive median filters (AMF), threshold decomposition filter (TDF), cascade, and recursive nonlinear filters. Unlike other nonlinear filters, this method, removes only corrupted pixel by the median value or by its neighboring pixel value.

Previously, many linear and nonlinear filtering techniques have been described to remove impulse noise. However, these filters often bring along blurred and distorted image of details. A detail preserving filter for impulse noise removal was proposed by Dagao Duan et al. [4]. on the basis of the Soft-Switching Median (SWM) filter. Moreover, Eduardo Abreu [5] reported a new framework for removing impulse noise from images, in which the nature of the filtering operation is conditioned on a state variable defined as the output of a classifier that operates on the differences between the input pixel and the remaining rank-ordered pixels in a sliding window. As part of this framework, several algorithms are examined, each of which is applicable to fixed and random-valued impulse noise models. Also, Chenhen et al. [6] reported a novel nonlinear filter, called tri-state median (TSM) filter, for preserving image details while effectively suppressing impulse noise. The standard median (SM) filter and the center weighted median (CWM) filter into a noise detection framework to determine whether a pixel is corrupted, before applying filtering unconditionally.

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To restore images corrupted by salt–pepper impulse noise, a new median-based filter such as progressive switching median (PSM) filter was presented in Ref. [7]. It was developed on the basis of the following two main points: 1) switching scheme an impulse detection algorithm is used before filtering, thus only a proportion of all the pixels will be filtered and, 2) progressive methods both the impulse detection and the noise filtering procedures are progressively applied through several iterations.

A generalized framework of median based switching schemes, called multi- state median (MSM) filter is presented in Ref. [8]. By using simple thresholding logic, the output of the MSM filter is adaptively switched among those of a group of center weighted median (CWM) filters that have different center weights. A novel switching-based median filter with incorporation of fuzzy-set concept, called the noise adaptive soft-switching median (NASM) filter [9], to achieve much improved filtering performance in terms of effectiveness in removing impulse noise while preserving.

signal details and robustness in combating noise density variations. Also, Luo et al [10] designed a new efficient algorithm for the removal of impulse noise from corrupted images while preserving image details. It was interpreted on the basis of the alpha-trimmed mean, which is a special case of the order-statistics filter.

II. Methodology

The proposed image denoising corrupted by salt and pepper noise is built on Stationary wavelet transform. The following section describe the Stationary Wavelet transform (SWT) and Proposed Algorithm used in the present work (Figure.1).

a) Stationary Wavelet Transform

The SWT provides efficient numerical solutions in the signal processing applications. It was independently developed by several researchers and under different names, e.g. the un-decimated wavelet transform, the invariant wavelet transform and the redundant wavelet transform. The key point is that it gives a better approximation than the discrete wavelet transform (DWT) since, it is redundant, linear and shift invariant. These properties provide the SWT to be realized using a recursive algorithm. Thus, the SWT is a very useful algorithm for analyzing a linear system.

A brief description of the SWT is presented here. It shows the computation of the SWT of a signal$x(k)$, whereW_{jk}, and V_{jk} are called the detail and the approximation coefficients of the SWT. The filters H_j and G_j are the standard lowpass and highpass wavelet filters, respectively. In the first step, the filters H_1 and G_1 are obtained by upsampling the filters using the previous step (i.e. $H_j - 1$ and$G_j - 1$).

Block Diagram

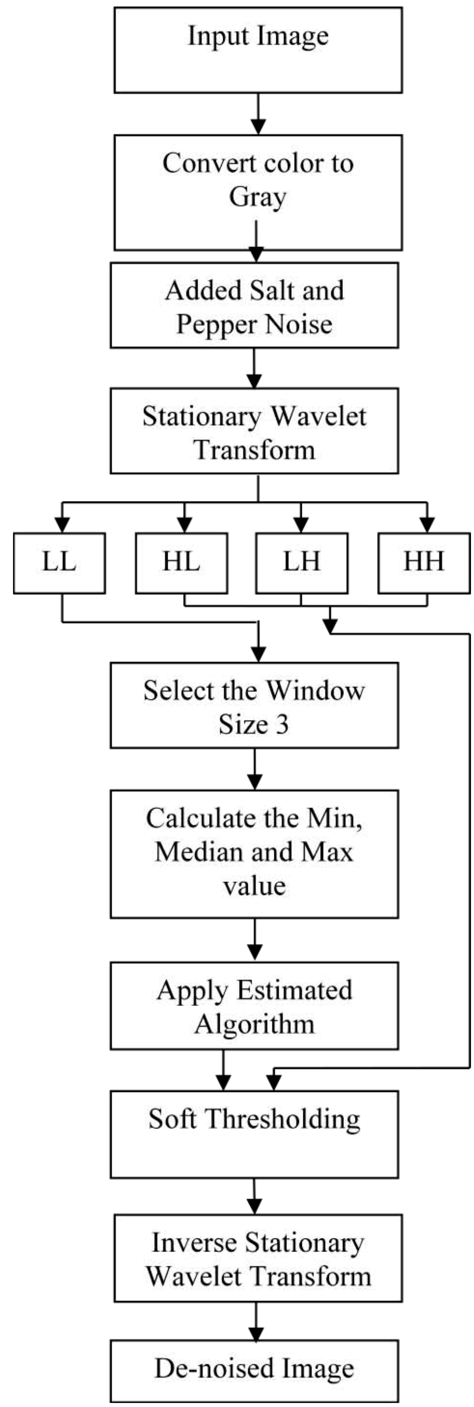

Fig 1: Block Diagram of Proposed Method

III. Proposed Method

Let X denote the noise corrupted image, apply the stationary wavelet transform of the noise image to get the LL, LH, HL and HH bands. In LL band for each pixel $X(i,j)$ denoted as X_{ij} a sliding or filtering window of size $2(L+1)X(2L+1)$ centered at X_{ij} is defined as shown in Table.1. The elements of this window are $S_{ij} = \{X_{i-u,j-v}, -L \le u,v \le L\}$.

X(i-1,j-1)	X(i-1,j)	X(i-1,j+1)
X(i,j-1)	X(i,j)	X(i,j+1)
X(i+1,j+1)	X(i+1,j)	X(i+1,j+1)

Table.1: 3 x 3 Filtering window with X (i,j) as center pixel

1. Set the minimum window size w=3;
2. Read the pixels from the sliding window and store it in(S).
3. Compute minimum, maximum and median value inside the window.
4. If the center pixel in the window X(i,j),is such that min<X(i,j)<max, then it is considered as uncorrupted pixel and retained. Otherwise go to step 5.
5. Select the pixels in the window such that min<Sij<max if number of pixels is less than 1 then increase the window size by 2 and go to step2 ,else go to step 6.
6. Difference of each pixel inside the window with the median value is calculated as x and applied to robust influence function.

$$f(x) = \frac{2x}{(2\sigma^2 + x^2)} \quad (1)$$

where σ is outlier rejection point which is given by

$$\sigma = \frac{\tau_s}{\sqrt{2}} \quad (2)$$

where $\tau_s$the maximum is expected outlier and is given by

$$\tau_s = \varsigma\sigma_N \quad (3)$$

where σ_N the local is estimate of the image standard deviation and ς is a smoothening factor. Here δ =0.3 is taken for medium smoothening.

7. Pixel is estimated using equation (4) and (5)

$$S1 = \sum_{l\in L} \frac{pixel(l) * f(x)}{x} \quad (4)$$

$$S2 = \sum_{l\in L} \frac{f(x)}{x} \quad (5)$$

For all higher bands (LH, HL and HH) the de-noising can be achieved by applying a thresholding operator to the wavelet coefficients in the transform domain followed by reconstruction of the signal to the original image in spatial domain. In our proposed method, soft shrinkage and Median Absolute Difference (MAD) are used. The scaled MAD noise estimator is calculated by (6).

$$MAD = \frac{median(|X|)}{0.6745} \quad (6)$$

where X is the high frequency sub-bands coefficients. From the estimated noise, the non linear threshold T is calculated by (7)

$$T = MAD * \sqrt{2logn} \quad (7)$$

where N is the size of the high frequency sub-band array. Then the soft thresholding is applied to remove the noise and the soft shrinkage rule is defined by (8). Finally, the noise free image is obtained by taking then inverse SWT

$$\rho_T(x) = \begin{cases} x - T, & if \quad x \geq T \\ x + T, & if \quad x \leq -T \\ 0, & if \quad |x| < T \end{cases} \quad (8)$$

The noise free sub-bands are obtained by using adaptive thresholding. Finally, the noise free image is obtained by taking the inverse SWT using the modified high frequencies sub-bands and the low frequency sub band of SWT.

IV. Experimental Results

The proposed algorithm tested for 256x256 images. It is tested for various levels of noise values and also compared with Standard median filter (SMF). Figure 2 shows the de-noising performance of the proposed algorithm. Table 2 show the PSNR values of the proposed method and based soft shrinkage and SWT method with different noise variance. Figure 3 shows the comparison of PSNR value for median filter and our proposed method.

Figure 2 : (a) Input image, (b) Noise added Image, (c) Median filtered Image and (d) Our proposed method

Table 2 : PSNR value for the proposed method

Noise Level	Median Filter	Proposed Method
20	27.26	31.03
30	22.56	29.69
40	18.33	28.05
50	15.07	26.35
60	12.2	24.27
70	9.67	21.86

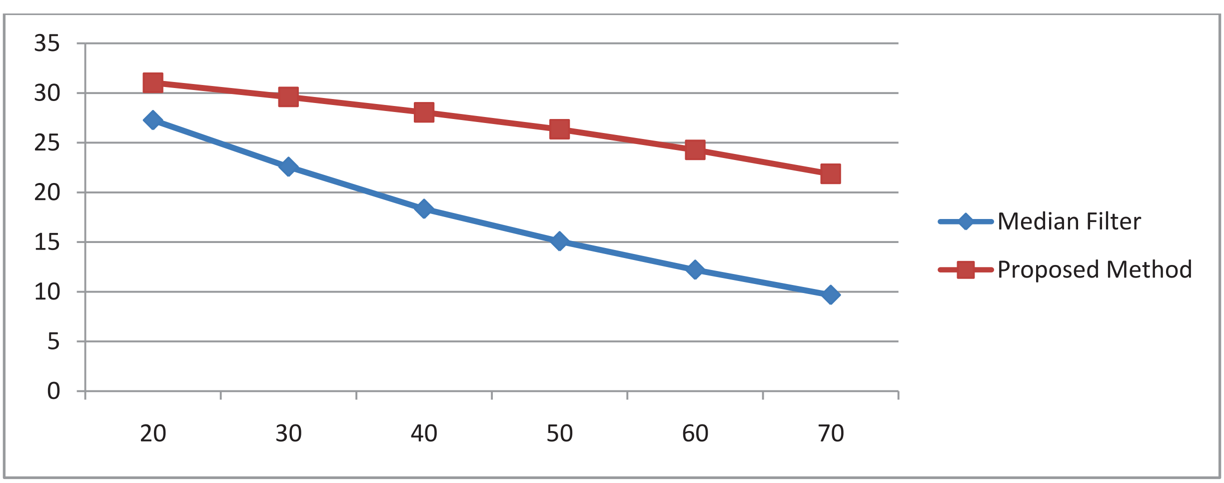

Figure 3 : Comparison graph of PSNR at different noise densities

V. Conclusion

In this work, we presented the image denoising based on Stationary Wavelet transform (SWT) and soft threshold method is presented. Experimental results show that the proposed method restore the original image much better than standard non linear median-based filters and some of the recently proposed algorithms. The proposed filter requires less computation time compared to other methods. The visual quality results clearly shows the proposed filter preserve fine details such as lines and corners satisfactorily. This filter can be further improved to apply for the images corrupted with high density impulse noise upto 90% and random valued impulse noise.

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