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Removal of Impulse Noise using Adaptive Weighted Median Filter

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Abstract

Median filters are known for their capability to remove impulse noise as well as preserve the edges. Applying median filter unconditionally across the entire image as practiced in the conventional schemes would inevitably alter the intensities and remove the signal details of uncorrupted pixels. A new adaptive weight algorithm is developed for the removal of salt and pepper noise. It consists of two major steps, first to detect noise pixels according to the correlations between image pixels, then use different methods based on the various noise levels. For the low noise level, neighborhood signal pixels mean method is adopted to remove the noise, and for the high noise level, an adaptive weight algorithm is used. Experiments show the proposed algorithm has advantages over regularizing methods in terms of both edge preservation and noise removal, even for heavily contaminated image with noise level as high as 90%, it still can get a significant performance.

Keywords: Adaptive Weight Algorithm, Heavily Contaminated Image, Salt and Pepper Noise

1. Introduction

Images are often corrupted by impulse noise due to errors generated in noisy sensors or communication channels. It is important to eliminate noise in the images before some subsequent processing, such as edge detection, image segmentation and object recognition for this purpose, many approaches have been proposed. The most well-known version of the noise in images is the salt and pepper noise. A variety of filtering techniques has been proposed for enhancing images degraded by noise1-6. By adjusting their parameters, depending on local characteristics of the input image, these filters preserve sharp sustained changes (edges) in the image while reducing noise. All of the filters are useful for additive white noise suppression, but are generally ineffective in eliminating impulsive noise that appears as very large spikes of short duration. The adaptive filters in^{3,6} have been shown to be effective in suppressing signal-dependent noise as well a additive white noise.

The common salt and pepper noise filtering algorithms includes: Mean Filter (MF) algorithm; Vector Median (VM) filter algorithm; Switching Median (SM) filter

algorithm² etc. MF filter algorithm is simple and speed, but it does not have the ability of effectively removing salt and pepper noise and protection for edges and details in high noise density case⁵. VM & SM filter algorithms are sensitive to different noise density. Their filtering properties get worse with the noise density increasing. In ⁶, decision-based median filtering algorithms are used.

These methods first identify noisy pixels and then replace them with appropriate estimates using neighbor pixels, but noisy pixels are not effective to detect. In ⁷, an Adaptive Weight (AW) approach was proposed, in which the output is a weighted sum of the image and a denoising factor. These weighting coefficients depend on a state variable. The state variable is the difference between the current pixel and the average of the remaining pixels in the surrounding window. Because the coefficients are various, it's difficult to select an appropriate one.

In view of these shortcomings and deficiencies, a switching adaptive filtering algorithm is proposed. Its emphasis is on improving the de-noising ability.

The schematic for the algorithm reference is shown in Figure 1. The proposed method consists of two major

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blocks, detection and filtering. The detection block uses neighborhood pixels correlations to divide the pixels into signal pixels and noise pixels. Signal pixels are kept the same and only noise pixels are processed. For filtering block, the different approaches were taken according to the noise density situations. In the low noise density case, neighborhood signal pixels mean method is adopted. In the high noise density case, adaptive weight algorithm is used.

2. Adaptive Weighted Median **Filter**

Several types of noise have been defined¹. In this paper the impulse noise is considered. In case of images corrupted by this kind of noise, intensity of the pixel xij at location (i, j) is described by the probability density function given by the following equation

☐ It is known that the salt and pepper noise's value is the max or min value in the image according to the characteristic of the noise sprinkling on images.

If f_i , j = 0, it means the pixel is a signal point, else it is a noise one. Because the values of some signal pixels are absolutely around 0 or 255, it is needed to further decide whether the pixel is a noise one or not. After 40 images experiments, we find that it is advantage to use the temple window whose size is 5×5 to the noise detection, so as the paper.

If f_i+s , j+t ($s,t \le 2$ and $s \cdot t \ne 0$) are not all zero, it means that there are some signal pixels in the temple

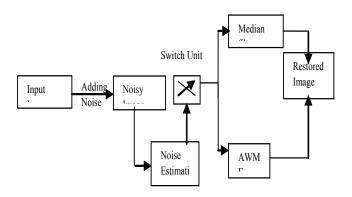


Figure 1. Adaptive weighted median filter Schematic.

window entered at (i + s, j + t). Let T be the threshold and xi, j be the mean value of signal pixels but the center pixel itself in the temple window. Compare the D-value between xi, j and xi, j with. If xi, j - xi, j > T, the pixel is regarded as a signal point, else it is a noise one.

3. Weighted Median Filter

The Weighted Median (WM) filter was first introduced as a generalization of the standard median filter, where a negative and nonnegative integer weight is assigned to each position in the filter window. In this subsection, we give three alternative definitions of WM filters.

As shown in Figure 2, the structure of a WM filter is quite similar to that of a linear FIR filter. For real-valued signals, WM filters can be defined in three different but equivalent ways. The first definition can be used in the common case of positive integer weights.

Definition 1: for an uncorrupted pixel its value is added with zero weight or it will be unchanged.

$$X=[x1,x2...xn], W=[w1,w2,...wn]$$

 $Y=MED [x1 \cdot w1, x2 \cdot w2,....xn \cdot wn]$

Definition 2: If the selected windows contains only 0's and 255's. Then add weight as '-1'of each element in the window.

Definition 3: If the selected window, ranges from (0+t)'s and (255-t)'s then add weight as '1' of each element in the window.

$$X=[x_1,x_2...x_n], W=[w_1,w_2,...w_n]$$

Y=Th: largest element in the set

$$[x1 \cdot w1, x2 \cdot w2, \dots xn \cdot wn]$$

$$Th = \frac{1}{2 \underbrace{\mathring{\mathbf{g}}_{1}^{n} + \mathring{\mathbf{a}}_{i=1}^{N} Wi \dot{\mathring{\mathbf{o}}}_{\overset{\circ}{\mathbf{o}}}^{n}}_{i=1} Wi \dot{\overset{\circ}{\mathbf{o}}}^{n}}$$

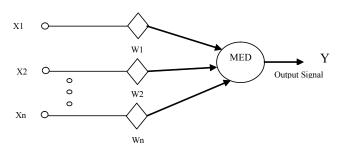


Figure 2. Weighted Median Filter.

4. The Simulation and Analysis

To verify the advantage and effectiveness of our filtering algorithm, a gray-scale image whose size is 256×256 was selected. First salt and pepper noise was added to it; then MF, VM & SM and our algorithm were used separately to restore the image corrupted by salt and pepper noise. Figure 3 is the visual results comparison of different methods.

Figure 4 is the image Peak Signal to Noise Ratio (PSNR) comparison of our method with different algorithms at various noise ratios for test image as shown in Figure 3 and Figure 4.

The results of four algorithms have shown that: TM algorithm is applicable for the situation of low noise density; With the noise density of the image increasing, EM algorithm is more similar to TM algorithm, Their filtering properties get worse with the noise density increasing; Although AW algorithm is better than TM and EM algorithms in high density noise situation, it still has some shortage either in the filtering result or in preserving the image details, compared with the proposed algorithm. Supposing *xi*, *j* and *yi*, *j* are separately the gray-scale values of the original image and the output image at the pixel location (i, j). The image size is $M \times N$, PSNR is the image peak signal to noise ratio.

Quantitative results of various filters for 30% corrupted image as shown in Table 1.

Noise density =20.5536, MSE = 17.6594, PSNR=35.66 Noise density =31.9717, MSE=15.6736, PSNR=36.1791 Quantitative results of various filters for above 30% corrupted image as shown in Table 2.

Input



Noisy image



MedianMF



Figure 3. MedianMF.

Table 1. SMF

METRICS	MEAN	MEDIAN	VMF	SMF
PSNR	30.9702	38.164	35.9337	31.9392
MSE	52.0063	9.9642	16.5848	41.6066

Input



Noisy Image



AWMF

Figure 4.

Table 2. AWMF

METRICS	MEAN	MEADIAN	VMF	AWMF
PSNR	30.9702	38.1640	35.9337	18.6689
MSE	52.0063	9.9642	16.5848	35.4196

5. Conclusion

In this paper, we proposed a weighted median filter, for removing impulse noise. It makes full use of the characteristics of impulse and edges to detect and restore noise. Since PSNR represents the ratio between the maximum possible power of a signal and the power of corrupting noise, the higher value of PSNR for filtered image gives better result.

Simulation results showed that this filter performs much better than many existing median-based filters in both subjective and objective (PSNR) evaluations. Especially, on some specific corrupted images, the proposed filter (AWMF) gives better embedded images than that of the Median filter.

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