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Image Denoising Using Adaptive Weighted Median Filter with Synthetic Aperture Radar Images

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Abstract: **An Adaptive Weighted Median (AWM) Filter is proposed for improving the performance of median based filters. The proposed adaptive technique used to determine whether the pixel is corrupted or uncorrupted pixel. If it is a corrupted pixel, it will be replaced by the weighted median value. Due to this, the unwanted filtering of uncorrupted pixels is reduced. This can be avoiding unnecessary loss of detail. The experimental results show that the proposed method outperforms the other type of filters for Synthetic aperture radar ice images.**

Keywords: **Adaptive Weighted Median Filter, Synthetic aperture radar images, Adaptive Median Filter, Weighted Median Filter.**

I. INTRODUCTION

The digital images get corrupted by noise during acquisition and/or transmission, due to the influencing parameters of these processes such as faulty sensors, atmospheric turbulence [1]. Noise is termed as any irrelevant data that obscures the authenticity of original data. Any noise prone image has to necessarily undergo normalization process in order to make it suitable for subsequent higher order processing. Image normalization is an objective of the preprocessing technique that aims to estimate the original intensities of the corrupted pixels based on the mathematical model of noise, as noises are classified as impulse noise, gaussian noise, poison noise, thermal noise, speckle noise, exponential noise, uniform noise etc., based on their pattern of distribution and characteristics. This paper proposes an efficient adaptive weighted median filter to normalize the images corrupted with noise [1].

The standard median filter algorithm is widely used for noise elimination due to good smoothing performance for noise with long-tailed probability distribution and some image detail preserving capability. Specialized median filters such as weighted median filter [2], center weighted median filter and recursive weighted median filter were proposed to improve the performance of the median filter by giving more weight to some selected pixel in the filtering window. But they are still implemented uniformly across the image without considering whether the current pixel is noise free or not. Therefore, a noise-detection process to discriminate between uncorrupted pixels and the corrupted pixels prior to applying nonlinear filtering is highly desirable. To distinguish between noise pixels and signal pixels a noise classifier is firstly employed in the adaptive median filter algorithm [2] which first detects the noisy pixels and removes it by applying either standard median filter or its variants.

Weighted median filter is an extension of the median filter. It introduces the concept of weight coefficient in to the median filter. Weighted median filters are used to reduce impulsive noise and to preserve sharp edges in image signal efficiently [4].

The performance of AWM filter is measured as SNR and MAE values. Further, the SNR and MAE values of AWM Filter are compared with its high performing median based filters. It is found that SNR values of AWM filter are higher than other type of filters.

II. PRINCIPLES OF THE PROPOSED METHOD

The proposed method is Adaptive Weighted Median (AWM) filter. The adaptive method is evaluated to verify whether it is a noisy pixel of an image or not. If it is a noise, it will be replaced by the weighted median value otherwise the pixel value of the filtered image is the same as that of the input image. This can avoid unnecessary loss of detail.

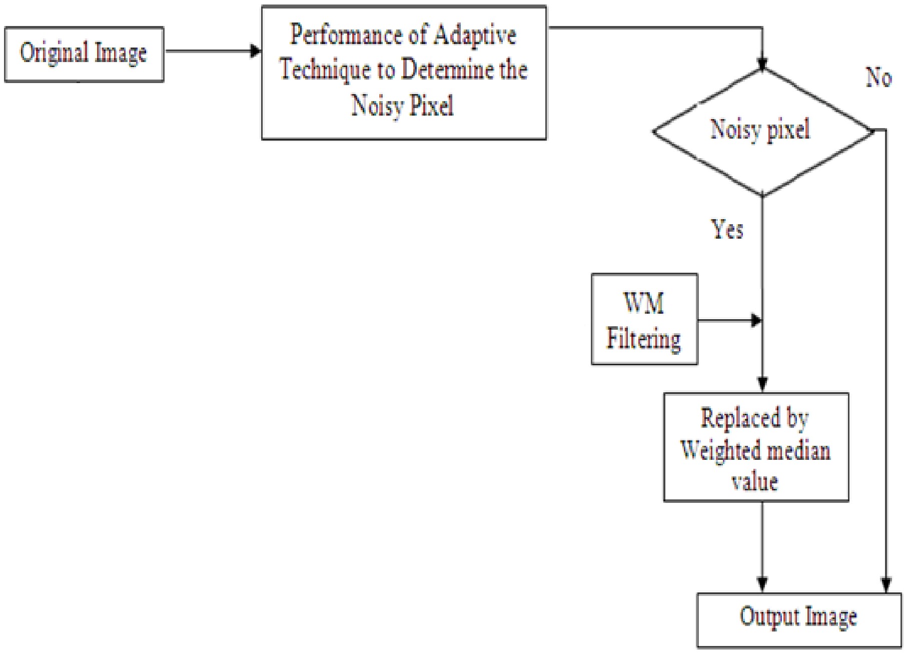


Figure 1: Frame work for the proposed methodology

III. ADAPTIVE WEIGHTED MEDIAN (AWM) FILTER

The adaptive weighted median filtering algorithm proposed in the paper includes the following courses. They are noise detection over the image using adaptive median method and finding weighted median value by means of weighted median filtering algorithm

3.1 Noise detection over the image

The Adaptive Median Filter is designed to eliminate the problems faced with the standard median filter. The basic difference between the two filters is that, in the Adaptive Median Filter, the size of the window surrounding each pixel is variable [6].

The Adaptive Median Filter performs spatial processing to determine which pixels in an image have been affected by noise. The Adaptive Median Filter classifies pixels as noise by comparing each pixel in the image to its surrounding neighbor pixels. The size of the neighborhood is adjustable, as well as the threshold for the comparison. A pixel that is different from a majority of its neighbors, as well as being not structurally aligned with those pixels to which it is similar, is labeled as a noise [14]. These noise pixels are then replaced by the weighted median value of the pixels in the neighborhood that have passed the noise labeling test. Thus, the Adaptive Median Filter solves the dual purpose of removing the impulse noise from the image and reducing distortion in the image.

3.2 Finding Weighted median Value

One of the most important extensions of the median filter is the Weighted Median filter (WMF). With a proper weight set, the WMF has efficient impulsive noise suppression and an excellent image detail-preserving capability [4]. Figure 3 shows the structure of WMF.

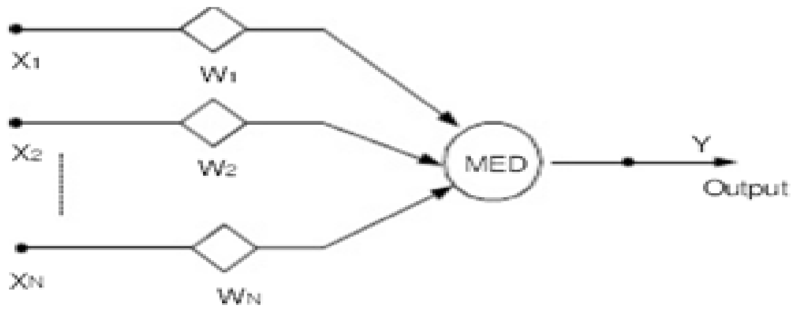


Figure 2: Structure of Weighted Median Filter

IV. IMPLEMENTATION OF PROPOSED METHOD

The general weighted median filter structure is as follows,

$$X = [X1, X2, X3 \ldots\ldots\ldots X_n]$$

$$W = [W1, W2, W3 \ldots\ldots W_n] \quad (1)$$

$$WM = MED[W1 * X1, W2 * X2, W3 * X3 \ldots\ldots\ldots W_n * X_n]$$

X is the input values form an input image, W is the array of weights and 'WM' is the weighted median value [13].

Adaptive median filter works on a rectangular region S_{xy} (the size of the neighborhood pixel). It changes the size of S_{xy} during the filtering operation depending on certain conditions [11]. The following notation is used:

Z_{min} = minimum pixel value in S_{xy}
Z_{max} = maximum pixel value in S_{xy}
Z_{med} = median pixel value from weighted median filter (WM)
xy = pixel value at coordinates (x, y)
S_{max} = maximum allowed size of S_{xy}

The adaptive median filtering algorithm works in two levels. We can denote it by level A and level B as follow [9]:

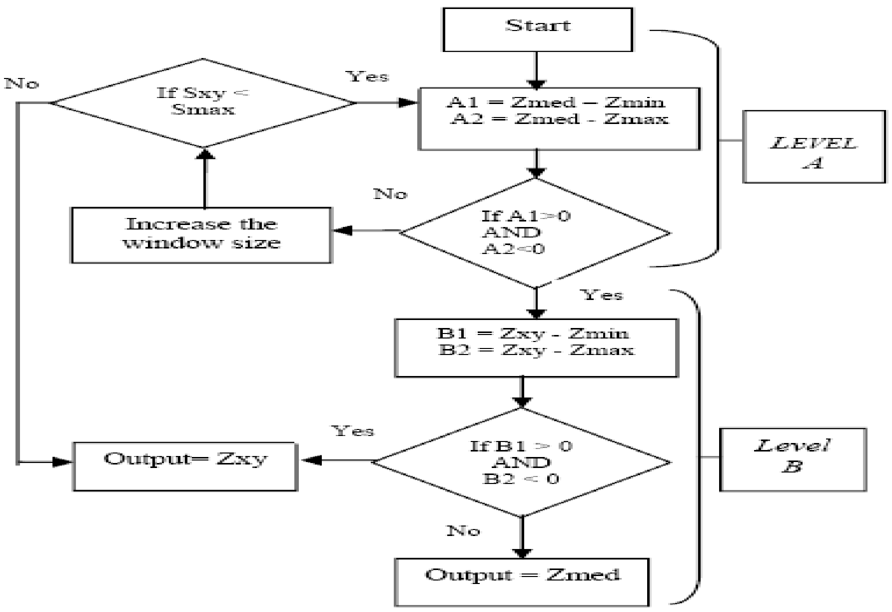


Figure 3: Structure of Adaptive Median Filter

Now we analyze the adaptive median filter. Impulse noise can be negative or positive. Because impulse corruption usually is large compared with the strength of the image signal, negative impulse generally is digitized as the minimum values and positive impulses generally is digitized as the maximum values. If Z_{min}, $Z_{med,}$ Z_{max} and Z_{med} are not identified as a noise, we go to Level B. The basic idea of Level B is as follows, Z_{xy} is evaluated to verify whether it is a noise or not. If it is a noise, it will be replaced by Z_{med}. Otherwise, Z_{xy} is not identified as a noise. Z_{xy} is retained in the filtered image. Thus, unless the pixel being considered is a noise, the pixel value in the filtered image is the same as that of the input image. This can avoid unnecessary loss of detail [10].

V. RESULTS AND DISCUSSION

In this section, the performance of the proposed method is tested for synthetic aperture radar images with standard median filters. The results are compared with well known filters such as Relaxed Median (RM) Filter, Adaptive Median (AM) Filter and Weighted Median (WM) Filter.

Table 1.Comparisons of different median based filters for synthetic aperture radar images

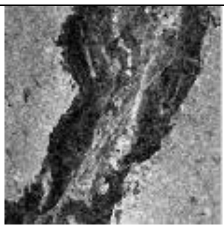
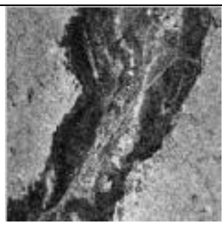
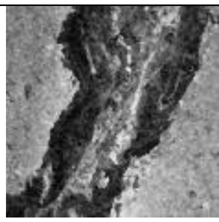
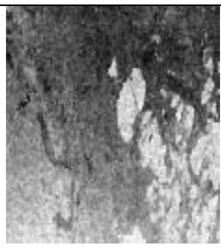
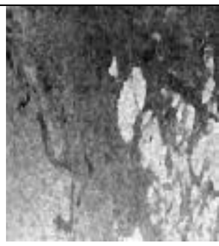
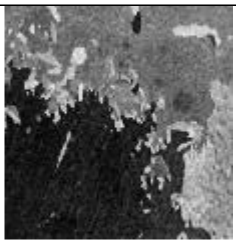
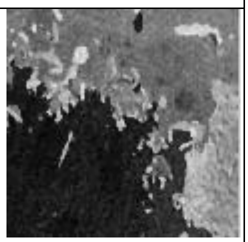
S.no	Original	RM	WM	AM	AWM
1					
2					
3					
4					
5					

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Table2 compares the execution time of operation with the different types of median based filters for Synthetic Aperture Radar (SAR) ice images. The speed of Adaptive Median (AM) filter is faster than the other type of filters.

Table 2: Performance evaluation for median based filters with SAR image based on time

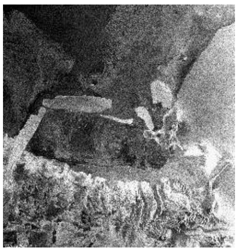
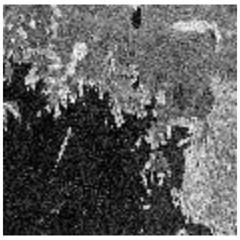
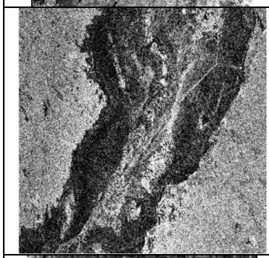
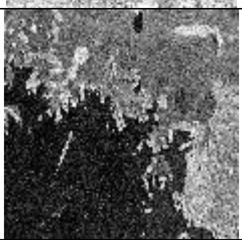
IMAGES	Time [Seconds]			
	Relaxed Median(RM)	Adaptive Median(AM)	Weighted Median(WM)	Adaptive Weighted Median(AWM)
	31.9531	0.1563	0.2344	0.5156
	14.7188	0.1094	0.2500	0.5625
	82.7656	0.1563	0.2500	0.5313
	23.1094	0.1406	0.2656	0.5625
	13.2344	0.1563	0.2344	0.5469

Table 3 show the SNR and MAE results of various filters for SAR image. The SNR and MAE results clearly show the superior performance of the proposed method over the other filters.

Table 3

IMAGES	Relaxed Median(RM)		Weighted Median(WM)		Adaptive Median(AM)		Adaptive Weighted Median (AWM)	
	SNR	MAE	SNR	MAE	SNR	MAE	SNR	MAE
	6.1533	2.5839	6.2258	2.7766	6.4239	2.5622	7.7266	2.0067
	5.7574	4.2973	5.8428	4.7997	6.0885	4.3345	6.7183	4.0514
	5.5052	3.6323	5.5941	3.9612	5.6152	3.6635	5.9070	3.0359
	11.4896	1.2552	11.6192	1.8508	11.7033	1.2883	11.9605	1.0959
	12.4801	0.3808	12.7870	0.4187	12.8488	0.3632	12.9835	0.2843

Median based filtering performances are measured by the signal-to-noise ratio (SNR) and the mean absolute error (MAE). The signal to noise ratio (SNR) is a representative of the average signal power to the estimated noise component present for a pair of original and filtered image [12]. The (SNR) is defined by the equation,

$$SNR = 10\log_{10}\left(\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(g_{i,j}^2 + f_{i,j}^2)}{\sum_{i=1}^{M}\sum_{j=1}^{N}(g_{i,j} - f_{i,j})^2}\right) \quad (2)$$

Let g $_{i,j}$ is the original image and f $_{i,j}$ is the estimated image. i = *1, 2.., M* (range index) and *j = 1, 2.., N* (cross-range index).

$$MAE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left(f_{i,j} - y_{i,j}\right) \tag{3}$$

In equation (10), $f_{i,j}$ is the original image and $y_{i,j}$ is the estimated image. i = *1, 2.., M* (range index) and *j = 1, 2.., N* (cross-range index).

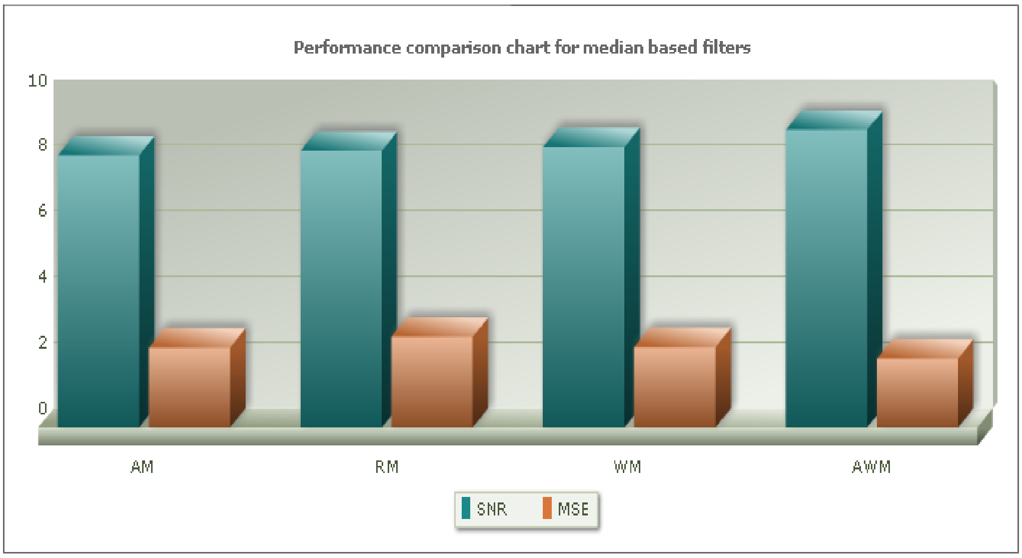


Figure 4. Performance comparison chart for median based filters and proposed method based on SNR and MSE

VI. CONCLUSION

Adaptive weighted median filter shows efficient impulsive noise suppression and an excellent image detail-preserving capability. The results confirm good performance of the new method, which could be used for the filtering the synthetic aperture radar ice noisy images. The effectiveness of the proposed method is demonstrated by the experimental results. The proposed filter can eliminate the noise without deteriorating the original image. Experiment results shows the proposed method can improve the filtering performance significantly.

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