

Threshold Value Based Switching Median Filters

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ABSTRACT:While transmitting digital images over noisy channel, images are getting corrupted with impulse noise which degrades image and causes loss of information. So it is necessary to filter impulse noise before subsequent operations. Various researchers have proposed number of schemes to filter impulse noise. In these, median based switching schemes filter only corrupted pixels by using noise detection stage and filtering stage. Switching median filters use methods like threshold value based, region based and clustering for noise detection. Review of threshold value based switching median filters is presented in this paper. This review shows that overall performance of filter depends on correct noise detection, filtering algorithm and computational complexity.

KEYWORDS:Impulse Noise, Median, Switching, Threshold

I. INTRODUCTION

Images are frequently corrupted by impulse noise due to malfunctioning pixel elements in the camera sensors, faulty memory locations, timing errors in analog-to-digital conversion, and transmission errors [1]. Impulse noise is random, sparse and it is of high or low amplitude level relative to local pixel values. One important property of this noise is only some pixels are corrupted while other pixels are noise-free. Removal of impulse noise is important as it may affect performance of subsequent image processing operations such as edge detection, object recognition etc.

The performance of an image restoration filter depends on the image and noise model. While defining filters it is assumed that the image to be filtered is locally smoothly varying and separated by edges. In impulse noise, some pixels are corrupted and other pixels are uncorrupted. Corrupted pixels have relatively high or low amplitude level. This leads to two types of impulse noises that may occur in image: positive impulse and negative impulse. Pixel corrupted by positive impulse takes a very large value in the dynamic range while pixel corrupted by negative impulse takes a very small value in the dynamic range.

Filters designed for removal of impulse noise classified as linear and nonlinear filters. It has been found that nonlinear filters are superior to linear filters [2]. The median filter is extensively studied nonlinear filter due to its ability to suppress impulse noise. The median filter replaces every pixel by the median of neighbourhood window without considering whether current pixel is corrupted or noise free. This space invariant feature of median filter leads to blurring of fine details. Several extensions of median filter like weighted median (WM) filter, Optimal WM filter, optimal stack filters have been proposed by various researchers for performance improvement. However, space invariant nature of the filters blurs image details. It clearly suggests solution as filtering only corrupted pixels and keeping noise free pixels intact by using an impulse noise detection scheme. Switching median filter (SMF) use such noise detection scheme to filter only noisy pixels. SMFs use methods like threshold value based, region based, cluster based techniques for noise detection. In this paper, review of threshold value based SMFs is presented.

II. LITERATURE REVIEW

Sun and Neuvo have proposed two switching schemes for impulse noise detection [2]. Impulse detector is devised on the fact that impulses are outliers i.e. biggest or smallest ones among the samples. So difference between central pixel value and median gives a good measurement. Switching scheme I is shown in Fig. 1. In first switching scheme, if absolute difference between central pixel and median is greater than a threshold value T , then pixel is deemed as corrupted and replaced by median else pixel is deemed as uncorrupted and kept as it is. Let D_{ij} be uncorrupted image, X_{ij} be corrupted image, Y_{ij} be filtered image and y_{med} be median of neighbourhood window.

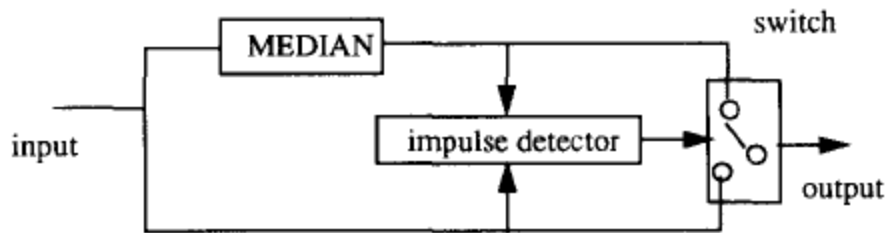


Fig. 1. Switching scheme I

The filtering output of scheme I is

$$Y_{ij} = \begin{cases} D_{ij}, & |X_{ij} - y_{med}| < T \\ y_{med} & |X_{ij} - y_{med}| \geq T \end{cases}$$

Using scheme I, impulses can be detected better but sometimes uncorrupted pixels can be deemed as corrupted and filtered unnecessarily. To overcome this problem, in scheme II, instead of median detector, detail preserving WM is used to detect impulses. Let y_{wmed} be weighted median then output of scheme II is

$$Y_{ij} = \begin{cases} D_{ij}, & |X_{ij} - y_{wmed}| < T \\ y_{wmed} & |X_{ij} - y_{wmed}| \geq T \end{cases}$$

Scheme II preserves more details at the cost of reducing impulse detecting ability. Scheme I and II have found to be effective at low noise density where corrupted pixels are sparsely distributed. However, when image is corrupted with high noise density, it contains noise blotches. Scheme I and II fails to detect impulses in noise blotches accurately, hence noisy pixels are impossible to be filtered [3].

Switching scheme I of Sun and Neuvo is used by Wang and Zhang in Progressive Switching Median Filter (PSMF) [3] iteratively to detect impulses progressively through several iterations. Pixels which are detected as impulses in impulse detection stage are only filtered in noise filtering stage iteratively. In noise filtering stage, impulses are replaced by median of noise free pixels of neighbourhood window. Simulation results shows that at higher noise density, PSMF outperforms switching scheme I. However iterative noise detection increases execution time.

Median based impulse detection scheme detects thin lines as impulse and filter those pixels though not desired. To overcome this problem, Zhang and Karim have proposed a new impulse detector for switching median filters [4]. This detector convolves input image with four convolution kernels, each of which is sensitive to edges in a different orientation. Then minimum absolute value of four convolutions is compared with a threshold for impulse detection. If this minimum absolute value is greater than threshold, pixel is corrupted; else pixel is uncorrupted. Computational complexity of this filter is low, so it is easy to implement.

Sun and Neuvo's switching schemes, PSMF and impulse detection based on convolution kernels use a fixed threshold obtained at a pre-assumed noise density and hence non-adaptive to noise density level [5]. It has also been found that as noise density increases, more misclassification of pixels are occurring and resulting in poor filtering performance.

To overcome these limitation, S. Akkoul et al. have proposed Adaptive SMF (ASMF) [6] in which threshold is not a priori choice. It is computed locally from image pixels. In this filter, weighted mean value and weighted standard deviation are estimated from neighbourhood window of current pixel. The weights are the inverse of the difference between the weighted mean value of pixels in a given window and the considered pixel. In each window, the weighted mean is estimated first iteratively. Then the weighted standard deviation is calculated and the local threshold is determined using weighted standard deviation. Then if absolute difference between the current pixel and weighted mean is greater than local threshold then current pixel is deemed as noisy and replaced by median of neighbourhood window. Simulation results shows that value of weighted standard deviation varies as per image regions. This adaptability is an important point to preserve image details.

However, at high noise densities, some noise values may be far from their neighbour's values. In such case, the weighted standard deviation could be large so that the absolute difference between the weighted mean value and the value of the current pixel itself is less than the local threshold. Thereby noisy pixel would be falsely deemed as uncorrupted [7]. Thus, it needs to find a way to overcome this drawback.

To overcome drawback of ASMF Adaptive Non-local Switching Median (ANSM) detector is proposed by X. LAN et al. in [7]. Noise detection scheme used is as follows. The processing pixel is in nine neighbouring sub-windows of size 3×3 . For each of these sub-windows weighted mean and weighted standard deviation, absolute difference between weighted mean value & current pixel and local threshold is estimated as in ASMF. The sum of these absolute differences of sub-windows in which absolute difference is greater than local threshold is computed. If this sum is greater than a threshold n which is chosen through extensive experiments then current pixel is noisy. Then noisy pixels are filtered by edge preserving regularization method proposed by N. Nikolova [8]. Simulation results show that performance of this filter is superior up to 70% noise density level.

In filters which are using single threshold value/ level to detect noisy pixel, pixels having value smaller than (or greater than) the given threshold level are considered as noisy. In this system, the range of pixel values used for identifying the noisy pixels will be large. This may increase the possibility of incorrect detection.

To overcome this limitation, V. Gupta et al. have proposed adaptive dual threshold median filter [9]. In this method, a filtering window W of size $r \times r$ is formed for each pixel. Generally, in images, gradual changes in adjacent pixel values are more common as compared to the abrupt changes. Noise corruption at any pixel would change its gray level with respect to its surrounding pixels. Average values of a set of samples (data values) always lie in close proximity to the values under consideration. Hence any sudden change in pixel value can be easily identified by analysing it with respect to average values. Based on this fact, averages of rows and columns of filtering window are calculated. Minimum and maximum value of these averages are used as minimum threshold (T_{min}) and maximum threshold (T_{max}) respectively. If value of pixel under processing is lying in between T_{min} and T_{max} then the pixel is deemed as noise free otherwise noisy. Noisy pixel is replaced by median of filtering window.

While detecting high density impulse noise, it may happen that, some of the noise-free pixels are detected as noisy pixels and vice versa. Hence the filtering stage not only fails to correct all the noisy pixels but also alters some noise-free pixels which were detected as noisy pixels. In order to overcome the miss detection, N. Singh et al. have proposed triple threshold statistical detection filter [10]. Statistical tools such as standard deviation, mean, and quartile are used to determine thresholds.

To determine first threshold, 5×5 window A , centering on current pixel is formed. Then mean (μ_A) and standard deviation (σ_A) of all pixels of A except Central Pixel (CP) is calculated. Absolute differences of all pixels of A with mean μ_A except CP are calculated. Then mean (μ_p) and standard deviation (σ_p) of all these absolute differences is calculated. Sum of this μ_p and σ_p defines first threshold T_1 . Then absolute difference of CP with rest all pixels of A is calculated. Mean of these values μ_q is used as Noise Signature (NS). If NS is greater than equal to T_1 , CP is noisy pixel otherwise algorithm moves to determine second level of thresholds as below

$$T_{2min} = \mu_A - K * \sigma_A$$

$$T_{2max} = \mu_A + K * \sigma_A$$

Here K is multiplication factor and its optimum value is derived empirically for various random sets of pixels through simulations. The reason behind taking mean μ_A and standard deviation σ_A for setting these thresholds is that most of the noise-free pixels would fall within the above thresholds since they smoothen out the pixel values and generally tend towards a value resembling a noise-free pixel. If CP is less than or equal to T_{2min} or CP is greater than or equal to T_{2max} , then CP is noisy else algorithm moves to estimate third level of thresholds T_{3min} and T_{3max} . T_{3min} is first quartile of set of all pixels of A except CP and T_{3max} is third quartile of set of all pixels of A except CP. If CP is less than or equal to T_{3min} or CP is greater than or equal to T_{3max} , then CP is noisy.

This algorithm uses three levels of thresholds to yield higher level of accuracy in detection and it also provides low computational complexity. Extensive simulation results shows that this algorithm outperforms various other filters both quantitatively and qualitatively even at very high noise intensity levels.

III. CONCLUSION

Removal of impulse noise is important to avoid loss of information and also to avoid performance degradation of subsequent image processing operations. Switching median filters using threshold value based impulse detection techniques are reviewed in this paper. These filters are using fixed threshold, noise adaptive threshold, dual threshold and triple threshold for noise detection and different filtering algorithms for processing of noisy pixels. Performance of these filters is required to be analysed in terms of correct noise detection, filter performance and execution time for their selection in real time applications.

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