Multiple Thresholds Switching Median Filtering for Eliminating Impulse Noise in Images

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Abstract: A switching median filter incorporated with a powerful impulse noise detection scheme called, Multiple Threshold Switching Median Filter (MTSMF) is proposed in this paper for enhancing the images corrupted by impulse noise during acquisition and/or transmission over communication channel. The impulse detection algorithm is used before the filtering process and therefore the noise-corrupted pixels are replaced with the estimated central noise-free ordered median value in the current filter window. The impulse detection technique is based on multiple thresholds with multiple neighborhood information of the signal in the filtering window. Extensive simulation studies and the results obtained from them show that the suggested technique is superior to the single threshold median filtering in terms of preserving edges and fine details and computational complexity. This proposed MTSMF is algorithmically simple and suitable for real-time implementation and applications.

Key words: Multiple thresholds · Median filter · Impulse detection · Mixed impulse noise

INTRODUCTION

Digital images are often corrupted by mixed impulse noise when they are reconstructed by noisy sensors and/or transmitted over noisy channels. Intuitively and ideally, the filtering should be applied to corrupted pixels only while leaving those uncorrupted ones intact. Applying median based filters like median, weighted median and center weighted median filters [1, 2, 3], unconditionally across the entire image as practiced in the conventional schemes would inevitably alter the intensities and remove signal details of those uncorrupted pixels. Therefore, a noise-detection process to discriminate the uncorrupted pixels from the corrupted ones prior to applying nonlinear filtering is highly desirable. The existing median based impulse detection techniques have been developed to suppress impulse noise while preserving image details. The decision based switching median filtering schemes is realized by thresholding operations to avoid damage to good pixels

MTSM Filtering Scheme: Impulse noise can appear because of a random bit error in a communication channel. In this work, the source images, which are often...
corrupted by impulse noise during acquisition and/or transmission, are considered. In an impulse noise contaminated image a noisy pixel assumes a high value due to positive impulse and a low value due to a negative impulse. Elimination of impulse noise without damaging the image features is an important requirement in image filtering. The Multiple Threshold Switching Median Filtering Scheme (MTSMFS), introduced in this paper is robust against impulse noise besides being capable of preserving the edges and fine details quite satisfactorily. In MTSMF, the impulse noise elimination is achieved using multiple thresholds with multiple neighborhood information of the signal in the filter window. The schematic diagram of MTSMFS is shown in Fig. 1.

MTSMFS basically consists of two stages, namely, impulse detection stage and the filtering stage. In the impulse detection stage, the image pixels are classified as corrupted and uncorrupted pixels using multiple thresholds. The filtering stage performs median filtering on the corrupted pixels and retains the uncorrupted pixels undisturbed.

**Impulse Detection:** Let \( \{x_i\} \) represent the image corrupted with the impulse noise. In the impulse detection stage, a window of size \((2N+1) \times (2N+1)\) is slid over the noise corrupted image. Let the pixel \( y(k,l) \) be the maximum/minimum-valued pixel inside the filter window. The neighboring pixels of \( y(k,l) \) is used to decide whether the pixels inside the window are noise corrupted pixels or not. The elements inside the filter window excluding \( y(k,l) \) are sorted in ascending order. Let the sorted vector be defined as:

The process of classifying the corrupted and uncorrupted pixels inside the filter window involves two steps. In the first step, the difference between \( y(k,l) \) and each element of \( s(p) \) inside the filter window is computed, referred to as grade-ordered difference which is described as:

The second step involves the process of classifying the pixels as corrupted and uncorrupted pixels by comparing the grade-ordered difference with multiple threshold values. If \( d(q) > T_a, a=1,2,3,...,8 \) (\( T_a \) denotes multiple threshold values) then the pixel corresponding to this grade-ordered difference is identified as an impulse; otherwise, it is treated as uncorrupted pixel.

**Filtering Operation:** The impulse detection stage has already classified the pixels inside the filter window as corrupted and uncorrupted pixels. The filtering stage performs median filtering on the corrupted pixels; no filtering action is applied on uncorrupted pixels. The image details contained in the uncorrupted pixels are preserved intact, since they are not subjected to median filtering operation. Median filtering is an effective order-statistic technique for cleaning the image signals contaminated with the impulse noise. It slides a window of size \((2N+1) \times (2N+1)\) over the noisy image \( \{x_i\} \), arranges the samples in ascending order at every point and sets the central sample as the filter output [10-14].

The output of the filtering stage is the enhanced image, freed from the impulse noise. In addition, since the corrupted pixels only are subjected to the filtering Operation, the image details are preserved satisfactorily.

**Simulation Results:** The proposed MTSM filter is evaluated, both objectively and subjectively, by applying it on various test images. The results obtained by applying the filter on flower image are presented in this section for discussion and analysis. Quantitative measures, that is, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are used to analyse the performance of the filter on the test image confounded by different levels of impulse noise and at different number of thresholds. Lower MSE and higher PSNR values are indicative of the desirable performance of the filter. The quantitative measures used for performance evaluation are defined as:

The enhancement results obtained, by applying the standard median and MTSM filters on the Flower image corrupted with 10% impulse noise, are summarized in Table 1. MTSM filter exhibits better performance than standard median filter in terms of all quantitative measures considered for evaluation and also it preserving edges and fine details is better than standard median filter.
Table 1: MSE and PSNR obtained using median and MDSM filters on Flower image corrupted with 10% impulse noise at multiple thresholds (8 thresholds)

<table>
<thead>
<tr>
<th>Types of filters</th>
<th>Performance Measures</th>
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<tbody>
<tr>
<td>Median filter</td>
<td>MSE: 20.506, PSNR: 33.0221</td>
</tr>
<tr>
<td>MDSM filter</td>
<td>MSE: 19.4, PSNR: 35.3</td>
</tr>
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</table>

Fig. 2: MSE obtained by applying MDSM filter on Flower image contaminated with different levels of mixed impulse noise using multiple threshold

Fig. 3: (a) Original image; (b) Image corrupted with 10% impulse noise; (c) MDSM filtered image with 1 threshold; (d) MDSM filtered image with 2 thresholds; (e) MDSM filtered image with 3 thresholds; (f) MDSM filtered image with 4 thresholds; (g) MDSM filtered image with 5 thresholds; (h) MDSM filtered image with 6 thresholds; (i) MDSM filtered image with 6 thresholds and (j) MDSM filtered image with 8 thresholds, respectively

For subjective evaluation, the results obtained, by applying the MDSM filter (with different number of thresholds) on Flower image corrupted with 10% impulse noise, are presented in Fig. 3. It can be seen that the noise filtering becomes more and more effective with increasing number of thresholds. Fig. 3(j) shows the filtered image using 8 threshold values and it can be observed that the impulse noise has been completely eliminated. In addition, the MDSM filter preserves edges and fine details of the images satisfactorily.

**CONCLUSION**

A Multiple Threshold Switching Median Filter is described in this paper. The proposed filter exhibits good noise cleaning properties in the presence of impulse noise. In addition, the important features of images, namely, edges and fine details are preserved satisfactorily. The proposed filter is superior to single threshold switching median filter in terms of noise filtering characteristics, feature preservation properties and computational complexity. Hardware implementation of this filter will make it suitable for real-time image filtering applications.

**REFERENCES**


