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Modified minimum-maximum exclusive mean filter

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Abstract: In an environment of fierce noise contamination, infected pixels tend to connect into noise blotches that could give the filtering algorithm an illusion of being part of the original image data. Therefore, many impulses would be difficult to detect, with the consequence of a less chance for proper detection and thus, filtering. Previously, median filters or its variant have been adopted to filter image corrupted with impulsive noise. Although advanced techniques have been added to these filters, many details such as thin lines and edges are either lost or blurred, especially at high noise situation. In this paper, a filtering method that consists of two stages, namely impulse noise detection and noise filtering is proposed, where the two stages are carried out separately and iteratively. Through computer simulation, the effectiveness of the suggested filter has been proven, especially at the high impulse noise levels.

Keywords: image processing, impulse noise, filter, iterative

Classification: Science and engineering for electronics

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1 Introduction

Digital images are often degraded by different kinds of random errors or infections. Noise can occur during image capture due to a defected camera light sensor, noisy transmission channel, or during storing and retrieval processing. This leads to the inevitable development of a suitable counter measure namely filters in order to enhance image quality. In image processing and computer vision, noise filtering is an essential preliminary step before different aspects of image processing, such as, histogram manipulation, edge detection, image enhancement and segmentation can be done.

The limited performance of linear filters has steered the attention to the non-linear filters. Median filter, originally introduced as a one-dimensional signal smoother, gained popularity due to its ability to suppress impulse noise spikes. Although noise smoothing is obtained, too much signal distortion is introduced, consequently image details such as sharp corners are lost. A good filtering action should distinguish between unwanted noise, to be identified and removed, and image contents with distinguishing features, such as edges, to be preserved.

To overcome this problem, several enhancements to the original median filter have been developed. Apart from the simple median filter that lacks noise detection, several switching schemes with different types of noise detectors have been suggested [1, 2, 3]. The common key concern in these filters was the introduction of some sort of noise detection scheme to first classify image pixels as either corrupted or not, before any filtering action take place. This is normally done by replacing the noisy pixels by values derived from local image contents. A noise detection scheme of some type has become a basic filter component as in the maximum-minimum exclusive mean filter (MMEM) [4] which is non median based. Typical examples of noise detectors are threshold or median value based comparator, with a constant threshold as in the MMEM or adaptive as in the progressive switching median (PSM) [5].

2 Methodology

The idea behind this methodology is based on the observation that, while the filter window is scanning the image, from left to right and top to bottom, moving one pixel at a time within each row and changing from one row to the next, the contents of the window at each position are overlapped with its contents in other locations both horizontal and vertical. Thus, combining the filtering stage simultaneously with impulse noise detection as in [4] could easily mislead the filter and this tends to create error propagation that could affect the entire image. Therefore, noise detection based on comparison with

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the threshold value T, and the substitution of the central pixel value of the scanning window will be done in separate phases, where the result of one iteration is an input to the next iteration. The proposed modified filter can be summarized as follows:
Let the scanning window of size $n \times n$ centered at (i, j) be $W_n(i, j)$.

1. Start with iteration $k = 1$ and window size $n = 3$.
2. Find the average value defined as:

$$av = \frac{1}{m}\sum_{n=1}^{m} \overset{k}{P}_{n\ (a,b)} \qquad \text{where} \quad a, b \in w(i, j) \tag{1}$$

   and m is the number of pixels within $W_n(i, j)$ satisfying the condition

$$\overset{k}{P}_{(a,b)} \neq \min(w(i, j)) \ \text{ or } \ \overset{k}{P}_{(a,b)} \neq \max(w(i, j))\,.$$

3. For high level noise corruption, if the result of step 2 is that $m = 0$, increase window size by setting $n = n + 2$ and repeat step 2. If the maximum window size $W_{\max}(i, j)$ is reached and still $m = 0$, let

$$av = \frac{1}{4}\sum_{c=-1}^{1}\sum_{d=-1}^{1} \overset{k}{P}_{(i-c,j-d)},\ c, d \neq 0 \quad c, d \in w(i, j)|_{w=3} \tag{2}$$

4. If $|av - \overset{k}{P}_{(i,j)}| > T$, then the centre pixel is considered as noisy and will be replaced at the next iteration by av. Otherwise, it will be left unchanged.

It has been found that the number of iterations will not exceed 4 for the highest impulse noise level of 80%, and the threshold value T that gives the best results is $25 \leq T \leq 30$.

The filter performance using this methodology is affected by the selection of the window size. As reported in [6], the use of a smaller window size achieves superior filtering at the lower range of noise densities whereas a larger window size is more appropriate to be used at the higher range of noise densities. While trying to derive an average value for the center pixel using the local image contents of the non-discarded pixels at the current window; if all the elements of the 5×5 window were again discarded, a larger 7×7 window will be used. In most cases, the majority of the filtering action is done within the first iteration. Therefore, the use of this larger 7×7 window will be limited to the case of the higher range of noise densities only. It was verified that a considerable amount of time would be saved using this optimization procedure without largely affecting MSE values.

3 Simulation Results

Different standard images corrupted with different noise levels were tested and the performance of the suggested method was compared with progressive

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switching median (PSM), histogram based fuzzy filter (HBFF) and the original minimum-maximum exclusive mean (MMEM) filter. The mean square error (MSE) is used as an objective measurement of the restored image quality. To evaluate edge-preserving capability, the Bit Correct Ratio (BCR) measurement was used. This is done by first segmenting the filtered images by using the Sobel operator with automatic threshold detection in both horizontal and vertical directions. The percentage of pixels with a logic 1 value in the restored segmented image that coincide with those of the original segmented image is then taken as the BCR. The method has been tested with 5 different standard test images namely cameraman, Lenna, baboon, crowd and moon. However, only the result obtained using the cameraman image will be discussed in this paper, since this image has a nice combination of texture and straight lines. The ability to restore these features can be used to evaluate the effectiveness of the filter proposed.

Table I shows the performance comparison of the proposed method against the original MMEM and other methods. The MSE value of the noisy image is given for the respective noise contamination. The recorded MSE is given in bold and BCR is given in italic. It can be seen that the proposed method produces lower MSE values compared with other existing methods especially for high to very high noise levels. It is worth mentioning that for the cameraman image, the number of iterations needed by the proposed method are; 1 for noise level less than 40%, 2 for 50-70% and 3 for 80%, and the trend is similar for the other test images. The overall improvement from the original MMEM filter in term of MSE is 21%. The proposed method also recorded the highest BCR value at all noise levels. This shows the effectiveness of the proposed method in filtering the impulse noise as well as preserving the edges. Noise filtering and edge preserving are considered as two inherently conflicting criteria since noise reduction can destroy an edge while preserving edges can lead to unnecessary noise existence. A tradeoff between these two issues can be further made by visual inspection on Fig. 1. The original cameraman image is shown in Fig. 1 (a). Salt and paper noise was later added to the image as shown in Fig. 1 (b), where the noise level was set at 80%.

The result of the original MMEM filter is shown in Fig. 1 (c), where the

Table I. Comparison of MSE and BCR

Noise (%)	10	30	40	50	60	70	80
MSE Without filter	2,000	6,170	8,040	10,200	12,200	14,000	16,100
PSM	**133**	**320**	**386**	**450**	**593**	**1,064**	**3,543**
	62	*58*	*52*	*44*	*39*	*25*	*10*
HBFF	**178**	**207**	**231**	**269**	**327**	**453**	**666**
	70	*66*	*62*	*56*	*49*	*40*	*31*
MMEM	**132**	**171**	**205**	**236**	**286**	**375**	**537**
	71	*65*	*61*	*56*	*50*	*43*	*40*
Proposed	**124**	**161**	**179**	**206**	**234**	**269**	**360**
	71	*66*	*63*	*59*	*53*	*48*	*40*

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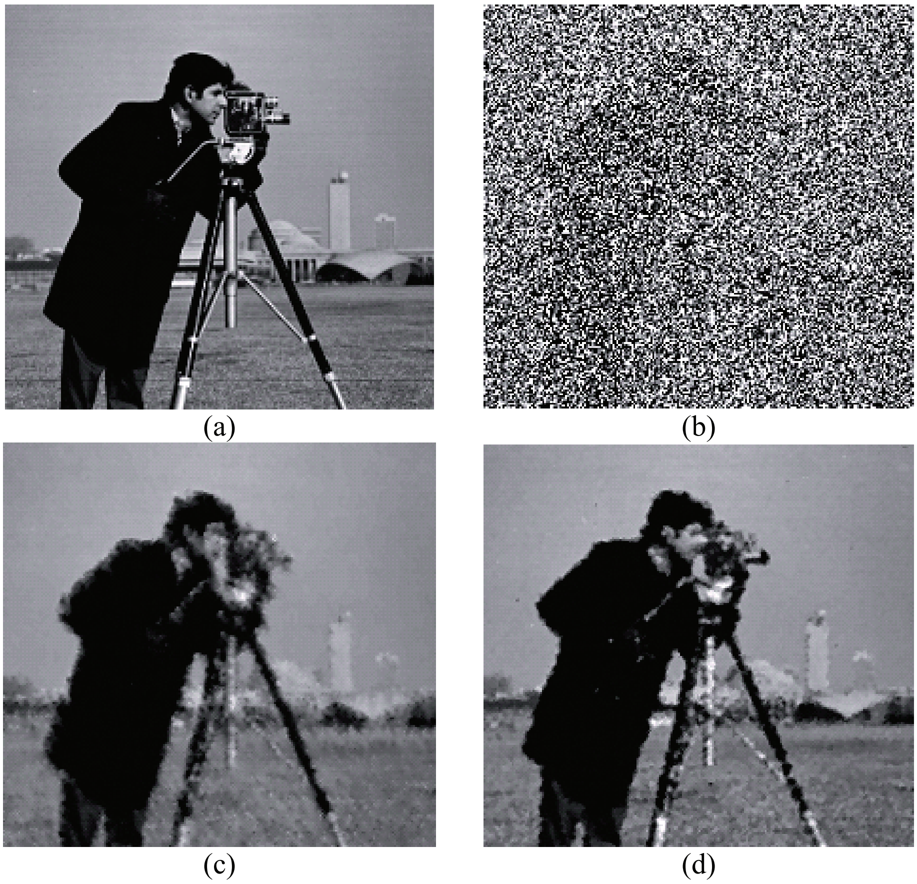

Fig. 1. Cameraman Images. (a) Original (b) Corrupted with 80% impulse noise (c) Filtered by MMEM (d) Filtered by the proposed method

filter had successfully filtered out most of the impulse noise to the extent of destroying the important features of the image such as texture and edge. It can be seen that most of the edges filtered by MMEM are destroyed, and causes blurring in the image. The proposed method on the other hand manages to filter the noise, while preserving most of the image contents. The difference can be seen clearly around the jacket of the cameraman and the face. The background structure can also still be recognized.

4 Conclusion

The performance of the minimum-maximum exclusive mean filter (MMEM) has been improved, both in terms of MSE and BCR measures. This is achieved through adaptive windowing via iteration and separate phase for noise detection and removal. Despite its simple structure, the proposed filter has shown a better performance, both, in terms of objective measurements, as well as visual inspection in comparison with the original MMEM filter.

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