MVA2009 IAPR Conference on Machine Vision Applications, May 20-22, 2009, Yokohama, JAPAN

A New Flat Pattern Oriented Order Statistic Filter for Impulse Noise Reduction from Highly Corrupted Images

Tomohiko Ohtsuka[1], Homare Sasaki[2], Masato Suzuki[1], Hiroyuki Aoki[1]
[1] Department of Electronics Engineering, Tokyo National College of Technology, Tokyo, Japan
[2] Advanced Course of Electric and Electronics Engineering, Tokyo National College of Technology, Tokyo, Japan

Abstract

When the image is highly corrupted, such as images photographed by the darkness regard camera, the detection of flat patterns is easier than that of edges. In this paper, a new adoptive order statistic filter by using flat pattern detection is proposed, and an approach to optimize the parameters of the order statistic filter is introduced. The proposed system is composed of the flat pattern detector, estimator of mean pixel value in flat pattern region, and the adopted order statistic filter. To evaluate the performance of the noise reduction by the proposed approach, several experiments are applied to reduce the impulse noise by this approach. These results show that the MSE by the proposed filter is the least in case that the image is highly corrupted.

1. Introduction

Images are often corrupted by impulse noise due to noisy sensors or channel transmission errors. The purpose of the reduction in impulse noise is to suppress noise, while preserving the integrity of edges and detail patterns. To realize this objective, several nonlinear techniques have been found to provide more satisfactory results than linear methods. The median filters and in general order statistic filters have demonstrated good proficiency in the removal of impulse noise [1] [2] [6]. However, because these techniques are typically implemented uniformly across an image, they tend to modify pixels that are not affected by noise. In addition, they are prone to edge jitter when the percentage of impulse noise is large. Consequently, the effective removal of impulses is often at the expense of blurred and distorted features. However, if only corrupted pixels are processed by the median filter, the degradation of image edges can be reduced. A median-based switched filter (called progressive median filter, PSM), where both the impulse detector and the noise filter are progressively applied in iterations, has been proposed. The aim is to process only the corrupted pixels. However, it is still difficult to detect the impulse noise around the edges and to remove the impulse noise at the edges [3]. In order to resolve this problem, a directional difference-based switching median filter and MAD-based PSM have been proposed [4]. If the image is highly corrupted by impulse noise, the image edges with burst noise cannot be distinguished from the original image.

When the image is highly corrupted, such as images photographed by the darkness regard camera, the detection of flat patterns is easier than that of edges. In this paper, a new adoptive order statistic filter driven by flat pattern detection is proposed, and an approach to optimize the parameters of the order statistic filter is introduced.

2. Adaptive order statistic filter using flat pattern detection

2.1. Impulse noise model

To detect impulse noise on the edge in the highly corrupted image is very difficult because the variation of the pixel value on each edge is large. On the other hands, because the variation on the flat pattern is enough small to distinguish impulse noise with non-corrupted pixels, it is rather easier to detect the flat pattern than the edge detection.

In this paper, the pixel value $x(i,j)$ degraded by the random-valued impulse noise is defined as

$$x(i,j) = \begin{cases} x_0(i,j) & : probability = 1-q \\ h & : probability = q \end{cases} \tag{1}$$

where $x_0(i,j)$ is the original pixel value at position (i,j); p, the probability of occurrence of the random-valued impulse noise; and h, a uniformly varied value whose range is $[0,d]$.

2.2. Overview of proposed system

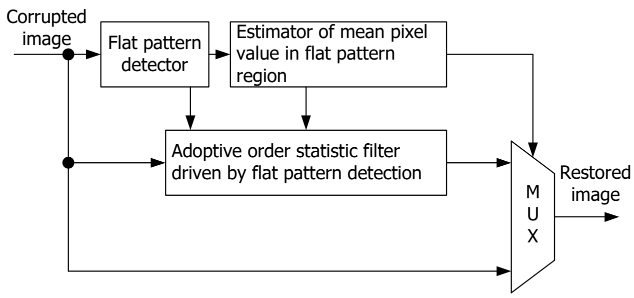


Figure 1. Overview of the adoptive order statistic filter by using flat pattern detection.

An overview of the adoptive order statistic filter driven by using flat pattern detection is shown in Figure 1. The proposed filter is composed of a flat pattern detector, mean value estimator in the flat pattern region, and adopted order statistic filter. The flat pattern detector extracts the regions as a *flat pattern region*, where the variation of pixel value is enough small. The estimator of the mean value in the flat pattern region estimates the average of the pixel value in the specified flat pattern region. The adoptive order statistic filter determines the noise eliminated value of the specified pixel based on the location of flat pattern regions and the average of the pixel value in the specified flat pattern region.

2.3. Flat pattern detector

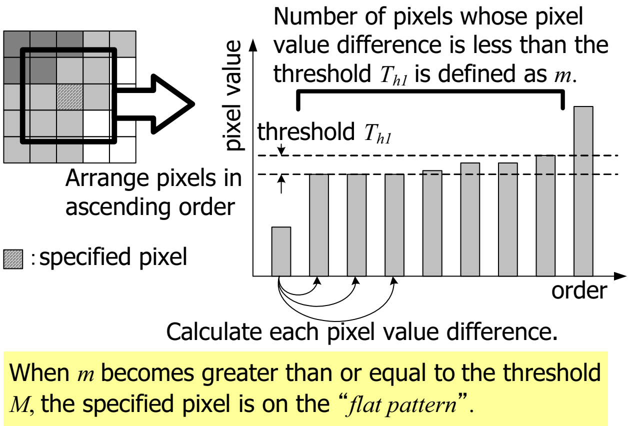


Figure 2. Overview of flat pattern detection.

To detect the flatness in an image, all the pixel values in every window with a specified size in the image are arranged in ascending order. In the proposed system, the window size is determined as 3 x 3 to improve the performance of the noise reduction with shorter computation time by the heuristic method. All the pixel value differences in each window are evaluated to detect *flat regions*. In the proposed system, the number of pixels, whose pixel value difference in each window is less than the threshold T_{h1}, is denoted as the variable m. When m is greater than or equal to the threshold M, the specified pixel, i.e., the center of the window, is defined as the flat pattern, where T_{h1} and M are obtained using the knowledge of the design. In this system, T_{h1} is determined as 15, and M is determined as 7. In flat pattern detection, every flat pattern pixel is extracted. The overview of the flat pattern detection is shown in Figure 2.

2.4. Estimator of mean pixel value in flat pattern region

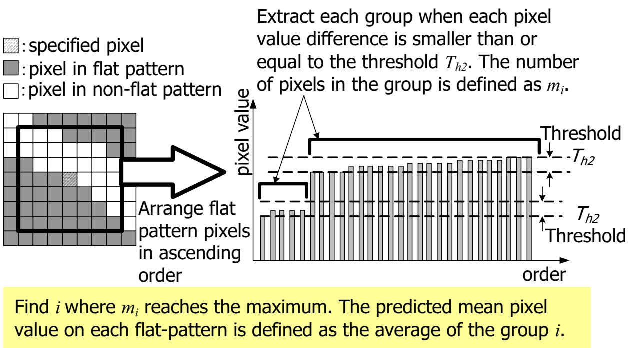


Figure 3. Overview of mean value estimation in each flat pattern region.

To estimate the mean pixel value of the flat pattern, every flat pattern pixel in the window is arranged in ascending order. In the proposed system, the window size is determined as 7 x 7 to improve the performance of the noise reduction with shorter computation time by the heuristic method. There are several groups in the window, in which all differences between specified two pixels are smaller than or equal to the threshold T_{h2}. In this step, every group is extracted to estimate the pixel mean value in each window. The threshold T_{h2} is determined manually by the filter design knowledge. The number of pixels in a group is denoted as variable m_i. In case that there are several groups where all differences between specified two pixels are smaller than or equal to the threshold T_{h2}, the group where m_i reaches the maximum is selected to calculate the mean pixel value. The mean pixel value of the group, where m_i is the maximum, is defined as the mean pixel value *ave* in the flat pattern region. In this system, T_{h2} is determined as 15 by the design knowledge.

2.5. Adoptive order statistic filter Estimator driven by flat pattern detection

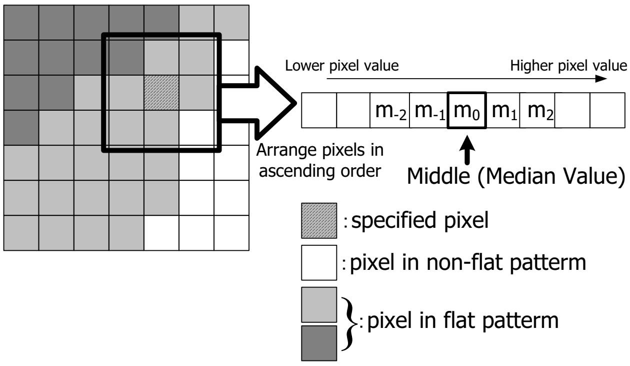


Figure 4. Overview of adoptive order statistic filter.

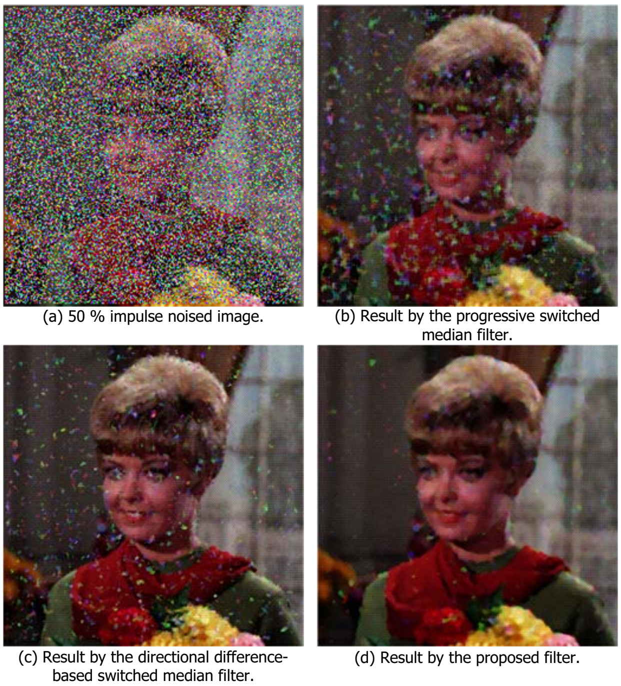
An overview of the method used to estimate the mean value of the flat pattern is shown in Figure 3. In the order statistic filter shown in Figure 1, the pixel values are arranged in ascending order. The filter output is switched on the basis of the mean value of the flat pattern. An overview of order statistic filtering is shown in Figure 4. In case of the high corrupted images, the median value in the window is rather far from the estimated mean value of the flat region. Thus, the normal median filter is not enough to reduce such corrupted impulse noise. Therefore, there needs to output the processing data adoptively based on the estimated mean value of the flat region. In this system, the output $p_{\text{out}}(i,j)$ at the location (i,j) from the adoptive order statistics filter is defined as,

$$p_{\text{out}}(i,j) = \begin{cases} m_2 & (204 \le ave). \\ m_1 & (153 \le ave \le 204). \\ m_0 & (102 \le ave \le 153). \\ m_{-1} & (\ \ 51 \le ave \le 102). \\ m_{-2} & (\qquad ave \le \ \ 51). \end{cases}$$

The output $p_{\text{out}}(i,j)$ is determined based on the mean pixel value *ave* of the flat pattern region to improve the image quality.

3. Experimental results

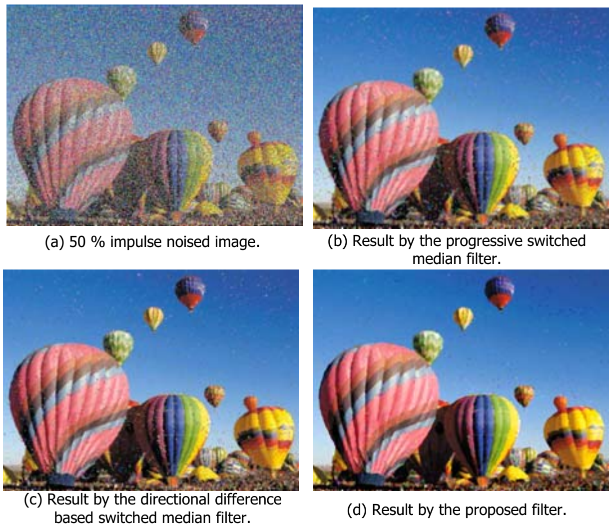
An experimental result of the restoration of corrupted images "girl", "balloons", "couple", "Lena" under a 50



(a) 50 % impulse noised image. (b) Result by the progressive switched median filter.

(c) Result by the directional difference-based switched median filter. (d) Result by the proposed filter.

Figure 5. Comparison of different filters for the restoration of corrupted image “girl” under the 50% impulse noise ratio.



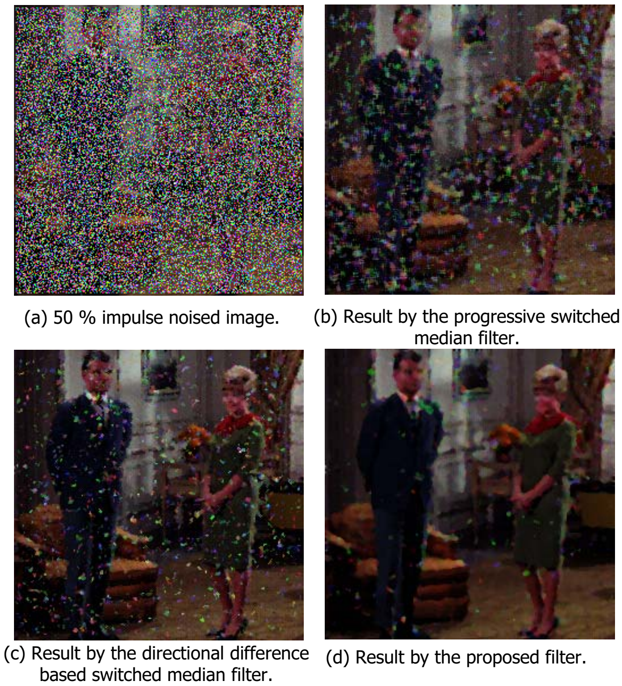
(a) 50 % impulse noised image. (b) Result by the progressive switched median filter.

(c) Result by the directional difference based switched median filter. (d) Result by the proposed filter.

Figure 6. Comparison of different filters for the restoration of corrupted image “balloons” under the 50% impulse noise ratio.

[%] impulse noise ratio are shown in Figure 5-8. For comparison, the results of the progressive switched median filter [3] and the directional differential-based switched median filter [5] are also shown. Though there remains noise that cannot eliminate in the results by conventional approaches, there is a little noise in the results by the proposed method.

The analysis results of the MSE values calculated by each filter are shown in Figure 9-12. In Figure 9-12, the ratio of the impulse noise is varied from 30 [%] to 50 [%] by the 5[%] step. Though the MSE results are larger than the conventional approach when the noise ratio is smaller than 35 [%], the MSE value of the proposed filter is the least when the image noise ratio is more than 35 [%] for each example result, in the case of the highly



(a) 50 % impulse noised image. (b) Result by the progressive switched median filter.

(c) Result by the directional difference based switched median filter. (d) Result by the proposed filter.

Figure 7. Comparison of different filters for the restoration of corrupted image “couple” under the 50% impulse noise ratio.

(a) 50 % impulse noised image. (b) Result by the progressive switched median filter.

(c) Result by the directional difference based switched median filter. (d) Result by the proposed filter.

Figure 8. Comparison of different filters for the restoration of corrupted image “Lena” under the 50% impulse noise ratio.

corrupted image. Another experimental results show that the MSE by the proposed filter is smaller than other methods against high corrupted images.

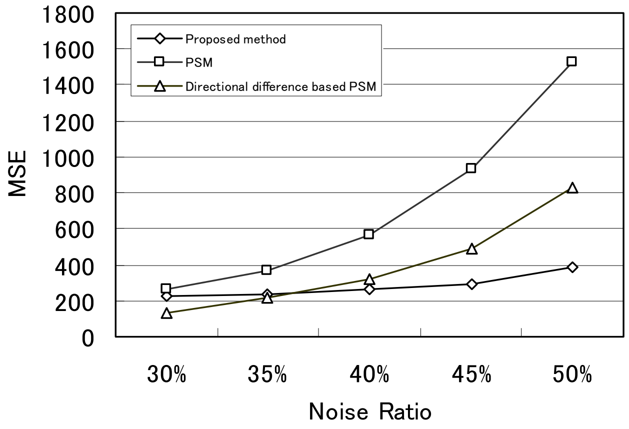


Figure 9. Comparison between different filters for the restoration of corrupted image "girl" with a large range of impulse noise ratio.

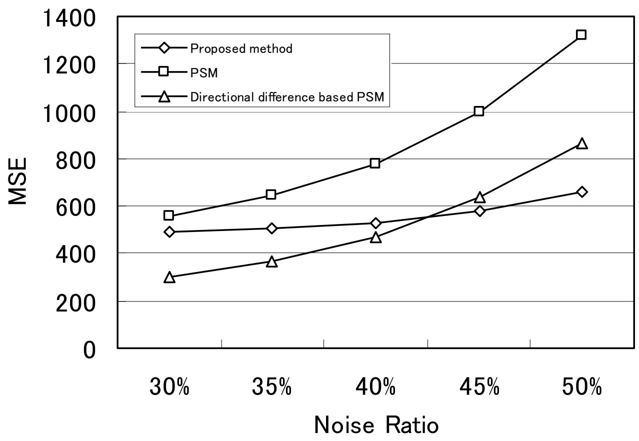


Figure 10. Comparison between different filters for the restoration of corrupted image "balloon" with a large range of impulse noise ratio.

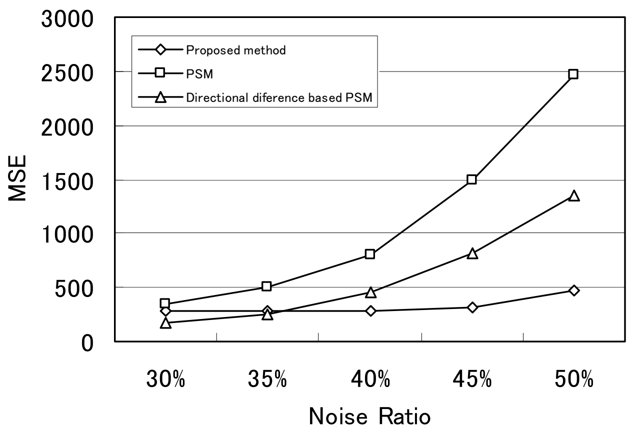


Figure 11. Comparison between different filters for the restoration of corrupted image "couple" with a large range of impulse noise ratio.

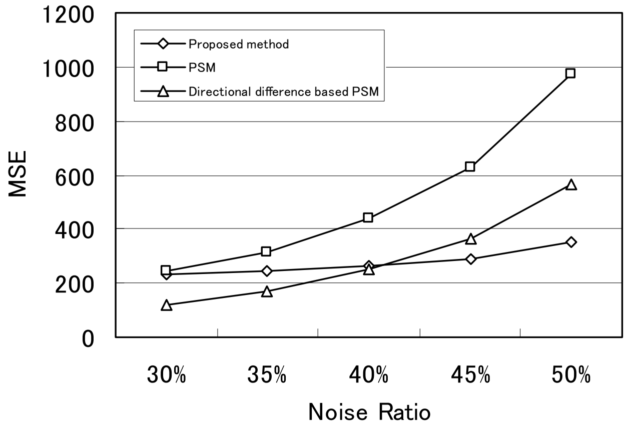


Figure 12. Comparison between different filters for the restoration of corrupted image "Lena" with a large range of impulse noise ratio.

4. Conclusion

A new adopted order statistic filter by using flat pattern detection is proposed. Several experimental results show that the MSE by the proposed filter is the least in case that the image is highly corrupted. The experimental results show that the proposed approach is effective to eliminate impulse noise for the darkness regard camera application.

Acknowledgements

This study is supported by a Grant-in-Aid for Scientific Research (C) No. 19560403.

References

[1] J. C. Russ, "Image Processing Handbook," A CRC Press, NY, 2007.

[2] S. E. Umbaugh, "Computer Imaging Digital Image Analysis and Processing," A CRC Press, NY, 2005.

[3] Z. Wang, D. Zhang, "Progressive Switched Median Filter for the Removal of Impulse Noise from Highly Corrupted Images," IEEE Trans. On CAS II, Vol. 46, No. 1, pp. 78–80, 1999.

[4] V. Crnojevic´, V. Senk, and Z. Trpovski, "Advanced Impulse Detection Based on Pixel-Wise MAD," IEEE Signal Processing Letters, Vol. 11, No. 7, pp. 589–592, 2004.

[5] Y. Hashimoto, Y. Kajikawa, Y. Nomura, "Directional Difference-Based Switching Median Filters," IEICE Trans. A, Vol. J83-A, No. 10, pp. 1131–1140, 2000.

[6] J. C. Russ, "The Image Processing Handbook Fifth Edition", CRC Press, 2007.

Note: The columns on the last page should be of approximately equal length.