I-087

Adoptive Order Statistic Filter Using Flat Pattern Detection

for Removal of Impulse Noise from Highly Corrupted images

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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]. 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, 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 driven by flat pattern detection

To detect impulse noise on the edge in the highly corrupted 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

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

where $x_0(i,j)$ is the original pixel value at (i,j); p, the probability of occurrence of the random-valued impulse noise; and h, a uniformly varied value whose range is $[0,d]$. An overview of the adoptive order statistic filter driven by using flat pattern detection is shown in Fig. 1.

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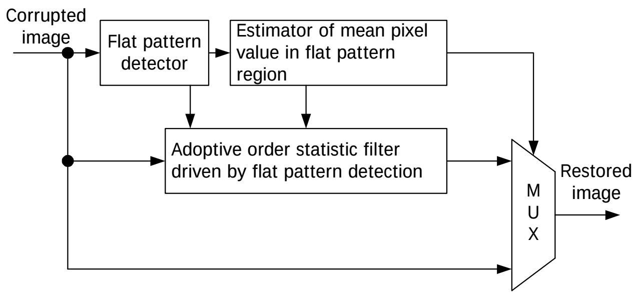


Figure 1: Overview of the adoptive order statistic filter by using flat pattern detection.

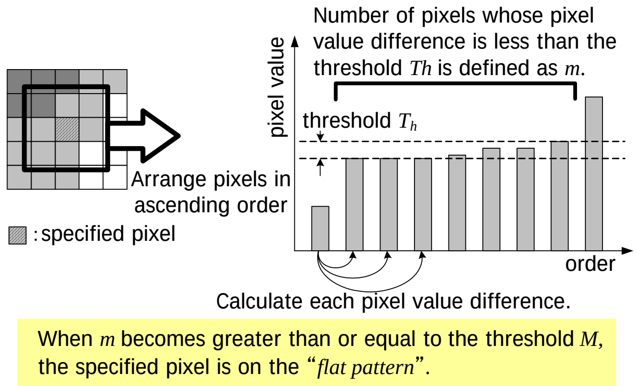


Figure 2: Overview of flat pattern detection.

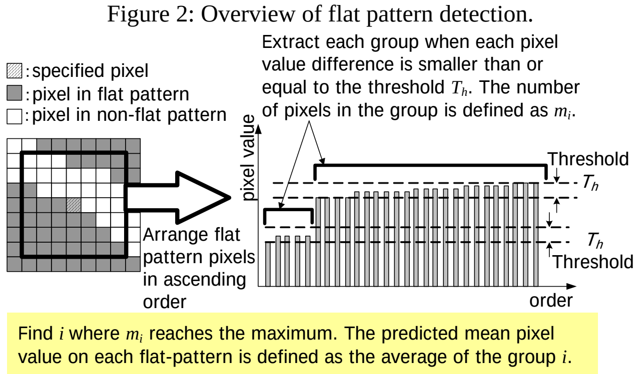


Figure 3: Overview of mean value estimation in each flat pattern region.

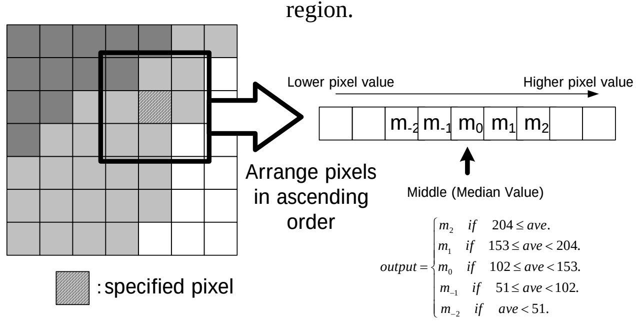
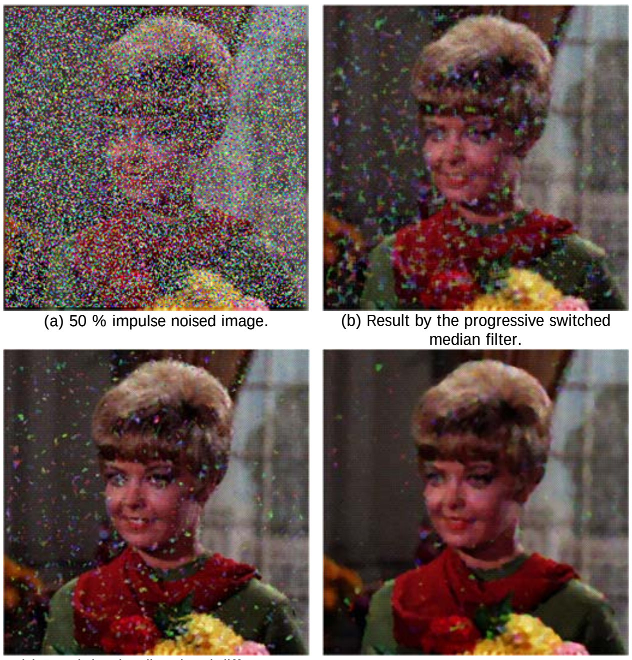


Figure 4: Overview of adoptive order statistic filtering.



(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.

The proposed filter is composed of a *flat pattern detector*, *mean value estimator* in the flat pattern region, and *adopted order statistic filter*. 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. All the pixel value differences in the window are determined. The number of pixels whose pixel value difference is less than the threshold T_h is defined as 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 m and M are obtained using the knowledge of the design. In flat pattern detection, every flat pattern pixel is extracted. The overview of flat pattern detection is shown in Fig. 2.

To estimate the mean pixel value of the flat pattern, every flat pattern pixel in the window is arranged in ascending order. Further, every group in the window, in which all the pixel value's differences are smaller than or equal to the threshold T_h, is extracted. The number of pixels in a group is defined as m_i. 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. An overview of the method used to estimate the mean value of the flat pattern is shown in Fig. 3.

In the order statistic filter shown in Fig. 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 Fig. 4.

3. Experimental Result

An experimental result of the restoration of corrupted image "girl" under a 50% impulse noise ratio is shown in Fig. 5. For comparison, the results of the progressive switched median filter [3] and the directional differential-based switched median filter [5] are also shown. The MSE value of each filter is shown in Table 1. In the case of the highly corrupted image, the MSE value of the proposed filter is the least when the image noise ratio is more than 40%. Another experimental results show that the MSE by the proposed filter is smaller than other method.

Table 1: Comparison between different filters for the restoration of corrupted image "*girl*" with a large range of impulse noise ratio.

Noise Ratio [%]	MSE of Progressive Switched Median Filter	MSE of Directional Difference-based Switched Median Filter	MSE of Proposed Filter
30	260.9	134.9	230.8
35	368.5	216.6	239.5
40	568.9	319.9	264.1
45	934.4	494.6	295.2
50	1527.0	833.9	382.2

3. Conclusion

The 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.

Acknowledgements

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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.