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ADVANCED ADAPTIVE MEDIAN FILTER FOR IMPULSIVE NOISES

Refik Samet[1], Muhammed Tanriverdi[2]

Ankara University, Ankara, Turkey
[1]*samet@eng.ankara.edu.tr*, [2]*muhammedtanriverdi@gmail.com*

One of the most important stages of signal and image processing is noise elimination. Noise is an unwanted perturbation to a wanted analog or digital signal or image [1]. A noise can be categorized depending on its source, frequency spectrum and time characteristics. Depending on a source, the noises are categorized into six types: acoustic noise; thermal and shot noise; electromagnetic noise; electrostatic noise; channel distortions, echo and fading; processing noise. On the other hand, depending on the frequency spectrum or time characteristics, the noises are also categorized into six types: white noise; band-limited white noise; narrowband noise; coloured noise; impulsive noise; transient noise pulses [2].

A lot of methods have been improved to eliminate noises. Filters are one of the most common tools which are used to eliminate noises. Many filters have been designed so far because of over plus of the noise varieties and differences between the properties of these noises. Generally, filters are divided into two groups as linear and non-linear. Linear filters have simple design and encoding and they are intended for general aim. These filters can be used to smooth the images or enhance the edges but they have weak capacity for noise elimination. Non-linear filters have been designed for specific aim and they produce better results. Non-linear filters are divided in many categories. Order statistic filter is one of the categories of non-linear filters. It is the most popular filter for noise elimination [3].

The subject of this study is to investigate and improve the noise eliminating methods related to digital images. Noise is unwanted pixels to be corrupted into digital images. The principal sources of noises in digital images arise during image acquisition (digitization) and/or transmission. The performance of imaging sensors is affected by a variety of factors such as bad focusing; motion and non-linearity of the sensors, etc. [1]. Type of noises has to be known for elimination of noises in digital image. If the noise type is unknown, the filter which will be applied to image can't be known. In such a case all filters are applied to images and each image is examined and then the filter which will produce the best result can be determined. The first problem occurs if it is unknown that there is noise in images or if the type of noises is unknown. This problem has not been solved yet. The second problem is the lack of values that will be used to compare the images which are filtered, without original image. The images, to which filters are applied, are being compared by using the relationships between original images.

Impulsive Noise (IN) is the most widespread and important noise in digital images [3]. IN is caused by malfunctioning pixels in camera sensors, faulty memory locations in hardware, or transmission through noisy channels. IN is categorized into two types: 1) SPN (Salt & Pepper Noise or Fixed Valued Impulsive Noise) and 2) RVIN (Random Valued Impulsive Noise). An aim of this study is to investigate and improve the techniques to deal with IN.

Many filters are used and investigated for elimination of SPN [3]. The most common ones are median filter (MF) and adaptive median filter (AMF). These filters produce good results in IN elimination because of being order statistics filters. AMF is suitable when ratio of noise is high. Because of adaptive property, it has decision mechanism for determining if the pixel is noisy or not. But this mechanism reduces time performance. Despite of producing better results on images, that have low noise, than other filters, they are not preferred on images when time performance is significant.

The noise properties of RVIN are different from the noise properties of SPN. Filters are used to eliminate this noise type and performances are compared. AMF may not eliminate well because of different noise types.

Because IN elimination in digital images is aimed, the filters which are used on spatial domain and the filters that are in order statistic category will be investigated, improved and analyzed. More specifically, enhancement of time performance of AMF and the elimination of RVIN type noises by AMF are aimed.

IN is corrupted to image by two different ways. One of them is SPN. In this noise types, there are 2 pixels which are corrupted in digital image. These 2 pixels are usually the minimum and the maximum values of the gray-level. Thus for 256 gray-level digital image, the minimum value is 0 and the maximum value is 255. The other one is RVIN. In this noise type, the noise pixels may be any value of the gray-level of digital image.

There are many works on the restoration of image corrupted by IN [4]. The median filter was one the most popular nonlinear filter for eliminating impulsive noises because of its good denoising power and computational efficiency [5]. However, when the noise level is over 50%, some details and edges of the original image are smeared by the filter. Different remedies of the median filter have been proposed, e.g., the adaptive median filter [6], the multistage median filter [7], and the median filter based on homogeneity information [8], [9]. These so-called "decision-based" or "switching" filters, firstly, identify possible noise pixels and then replace them by using the median filter or its variants, while leaving all other pixels unchanged. These filters are good at detection noise even at a high noise level. Their main drawback is that the noise pixels are replaced by some median value in their vicinity, details and edges are not recovered satisfactorily when the noise level is very high. A noise removal method by median-type noise detectors and detail-preserving regularization is proposed in [10]. In that method, SPN with noise ratio 90% can be cleaned quite efficiently, however its computation is huge.

AMF does not work well for RVIN when noisy pixels are not the minimum and maximum pixel value in the image. There are some works for RVIN [3].

As mentioned above, this paper aims to propose the advanced adaptive median filter which improves the time performance of AMF and eliminates the RVIN by AMF.

First, the existing AMF, and then, the model of proposed advanced AMF will be described.

Adaptive Median Filter. AMF is an updated version of median filter. It successfully removes fixed valued impulsive noise types (salt & pepper noise) from image. AMF increases size of the window S_{xy} during filtering depending on certain conditions. This is the most difference of adaptive median filter from other median type filters. AMF usage has 3 main purposes:

1. To remove the salt & pepper noise;
2. To smooth other noises;
3. To reduce the distortions such as excessive thickening or thinning of object boundaries.

Notation:

$Z_{\min}$ is minimum gray level value in window S_{xy};

$Z_{\max}$ is maximum gray level value in S_{xy};

Z_{med} is median of gray levels in S_{xy};

Z_{xy} is gray level value at (x, y);

$S_{\max}$ is maximum allowed size of S_{xy}.

AMF algorithm is divided into two levels:

Level A:

$A1 = Z_{med} - Z_{\min}$;

$A2 = Z_{med} - Z_{\max}$;

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if A1 > 0 and A2 < 0
        Go to Level B;
else
        Increase the window size by 2;
end

if window_size ≤ S_max
        Repeat Level A;
else
        Output Z_xy;
end
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Level B:

$B1 = Z_{xy} - Z_{\min}$;

$B2 = Z_{xy} - Z_{\max}$;

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if B1 > 0 and B2 < 0
        Output Z_xy;
else
        Output Z_med;
end
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Advanced Adaptive Median Filter. The noise corrupted pixels in the image are found. To do this, the noise gray-level value must be known. For SPN noise, the gray-level values are 0 and 255. However, for RVIN noise, the gray-level values are random values between 0 and 255.

1) Find the noise gray-level values.

$N_{\min}$ is a small gray-level value of noise;
$N_{\max}$ is a big gray-level value of noise.

2) Change the gray-level values of noise pixels.

if $X_{ij} = N_{\min}$
  $X_{ij} = 0$

if $X_{ij} = N_{\max}$
  $X_{ij} = 255$

3) Apply AMF only to 0 and 255 gray-level value pixels.

As conclusion, in this study, advanced adaptive median filter has been proposed. Proposed filter improves the performance of known AMF for IN and gives the best results for eliminating RVIN. Simulation results showed that proposed filter increase the time efficiency 50% and works better for RVIN.

References

1. R. C. Gonzalez and R. E. Woods. "Digital Image Processing." Addison Wesley, 2nd edition, 1992.
2. Saeed V. Vaseghi. "Advanced Digital Signal Processing and Noise Reduction." John Wiley & Sons, Ltd. 3td edition, 2006.
3. Subrajeet Mohapatra. Development of Impulsive Noise Detection Schemes for Selective Filtering in Images. Department of Computer Science and Engineering National Institute of Technology Rourkela, Rourkela–769 008, Orissa, India, September 2008.
4. J. Astola and P. Kuosmanen, Fundamentals of Nonlinear Digital Filtering. Boca Raton, FL:CRC, 1997.
5. T.A. Nodes and N.C. Gallagher, Jr., "The output distribution of median type filters," IEEE Trans. Commun., vol. COM-32, no.5, pp. 532-541, May 1984.
6. H. Hwang and R. A. Haddad, "Adaptive median filters: New algorithms and results," IEEE Trans. Image Process., vol. 4, no. 4, pp. 499-502, Apr. 1995.
7. T. Chen and H.R.Wu, "Space variant median filters for the restoration of impulsive noise corrupted images," IEEE Trans. Circuits Syst. II. Analog Digit. Signal Process., vol. 48, no. 8, pp. 784-789, Aug. 2001.
8. H.-L. Eng and K.-K. Ma, "Noise adaptive softswitching median filter," IEEE Trans. Image Process., vol. 10, no.2, pp. 242-251, Feb. 2001.
9. G. Pok, J.-C. Liu, and A. S. Nair, "Selective removal of impulsive noise based on homogeneity level information", IEEE Trans. Image Process., vol.12, no.1, pp. 85-92, 2003.
10. Raymond H. Chan, Chung-Wa Ho, and Mila Nikolova, "Salt-and-Pepper Noise Removal by Median-Type Noise Detectors and Detail-Preserving Regularization", IEEE Trans. Image Process., vol. 14, no. 10, Oct. 2005.