Noise Reduction Using Fuzzy Median Filter for Color Image

著者	Tamaru Naoyuki, Onizawa Rui
journal or publication title	Otsuma journal of social information studies
volume	25
page range	71-77
year	2016-12
URL	http://id.nii.ac.jp/1114/00006436/

Noise Reduction Using Fuzzy Median Filter for Color Image

Naoyuki Tamaru * and Rui Onizawa *

Abstract

This paper presents a fuzzy median filter for the removal of noises from digital color images. The aim of our proposed filter is to remove two kinds of noises and to gain vivid images while every detail of the image is preserved like the original image. By using the fuzzy membership function, the proposed filter is able to correct the detected noisy pixels with simple procedures. As a membership function, we select the absolute maximum difference in the intensity value between the center pixel and the adjacent pixels. As the compensation algorithm, we use two methods. One is that when the target pixel is calculated, the estimated values adjacent to the target that are previously derived, are used. The other is that there is no use. The mean square error (*MSE*) for the proposed filter is reduced almost to zero and the sharpness (*SH*) is kept unchanged to that of the original image as compared to those for the conventional median filter.

Key Words: impulse noise, uniform random noise, fuzzy filter, median filter, membership function, MSE(mean square error), sharpness

1. Introduction

Digital color images acquired through many electronic products of home use, such as digital cameras and digital televisions are often interrupted by various noises during image acquisition, recording and transmission[(1), (2)]. In TV weather newscasts, real time pictures or videos from the rainy or snowy location are corrupted by the rain or snow. A lot of papers deal with the noise reduction or cancellation algorithms for the images corrupted by the noises.

A famous median filter is a simple smoothing operation with which one calculates a median value of the image intensity inside a moving window around the centered pixels. This filter has been recognized as a simple and useful image correction technique while the detail of the image is preserved to a certain degree.

However, a disadvantage to the median filter is

* *Faculty of Social Information Studies, Otsuma Women's University*

the tendency to remove image details such as thin lines and sharp edges. In response to these disadvantages several variations of median filters have been introduced. These are fuzzy median filters, two step fuzzy filters[3], weighted median (WM) filters, a tri-state median (TSM) filter[4], center weighted median (CWM) filters[5], switching median (SW) filters,[2], [6] fuzzy impulse noise detection and reduction method (FIDRM) [7], a cluster-based adaptive fuzzy median (CAFSM) filter[8], a Kalman filter [9], and so on.

However, most of these filters deal with the salt-and-pepper noises in the gray images. Furthermore, the intensity values for impulse noise are 0 or 255 for 256 gray levels (i.e. 8 bit resolution). And there are no precise presentations about the effects of varying the noise ratio.

We adopted a fuzzy median filter [10], [11] to color images in order to remove the impulse noise. From the experiments we had effective results [10].

Therefore, we will try to extend this filter applying to the uniform random noise and also do to compare two algorithms for the noise reduction.

In Section 2, we define the noise, median filters and fuzzy median filters. The experimental results by the computer simulation are shown in Section 3. Finally, the paper is briefly summarized in Section 4.

2. Fuzzy Median Filter

2.1 Two Kinds of Noise

We deal with the digital color image of which the RGB pixel intensity is stored in 8-bit integer, respectively. That is to say, the RGB element in every pixel has 256 levels of 0 to 255 and one pixel has the data of 24 bits (=3 × 8 bits). We define the two kinds of image noise as follows.

One is impulse noise with the intensity value from 0 to 9, and from 246 to 255. Each variation width for the noise value is 10. The RGB elements of the original pixels - i.e. noise-free pixels - are substituted by these noises with certain probabilities. If we define the probability of the impulse noise as the rate p, the probability of the low noise value (0-9) and the high noise value (246-255) is p/2, respectively. If p = 0.1 (10%) for the color image with 256 × 256 pixels in size, the average number of noise elements is 19661 (= 256 × 256 × 3 × 0.1).

The other is the uniform random noise, whose level is 0 to 255. In generating the noises, the RGB element level in the pixel is replaced into the newly calculated noise, if the target RGB element is selected by the random number.

2.2 Median Filter[10]

The median filter outputs the median value of the samples in the 3 × 3 window $W_{i,j}$, that is centered at $X_{i,j}$ as shown in Figure 1. The output $M_{i,j}$ of the median filter is defined as

$$W_{i,j} = \{X_{i-1,j-1}, \cdot\ \cdot, X_{i,j}, \cdot\ \cdot, X_{i+1,j+1}\} \quad (1)$$

$$M_{i,j} = \text{median}\ \{W_{i,j}\}. \quad (2)$$

There are two methods for the calculation. In the A-method every elements of $W_{i,j}$ are given by the equation (1), but in the B-method the former 4 elements ($X_{i-1,j-1}$, $X_{i,j-1}$, $X_{i+1,j-1}$, and $X_{i-1,j}$) of $W_{i,j}$ in the equation (1) are replaced to each median filter output, that already are calculated by the median filter. As the calculation for each pixel is scanned from left to right, and top to bottom, the former 4 elements output of the median filter are already derived.

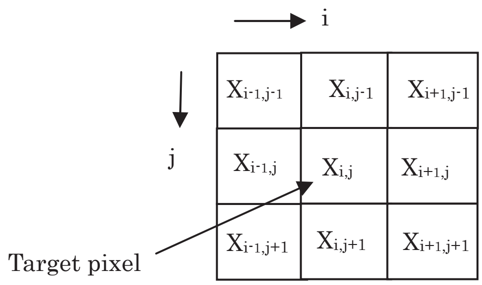

Fig. 1 Image pixel arrangement.

2.3 Fuzzy Median Filter[10]

We introduced a fuzzy flag $f_{i,j}$ indicating how much it looks like an noisy pixel. The $f_{i,j}$ is the membership function with two parameters, defined as

$$f_{i,j}=\begin{cases} 0 & m_{i,j} \leqq T_1 \\ (m_{i,j}-T_1)/(T_2-T_1) & T_1 \leqq m_{i,j} \leqq T_2 \\ 1 & m_{i,j} \geqq T_2 \end{cases} \quad (3)$$

where T_1 and T_2 are two pre-determined parameters, are reported[2] as $10 \leqq T_1 \leqq 20$ and $22 \leqq T_2 \leqq 32$, and $m_{i,j}$, the maximum value of the absolute differences between the intensities of the center pixel $X_{i,j}$ and the adjacent pixels, is defined as follows:

$$m_{i,j} = \max\{|X_{i,j} - S_{i,j}|\}$$

$S_{i,j} \in W_{i,j}$ and $X_{i,j} \neq S_{i,j}$.

The $m_{i,j}$ shows a measure for detecting noises.

After the membership function $f_{i,j}$ is calculated, the filtered output of the pixel $Y_{i,j}$, is defined as

$$Y_{i,j} = (1\text{-} f_{i,j}) \times X_{i,j} + f_{i,j} \times M_{i,j} \quad (4)$$

From (4), when $f_{i,j}$ is 1.0, the output $Y_{i,j}$ equals the value of the median filter, and if $f_{i,j}$ is 0.0, the output $Y_{i,j}$ equals the value of the original pixel $X_{i,j}$, - i.e. the unchanged value-.

This filter also uses the A-method or the B-method same to the median filter. For the B-method the former 4 elements in the equation (1) are replaced to the output of the fuzzy median filter.

2.4 Fuzzy Membership Function

Figure 2 shows an example of the fuzzy membership function $f_{i,j}$ with two parameters, $T_1=15$ and $T_2=25$. The horizontal axis shows $m_{i,j}$, the maximum value of absolute differences between the RGB intensities of the center and the adjacent pixels, and the vertical axis is the fuzzy membership degree. It is made up of three piecewise linear segments. The ranges of $m_{i,j} < T_1$, $T_1 < m_{i,j} < T_2$, and $m_{i,j} > T_2$ show the detail preservation of the original pixels, the partial augmentation, and the full correlation using the median filter, respectively.

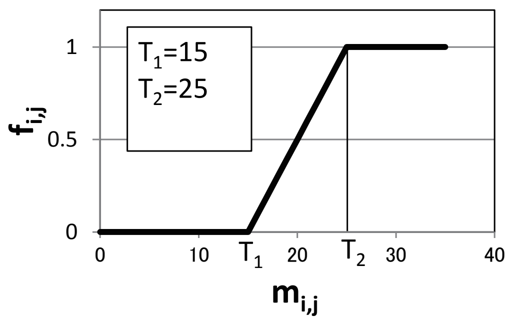

Fig. 2 An example of fuzzy membership function.

2.5 MSE[9]

In order to compare quantitatively the performance of the filters we have discussed, the mean square error (*MSE*) between the input and output images is evaluated. The *MSE* is given by

$$MSE = (\Sigma\Sigma (X_{i,j} - Y_{i,j})^2) / (M \times N), \quad (5)$$

where $X_{i,j}$ and $Y_{i,j}$ are the pixel values for the input and the output image at position (i, j), respectively, M and N are the number of the horizontal pixel, and vertical one, respectively. The *MSE* is able to evaluate the residual noise for the corrupted image.

2.6 SH[9]

In addition, in order to evaluate the sharpness of images, - i.e. the preservation of the detail -, we introduce the sharpness (*SH*) as follows:

$$SH = (\Sigma\Sigma (X_{i,j} - X_{i+1,j})^2) / ((M-1) \times N), \quad (6)$$

where $X_{i+1,j}$ is the pixel value just right adjacent pixel to $X_{i,j}$ as shown in Fig. 1. If the *SH* for the corrected image is a value closer to that for the original image (i.e. noise-free image), we can estimate that the corrected images are preserved the details.

3. Experimental Results

3.1 Median Filter

Figure 3 shows the *MSE* values obtained by varying the noise ratio. For the experiments we use the “Balloon” image in the standard color test image database SIDBA. The noise is uniform random noise with 0 to 255 in intensity. The MATLAB software is used for the all calculations of the noise reduction.

The horizontal axis shows the noise ratio within the range from 2% to 20%. The blue curve with the diamond plots displays the *MSE* values used by the A-method in the median filter, and the red that with the square plots does these for the B-method with the 3 × 3 window. Every plot is the averaged data from 5 experimental values with the same parameters. The *MSE* for the corrupted image by the noise of 2%, 5%, 10% and 20% is 126, 319, 642 and 1270, respectively.

From the figure it is seen that the A-method median filter is better than the B-method filter, because the *MSE* values for the A-method are closer to the zero. The residual noise using the A-method is decreased by about from 1/10 to 1/50 than the corrupted image noise.

Figure 4 displays the *MSE* values in case of the impulse noise. It shows the same character in Fig. 3 except for the A-method at the 20% impulse noise. The A-method median filter also is better than the B-method filter except at the 20% noise.

Figure 5 shows the *SH* (sharpness) values obtained by varying the random noise ratio. The blue curve with the diamond plots displays the *SH* values used by the A-method, and the red that with the square plots does these for the B-method.

It shows that the A-method filter also is better than the B-method filter, because it is closer to the *SH* value (65.9) for the noise-free image than that

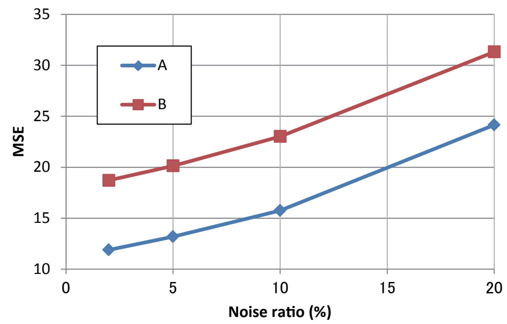

Fig. 3 A relationship between the MSE and the random noise ratio using median filter.

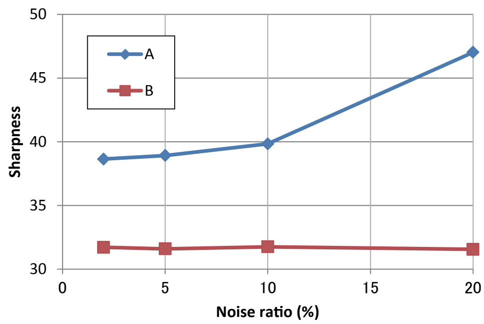

Fig. 5 A relationship between the SH (sharpness) and the random noise ratio.

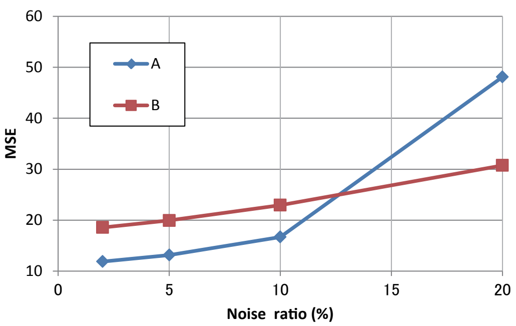

Fig. 4 A relationship between the MSE and the impulse noise ratio using median filter.

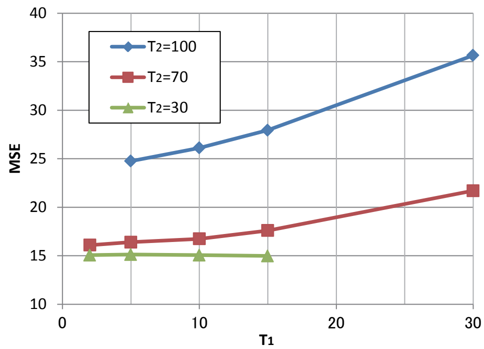

Fig. 6 A relationship between the MSE and the membership parameter of T_1 using the proposed filter.

for the B-method.

3.2 Fuzzy Median Filter

Figure 6 shows the *MSE* values obtained by varying the membership parameters T_1 and T_2 with 10% random noise and the A-method. It is seen that the *MSE* value with $T_1=15$, $T_2=30$ is the best condition.

Figure 7 shows the *MSE* values obtained by varying the parameter T_2 in the same condition as in Fig. 5, when $T_1=15$. It shows that the *MSE* value with $T_1=15$, $T_2=30$ is the best condition.

Figure 8 shows the *MSE* values in case of the random noise of 10%, $T_2=70$. From this figure it is shown that the A-method has the better *MSE* than the B-method does similarly to the median filter.

Figure 9 shows the *SH* values when the random noise of 10%, using the A-method. From this figure the *SH* values with $T_1=30$, $T_2=70$ is the best condition.

Figure 10 shows the *SH* values in the random noise of 10%, when $T_1=15$. From this figure it is seen that the condition of $T_2=80$ is the better.

Figure 11 shows a relationship between the *SH* value and the parameter T_1 with the random noise of 10%, $T_2=70$. From the figure the *SH* values using the B-method is better than that for the A-method. This result is the only one exception because the noise ratio is large.

3.3 Comparison of Median Filter

Figure 12 shows the comparison between the *MSE* values of the remained random noise using the median filter and that using the proposed (fuzzy

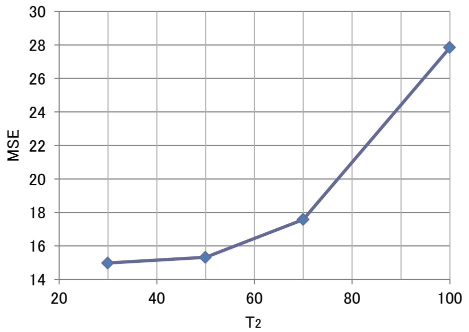

Fig. 7 A relationship between the MSE and the membership parameter of T_2 using the proposed filter.

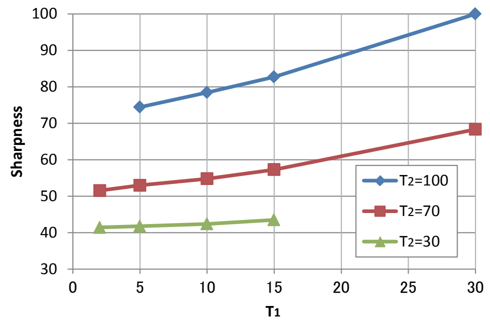

Fig. 9 A relationship between the SH and the membership parameter of T_1 using the proposed filter.

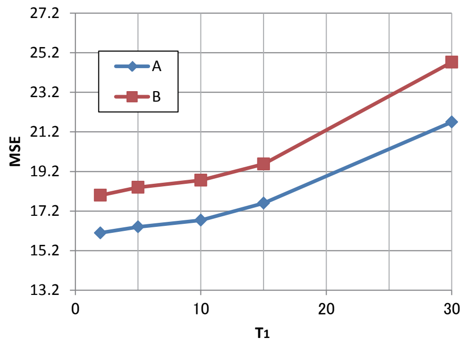

Fig. 8 A relationship between the MSE and the membership parameter of T_1 using the proposed filter.

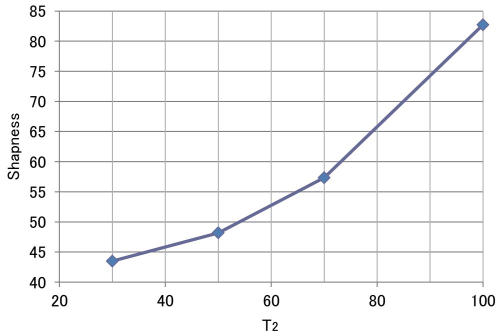

Fig. 10 A relationship between the SH and the membership parameter of T_2 using the proposed filter.

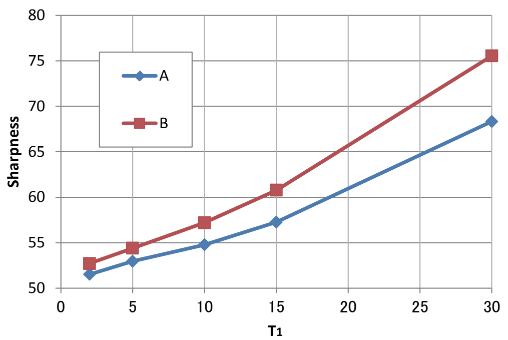

Fig. 11 A relationship between the SH and the membership parameter of T_1 using the proposed filter.

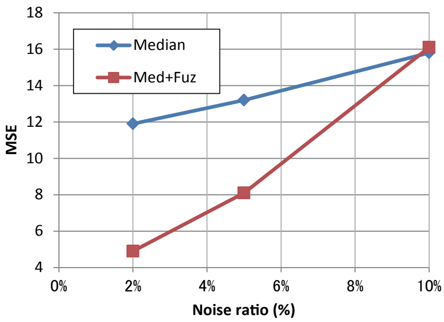

Fig. 12 A MSE comparison between the median filter and the proposed filter.

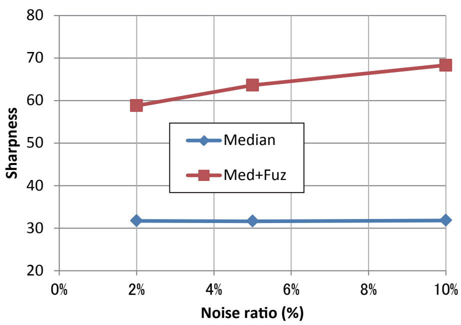

Fig. 13 A SH comparison between the median filter and the proposed filter.

median) filter. The proposed filter is the better *MSE* than the median filter especially in low noises.

Figure 13 represents the comparison between the *SH* values of the remained random noise using the median filter and that using the proposed filter. The proposed filter is the better *SH* than the median filter every noise range, because the *SH* values of the proposed filter is closer to the *SH* (=65.9) for the noise-free image.

Fig. 14 Simulation results.
(a) Original (noise-free) image. (b) Corrupted image with 10% noise. (c) Median filter. (d) Proposed filter.

Figure 14(a) shows the original “Balloon” image, Fig. 14(b) does the corrupted image by the random noise of 10%, Fig. 14(c) does the image of the median filter using the A-method, and Fig. 14(d) does the image of the proposed filter using the A-method with $T_1=30$, $T_2=70$. We can see that there is almost no remaining noise for both filters and the details in the image by the proposed filter are more preserved than those by the median filter.

4. Conclusion

This paper presents a fuzzy median filter for the removal of the impulse noises and the uniform random noises from digital color images. The aim of our proposed filter is to remove the noises and to gain the vivid image while every detail of the image is preserved like the original image.

By using the fuzzy membership function our filter is able to correct the detected noisy pixels with simple procedures. As the membership function we select the absolute maximum difference in the intensity value between the center pixel and the adjacent pixels.

The mean square error (*MSE*) for the proposed filter is reduced almost to zero, that is to say, the remained noise is almost zero and the sharpness (*SH*) is kept unchanged to that of the original image as compared to the conventional median filter.

It is clear that the experimental results for the impulse noise are almost similar to those for the uniform random noise. And the A-method is better by over 20% than the B-method for the *MSE* values and the *SH* values.

References

(1) K. Kal Vin Toh, H. Ibrahim and M. Nasiruddin Mahyuddin, “Salt-and-pepper noise detection and reduction using fuzzy switching median filter”, IEEE Transactions on Consumer Electronics, 54 (4), pp.1956-1961 (2008).

(2) W. Luo, “Efficient removal of impulse noise from digital images”, IEEE Transactions on Consumer Electronics, 52 (2), pp.523-527 (2006).

(3) F. Russo and G. Ramponi, “A fuzzy filter for images corrupted by impulse noise”, IEEE Signal Processing Letters, 3 (6), pp.168-170 (1996).

(4) T. Chen, Kai-Kuang Ma and Li-Hui Chen, “Tri-state median filter for image denoising”, IEEE Transactions on Image Processing, 8 (12), pp.1934-1938 (1999).

(5) Sung-Jea Ko and Y. Hoon Lee, “Center weighted median filters and their applications to image enhancement”, IEEE Transactions on Circuits and Systems, 38 (9), pp.984-993 (2006).

(6) S. Zhang and M. A. Karim, “A new impulse detector for switching median filters”, IEEE Signal Processing Letters, 9 (11), pp.360-363 (2002).

(7) S. Schulte, M. Nachtegael, V. De Witte, D. Van der Weken, and E. Kerre, “A fuzzy impulse noise detection and reduction method”, IEEE Transactions on Image Processing, 15 (5), pp.1153-1162 (2006).

(8) K. Kal Vin Toh and N. Ashidi Mat Isa, “Cluster-based adaptive fuzzy switching median filter for universal impulse noise reduction”, IEEE Transactions on Consumer Electronics, 56 (4), pp.2560-2568 (2010).

(9) M. Nikaido and N. Tamaru, “Noise reduction for gray image using a Kalman filter”, SICE Annual Conference 2003 (Society of Instrument and Control Engineers, pp. 92-95, Aug. 5 (2003).

(10) N. Tamaru and R. Onizawa, “Impulse noise reduction using Fuzzy median filter for color image”, Otsuma Journal of Social Information Studies, Vol. 22, pp.123-128 (2013)

(11) N. Tamaru and R. Onizawa, “Noise reduction using Fuzzy median filter for audio signals”, Otsuma Journal of Social Information Studies, Vol. 24, pp. 61-69 (2015)