An Improved Median Filtering Image De-noising Algorithm

Xiongjun Wen, Zhiqiang Deng, Hui Xue

School of Information Science and Engineering, Hunan International Economics University, Changsha 410205, Hunan, China

Abstract
Noise will occur in the image acquisition. These noises deteriorate the image quality, blur the image and even submerge and change the features, which will bring difficulties to image analysis and recognition. Therefore, filtering methods are usually used to eliminate these noises. Median filtering is quite effective in image de-noising. This paper proposes an improved median filtering algorithm. This algorithm uses the characteristic of the motion of the filtering window and the data relevance, which will reduce the time of image de-noising. Based on the median filtering algorithm, it improves the method to seek the median value, gives the optimal weight coefficient to the pixel point according to the relevance between the signal pixel and the central pixel in the filtering window, and improves the de-noising effect accuracy. This improved median filtering algorithm can preserve the image details and achieve better de-noising effect. The simulation experiment proves that the algorithm of this paper can reduce the time the median filtering requires and enhances the signal to noise ratio of the image so that it can improve the efficiency while guarantee the de-noising effect, which is of great practical significance to eliminate noises.

Key words: Median Filtering, Image De-noising, Noise Ratio.

1. INTRODUCTION

In the image acquisition and transmission, it can be polluted by various noise to a certain extent and the appearance of the noise will affect the image quality and the image information. If the signal to noise ratio is below a specific threshold, the noise will be in an obvious particle shape, which will severely degrade the image quality(Saroj and Brijraj, 2014). Additionally, these noises can also cause a loss of the image details. Therefore, in order to improve the image quality and to extract effective information from the image, de-noising pre-processing is required to the image. Median filtering is a non-linear filtering method with few blurry edges. It can not only remove or reduce the random noise and the impulse interference, but it can also better preserve the image edge information(Vijaykumar and Santhana, et al., 2014; Jin, 2013).

According to the rules and statistical characteristics of the spectral distribution of the noise as well as the image features, there are many kinds of image de-noising methods(Zhou, 2016; Chen, 2016; ). The common methods include spatial domain synthetic method, frequency domain synthetic method and the optimal synthetic method and their corresponding application methods include mean filter, median filter, low-pass filter, Wiener filter and minimum distortion method. In 1974, Turkey has proposed the idea of median filter for the smoothing problem of the discrete data for the first time. Then this new filter idea has been introduced into some important digital signal processing fields soon. The median filtering algorithm can maintain smooth image and preserve the image details(Saroj K., 2014). Therefore, it has been widely applied in the image de-noising processing. However, in the image processing, the traditional median filtering algorithm requires plenty of median value calculation, which affects the de-noising efficiency. In particular, it is not applicable for some large-scale images, reducing its practicability(Xu et al., 2014).

Firstly, this paper makes in-depth research on the principles of median filtering as well as the specific de-noising procedures. Then it proposes the improved median filtering algorithm to solve the short-comings of median filtering algorithm in the image de-noising and detail preservation. This algorithm improves the de-noising effect and guarantees the real-time of the algorithm operation. The final experiment result shows that the algorithm of this paper works well in de-noising of the smooth images and it can better preserve the image details.

2. PROCESSES AND REALIZATION OF MEDIAN FILTERING

Median filter is the most commonly used non-linear smoothing filter. The basic idea of median filtering is to produce a rectangle slide window with every pixel of the image as the center, sort all the pixels within the window in accordance with the order from small to large in gray-scale value, calculate the median value and replace the pixel value of the central point of the window(Lu, 2014).

In the process of median filtering, sort the pixels within the template (window) in accordance with the order from small to large in the grayscale value, take the value of the median point as the median value and see
it as the output value of the filter. In the circumstance with strong impulse as well as salt-and-pepper noises, because there are huge differences between the interference value of the grayscale value and the grayscale value of the neighborhood pixels, the result of the median value is to force such interference point as the same of the grayscale value of certain neighborhood pixels so as to eliminate the interference. The process of median filtering is a non-linear operation process, which can not only preserve the outline of the image, but also remove the impulse and salt-and-pepper noises. The key to median filtering is the calculation of the median value and the selection of the sorting algorithm is a key factor that affects the efficiency of the median filtering (Hsieh et al., 2013; Yuan et al., 2013).

The method of median filtering is to sort the pixels of the template as per the order from small to big in grayscale value with the two-dimensional slide template of certain structure and produce the monotonically ascending (descending) two-dimensional data series. The template is usually 3x3 and 5x5 and it can also be in other shape, including linear, circle, cross and circular (Bian et al., 2013). Figure 1, Figure 2 and Figure 3 are the filtering results of median filtering places on salt-and-pepper noise with different size windows.

**Figure 1.** Median filtering with 3x3 filter window

**Figure 2.** Median filtering with 5x5 filter window

**Figure 3.** Median filtering with 7x7 filter window

The shape and size of the window of the two-dimensional median filter affect the filtering effect. Different shapes and sizes of the filter window are used for different image contents and different application requirements. Fig.4 is the shape of the two-dimensional median filter window with a size of 5x5.
Process the image with salt-and-pepper noise with the median filtering algorithm. The filtered image is not only suitable for the visual feeling of human eyes, but it can also eliminate the interference of the image. It is obvious that median filter is very effective in removing the salt-and-pepper noise in the image, especially in the elimination of superimposed white noise and long-tail superimposed noises (Shi-Jinn and Ling-Yuan et al., 2013; Yang, 2015).

3. REALIZATION OF IMPROVED MEDIAN FILTERING ALGORITHM

To realize the median filtering is to replace the value of a point in the digital image or digital sequence with the median value of the value of each point which neighbors this point. If there are an odd number of elements in the window, the median value is the grayscale value of the median element after sorted in accordance with the order from small to big in grayscale value while if there are an even number of elements, the median value is the mean value of the two median elements after sorted in accordance with the order from small to big in grayscale value.

The improved median filtering is to roam the filtering template in the image, overlap the template center with the position of a certain image pixel, take the corresponding grayscale value in the template to each pixel, sort the grayscale value in accordance with the order from small to big, take the median data of this series of data and give it to the pixel in the center of the template.

Assume that there is a one-dimensional sequence \( f_1, f_2, \ldots, f_n \) and the window length is \( m \) (\( m \) is an odd number). To perform median filtering to this sequence is to extract \( m \) numbers from the input sequence, namely \( f_{i-m}, \ldots, f_i, \ldots, f_{i-m} \). Here, \( i \) is the central position of the window and \( v = \frac{m-1}{2} \). Sort these \( m \) points in accordance with the order from small to big in the numerical value and take the middle point with the middle order as the output. The mathematical formula is:

\[
Y_i = \text{Med} \{ f_{i-m}, \ldots, f_i, \ldots, f_{i+m} \}, \quad i \in \mathbb{Z}, v = \frac{m-1}{2}
\]  

In the median filtering of the two-dimensional sequence \( \{X_{ij}\} \), the filtering window is also two-dimensional and the median filtering with two-dimensional data can be represented as follows:

\[
Y_{i,j} = \text{Med}_A \{X_{ij}\}, \quad A \text{ is filter window}
\]  

If the grayscale value of a certain point is the maximum or minimum in the window neighborhood, then this point is the noise point, otherwise, it is the signal point. That is to say

\[
Y_{ij} = \begin{cases} 
N, & X_{ij} \leq \min \text{ or } X_{ij} \geq \max \\
S, & \min < X_{ij} < \max
\end{cases}
\]  

In the above formula, \( S \) is signal and \( N \) is noise.
In the image affected by salt-and-pepper noises, the grayscale value of the noise point is distributed in the maximum or minimum grayscale value of the image. However, if the noise is quite dense, the pixel located in the middle of the extremum value may also be the noise point. In order to reduce the omission rate, this paper has proposed the improved judging criteria.

\[
Y_x = \begin{cases} 
N, & |X_{y} - \min| \leq T_1 \text{ or } |X_{y} - \max| \geq T_1 \\
S, & \text{Otherwise}
\end{cases}
\]  \hspace{1cm} (4)

After being sorted, the image edge minutiae point can also be located in both ends of the sequence. The omission rate is higher in case of high signal to noise rate. This paper has given the second condition for noise detection.

\[
f_y = \begin{cases} 
1, & |X_{y} - M| \geq T_2 \\
0, & \text{Otherwise}
\end{cases}
\]  \hspace{1cm} (5)

Here, \(M\) is the mean value of all signal points within the window; \(f_y\) is the noise mark point, \(f_y = 1\) is the noise point of \(X_y\) and \(f_y = 0\) is the signal point of \(X_y\). The threshold \(T_2\) greatly affects the noise detection and it determines the noise density. From the experience, it can be seen that when the noise density is small, \(T_2\) is bigger, otherwise, \(T_2\) is smaller.

In the practical application of the window, sort the local pixels in accordance with the order from small to big in the grayscale value and take the mean value of the grayscale in this area as the grayscale value of the current pixel. The window size increase from 3x3, 5x5 and others until it has a satisfactory filtering result.

4. EXPERIMENT RESULTS AND ANALYSIS

In order to verify the effectiveness of the algorithm of this paper, two groups of simulation experiments have been conducted. Add the salt-and-pepper noise 0.25 into the cameraman grayscale image and circuit grayscale image with a size of 256x256, compare the results of the improved median filtering algorithm of this paper, the mean filtering algorithm and the median filtering algorithm.

![Figure 5. Comparison of cameraman image de-noising effect](image)
Peak signal to noise ratio can be used in the quantitative analysis of image de-noising effect. Firstly, use mean filtering algorithm. Then, use the median filtering algorithm. Finally, use the method of this paper. The statistics of the peak signal to noise ratio are shown in Table 1 and Table 2.

The most commonly used parameter in measuring the de-noising effect is the peak signal to noise ratio (PSNR), which is an objective criterion to evaluate the image.

\[
PSNR = 10 \log_{10} \frac{255^2}{MSE}
\]  

(6)

In this formula, MSE is the minimum mean square error, \(x_{i,j}\) is the \((i, j)\)th pixel of the original image and the image size is \(M \times N\).

**Table 1.** Peak signal to noise ratio of cameraman image de-noising

<table>
<thead>
<tr>
<th>Noisy image</th>
<th>Mean filtering</th>
<th>Median filtering</th>
<th>Method of this paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.97</td>
<td>27.59</td>
<td>30.65</td>
<td>33.72</td>
</tr>
<tr>
<td>21.29</td>
<td>27.05</td>
<td>29.23</td>
<td>31.12</td>
</tr>
<tr>
<td>20.35</td>
<td>26.73</td>
<td>28.89</td>
<td>32.36</td>
</tr>
<tr>
<td>19.66</td>
<td>24.58</td>
<td>27.41</td>
<td>30.38</td>
</tr>
</tbody>
</table>

**Table 2.** Peak signal to noise ratio of circuit image de-noising

<table>
<thead>
<tr>
<th>Noisy image</th>
<th>Mean filtering</th>
<th>Median filtering</th>
<th>Method of this paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.02</td>
<td>26.21</td>
<td>28.30</td>
<td>32.62</td>
</tr>
<tr>
<td>20.17</td>
<td>24.87</td>
<td>27.28</td>
<td>29.37</td>
</tr>
<tr>
<td>19.23</td>
<td>24.34</td>
<td>26.06</td>
<td>30.28</td>
</tr>
<tr>
<td>18.59</td>
<td>22.95</td>
<td>24.37</td>
<td>27.03</td>
</tr>
</tbody>
</table>
It can be seen from the statistical result of peak signal to noise ratio that both mean filtering and median filtering are not good at eliminating impulse noise with a serious loss of image edge details. The median filtering algorithm also suffers the loss of certain edge details and it fails to effectively suppress the noises. However, the algorithm of this paper has done a great job in the elimination of noise and it has also obviously improved the visual effect of the image. In the meanwhile, the peak signal to noise ratio has been enhanced to a certain extent and the staircase effect caused by filtering has been avoided. In this way, it can remove the noise in a more effective manner. Besides, it can also effectively preserve the detailed information of the image and the de-noised image is closest to the original image. The experiment result has indicated that the algorithm of this paper has significantly improved both the peak signal to noise ratio and the subjective visual effect of the de-noised image.

5. CONCLUSIONS

In terms of the standard median filter, one of the main problems is that it can cause the damage or loss of such detailed structure as thread and corner of the image, which usually contain very important image information. This paper has proposed improved idea for the traditional median filtering algorithm. It can better solve the conflict between noise suppression and detail preservation and enhance the de-noising ability and detail preservation. The experiment result has proven the effectiveness of method of this paper.

Acknowledgements

This work was supported by Hunan education department notice [2016] no. 96.733, College students in hunan province and inquiry-based learning Innovative experimental project ; Hunan Provincial Department of education scientific research general fund project (14C0651).

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