Image adaptive filtering based on the improved Alpha-trimmed mean algorithm

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Abstract

Filtering is an important research direction of image processing. In view of the characteristics of image noise, an adaptive image filtering algorithm is proposed based on the improved Alpha-trimmed mean algorithm. The algorithm dynamically selects parameter d of Alpha-trimmed mean algorithm through the calculation of the pixel correlation within the filter window, so that the algorithm can filter accordingly with the degree of noise. The experiment results show that the filtering effect of the proposed algorithm is excellent for the images corrupted by Gaussian noise, salt and pepper noise or mixed noise, and this algorithm is also capable of maintaining the detailed information of the original image.

Keywords: image filtering, alpha-trimmed mean filter, neighbourhood correlation

1 Introduction

Image is a kind of file, which is easier to be seen and used in people's daily life. So the studies for image processing method have been carried out for many years and have achieved good results in many areas [1, 2]. However, whether the traditional imaging devices or modern digital imaging equipments, most of them worked based on the principle of transmission and refraction of the light. So the imaging process easy to be affected by the natural or human factors, resulting the image contains much noise and not clear enough [3, 4]. In addition, modern digital cameras and other electronic equipments will be involved in the use of related integrated circuits which also exist some features that affect the imaging process, such as drift, edge nonlinearity and so on [5]. These factors can also cause the image contains noise more or less, so the image filtering has become a research focus.

The main purpose of the image filtering is to remove the noise and improve image quality, which directly affect the subsequent analysis of the image processing. So we not only consider the noise filtering ability of an algorithm, but also to try to keep details of the original image when carried on the image filtering. For all the image filtering methods, linear filtering is studied much earlier, mainly includes Gaussian filter, mean filter, Wiener filter, etc. [6,7]. The advantage of these methods is very effective for Gaussian noise, but cannot filter the impulse noise, and will also cause the loss of image details. To compensate for the defect of the linear filtering algorithm, then many scholars studied another form of filtering algorithm—nonlinear filtering algorithm, mainly includes median filter, statistical filter, morphological filter, etc. [8-10]. Such filtering algorithm can better maintain the details of the image and can filter the impulse noise effectively, but these algorithms emphases on the ability of maintaining the details so much, so cannot filter Gaussian noise with the normal distribution. Generally, the image noise includes many kinds of noises, in this case, whether to use a linear filter or non-linear filter cannot yield satisfactory results.

To solve these problems researchers have proposed an Alpha-trimmed mean filtering algorithm that fully makes use of the advantages of linear filters and nonlinear filters. This algorithm solves the problem of image filtering to a certain extent, especially in the case of mixed noise exists. However, this algorithm also has some defects. Firstly, the size of the filter window is fixed, some useful information is not fully used to deal with the problem that the noise of the image with different intensity. Secondly, the parameter *d* of the algorithm is determined according to the human experiences, which cannot be changed adaptively with different circumstances. These factors limit the promotion and using of the algorithm. Therefore, in this paper, the parameter *d* is selected dynamically by the noise intensity within the filter window and the noise intensity is estimated by the mean and standard deviation of the pixel neighbourhood correlation. The innovation of this paper is to make the traditional Alpha-trimmed mean filtering algorithm has the adaptive ability. The simulation results also proved the correctness and effectiveness of the filtering algorithm proposed in this paper.

2 The Alpha-trimmed mean filtering algorithm

Assume that the centre pixel within the filter window is $f(x,y)$, where x and y are pixel coordinates, $f(x,y)$ is grey value. The size of the window is $n \times n$, all the pixels

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within the window represented by $g_p(s,t)\quad p\in n\times n$, then removes *d/*2 max pixels and *d/*2 min pixels, the left n^2-d pixels represented by $g_c(s,t)c\in n^2-d$. Finally, the Alpha-trimmed mean filtering algorithm is given as follows, see Equation (1):

$$\hat{f}(x,y)=\frac{1}{n^2-d}\sum g_c(s,t)\,, \tag{1}$$

where, $d\in\left[0,n^2-1\right]$. When $d=0$, the Alpha-trimmed mean filtering algorithm equal to the mean filter, while it equal to median filter when $d=(n^2-1)/2$.

It can be seen from the Equation (1) that the performance of the algorithm affected largely by the parameter *d*. When the type of image noise is Gaussian noise, the parameter *d* should not be too large; while when the noise is salt and pepper noise, the parameter *d* should not be too small. The situation is even more complicated when the image contains some different noises. Thus, although the principle of the algorithm is relatively good, the satisfied filtering result cannot be got when the parameter *d* is not suitable.

3 The neighbourhood correlation

The characteristic of neighbourhood information relation exists among all the adjacent pixels, so the difference between adjacent pixels can reflect their degree of association. This characteristic is used to calculate the neighbourhood correlation within the filter window in this paper. For the convenience of description, the 3×3 window is as an example, please seeing Figure 1.

1	2	3
4	5	6
7	8	9

FIGURE 1 The 3×3 filter window

Firstly, calculates the neighbourhood correlation of each pixel. For example, the pixel 1 is calculated as follows, see Equation (2):

$$r_1=\frac{\sum\limits_{j=2,4,5}\left|f_1(x,y)-f_j(x,y)\right|}{3}\,. \tag{2}$$

The neighbourhood correlation of other pixels $r_i,\ i=2,\cdots,n$ calculated follows this method. Next, calculate the mean of neighbourhood correlation within the window by the Equation (3):

$$r_{avg}=\frac{\sum\limits_{i=1}^{n}r_i}{n}\,. \tag{3}$$

Next, calculate the standard deviation of the neighbourhood correlation by the Equation (4):

$$\sigma_r=\sqrt{\frac{\sum\limits_{i=1}^{n}(r_i-r_{avg})^2}{n-1}}\,. \tag{4}$$

Now, we have got all the needed parameters of pixel neighbourhood correlation.

4 Implementation steps of improved Alpha-trimmed mean filtering algorithm

As described in Section 2, the Alpha-trimmed mean filtering algorithm has some flaws, i.e. the parameter *d* and the size of filter window are fixed value and cannot be adaptive changes according to the situation. The improved method presented in this paper is: the intensity of noise within the filter window is calculated firstly, and then the value of the parameter *d* is determined by it. While the intensity of noise is estimated mainly through calculates the neighbourhood correlation of each pixel within the filter window. The specific process is: first calculates the neighbourhood correlation of each pixel within the filter window, and then calculates the mean and standard deviation of the neighbourhood correlation, finally, using the 3σ rule to count the amount of noise, that is, the pixel is noise when its neighbourhood correlation greater than $r_{avg}+3\sigma_r$. The size of the filter window is adjusted by whether n^2-d greater than 1. Based on the principle of the improved method described above, the specific implementation steps are as follows:

Step 1: selects an initial $n\times n$ filter window, *n* is odd and $n\geq 3$;

Step 2: calculates the neighbourhood correlation of each pixel according to the Equation (2), and then calculates its mean and standard deviation by the Equations (3) and (4) respectively;

Step 3: calculates the parameter *d* according to the amount of pixel whose neighbourhood correlation greater than $r_{avg}+3\sigma_r$;

Step 4: go to the next step if $n^2-d>1$, otherwise, enlarge the filter window and go to step 2;

Step 5: calculates the filtering output result by the Equation (1).

According to the improved method above, the parameter *d* and the size of the filter window of the Alpha-trimmed mean filtering algorithm can be selected adaptively by the intensity of noise, so the filtering effect is better and the efficiency of the algorithm is higher.

5 Experiment analysis

In order to test and verify the efficiency of the algorithm proposed in this paper, the software Matlab and its image library are used to carry on some simulation experiments and the filtering performance will be compared to the mean filter and median filer, which are very representative. Now, the image Lena in the image library is selected as the test example, and the test process includes 3 cases:

1) we will add Gaussian noise in the image Lena with different intensity;

2) we will add salt and pepper noise in the image Lena with different intensity;

3) we will add mixed noise in the image Lena with different proportion. The criterion of objective image fidelity is used to evaluate the effect on image filtering, which includes the following two expressions:

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(S_{ij} - Y_{ij})^2 \,, \tag{5}$$

$$PSNR = 10\lg\frac{255^2}{MSE} \,, \tag{6}$$

where, M, N are the height and width of the image respectively, S_{ij} is the original image, Y_{ij} is the image after filtering. We can see from the Equation (5) that the smaller the value of MSE, the better image fidelity, that is, the noise is filtered effectively. The similar conclusion can be got from Equation (6), while the difference is the larger the value of $PSNR$, the better filtering result, image after filtered closer to the original image.

The filtering results are shown in Figures 2-7, where, the intensity range of Gaussian noise and salt and pepper noise is 0.02~0.4.

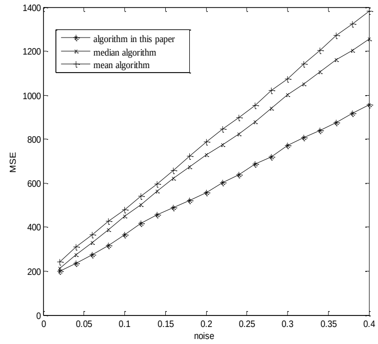

FIGURE 2 The *MSE* result of Gaussian noise with different intensity

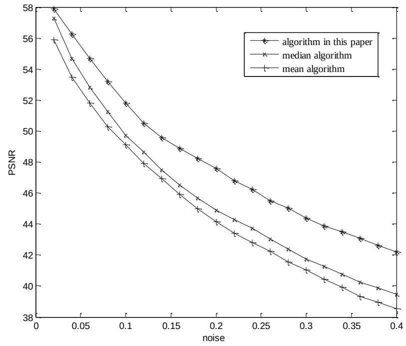

FIGURE 3 The *PSNR* result of Gaussian noise with different intensity

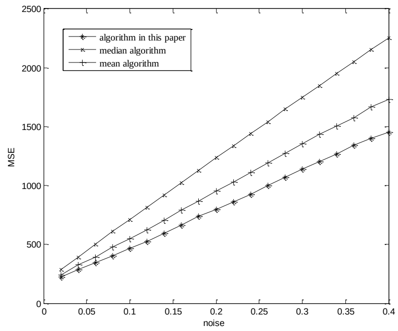

FIGURE 4 The *MSE* result of salt and pepper noise with different intensity

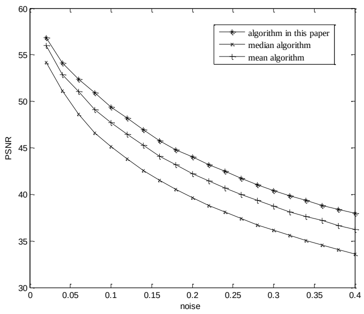

FIGURE 5 The *PSNR* result of salt and pepper noise with different intensity

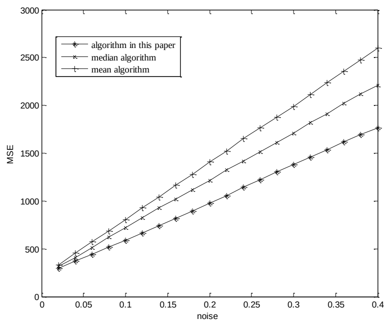

FIGURE 6 The *MSE* result of mixed noise with different intensity

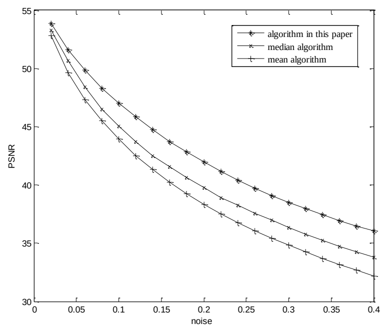

FIGURE 7 The *PSNR* result of mixed noise with different intensity

It can be seen from Figures 2 to 7 that the mean algorithm, median algorithm and the algorithm in this paper all could reduce the *MSE* of the image in varying extents, and enhance the *PSNR* simultaneously. We can easily find that, however, the filtering results of the algorithm in this paper for Gaussian noise and salt and pepper noise with different intensity, and for mixed noise with different proportion all so good, and can remain more local details of the image. Moreover, the filtering results of the traditional mean filter and median filter for mixed noise are poor, where the mean filter is more sensitive to salt and pepper noise, while the median filter is more effective to the Gaussian noise. Therefore, the overall performance of the proposed filter algorithm is better.

In order to further judge the filtering effect of the algorithm presented intuitively, the image filtering output also given in this paper. The result is shown in Figure 8, where the noise is a mixture of the Gaussian noise with intensity 0.01 and salt and pepper noise with intensity 0.1.

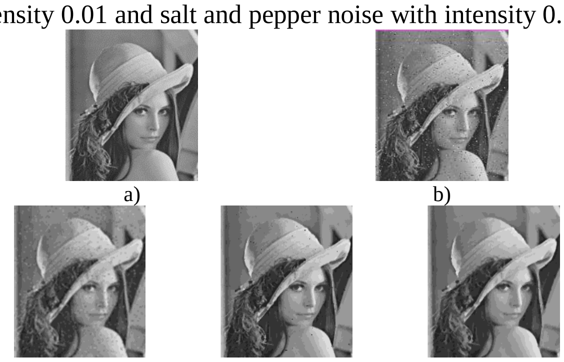

FIGURE 8 The filtering result of various algorithms

As seen from the visual effects in Figure 8, the proposed method shows better filtering performance, enabling a sharper edge of the original image. This fully shows that the true information of the image is better protected by the algorithm in this paper, the ability to protect the edge of the image also to be improved, and can filter the noise effectively. In short, the proposed algorithm is much better, whether the subjective or objective analysis.

6 Conclusions

The image is likely to be mixed with the noise when imaging, transmission, processing, display and other operation by various reasons, which can affect the clarity of the image, and is not propitious for the subsequent processing. To solve this problem, this in-depth comparison of the advantages and disadvantages of the traditional linear filtering method and nonlinear filtering method is carried on in this paper, and then we propose a new filtering method. This method introduces the concept of neighbourhood correlation of pixels whose mean and standard deviation is used to select the parameter d of the traditional Alpha-trimmed mean filtering algorithm dynamically, simultaneously, this method can adjust the size of the filter window according to the situation. The improved method not only retains the advantages of the traditional Alpha-trimmed mean filtering algorithm, but it has adaptive characteristics. Simulation results show that the noise filter effect of the improved algorithm is better for Gaussian noise, salt and pepper noise and mixed noise, a significant improvement over the existing median filtering and mean filtering algorithm. The capacity of the filtering and image details keeping are both good, while the efficiency of the algorithm is enhanced greatly because of the adaptive feature, which is very suitable for practical application.

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