An Adaptive Weighted Mean Filtering Algorithm

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Abstract. In order to remove the salt and pepper noise and Gauss noise in an image, an improved mean filtering algorithm was presented. The algorithm statistics the non-extreme pixels in a 3x3 filtering window, if the number is smaller than five, then expends the size of filtering window to 5x5, finds out the median of these pixels, and gets the absolute values of difference between these pixels and their median, uses these absolute values and their median to calculate every non-extreme pixel corresponding weight according to normalizing method, then uses these weights and corresponding pixels to weight, the result is used as the center pixel filtering out. Simulation experiments demonstrate the proposed algorithm has strong denoising ability and good detail preserving performance for images polluted by salt and pepper noise and Gauss noise, the filtering effects are better than traditional mean filtering algorithm and other two improved filtering algorithms.

Introduction

During the processes of imaging, transferring, storing, and so on, image is usually polluted by some noise. The purpose of image denoising is to filter out the noise, at the same time, protects the edge details as far as possible. There are many kinds of image noise, such as salt and pepper noise, Gauss noise and gamma noise [1], and so on, among them, salt and pepper noise and Gauss noise is the most common. The noise can destroy original gray of some pixels in image, so the image quality degrades and can't reflect the true objective scene, which seriously affects the following processing effects.

Image denoising method mainly has two kinds: median filtering and mean filtering. Traditional median filtering algorithm uses the median of all pixels in the filtering window to replace the central pixel gray value in the window, which has good denosing effects for impulse noise in an image and protects the image details well, but the algorithm takes the same conduction method for all pixels, so when noise density is high (more than 50%), its filtering ability will lose efficacy. Traditional mean filtering algorithm uses average of all pixels in filtering window to replace the central pixel gray value in the window, which can suppress Gauss noise well, but the image details is lost easily, which makes the image blurred. Actual images often include impulse noise and Gauss noise simultaneously, median filtering algorithm or mean filtering algorithm alone can't get good effects of eliminating noise, so many improved algorithms based on traditional filtering algorithms are proposed. Lee and Kassam proposed an improved mean filtering algorithm (MTM)[2], the algorithm combines the advantages of median filter and mean filter algorithm, its performance of eliminating noise is greatly improved, but the algorithm is restricted by threshold, has not adaptability. Zhang Heng et al. presented an improved median filtering algorithm (IMF)[3] based on MTM algorithm, the algorithm is no longer under the threshold limit, compared with MTM, its effects of eliminating noise has been improved. Chang Ruina et al. proposed an adaptive weighted average filtering algorithm based on medium value (IAAF)[4] based on IMF algorithm, the algorithm can get better denoising effects for mixed noise image. In this paper, we analyzed the disadvantages of IMF algorithm, and proposed an adaptive weighted mean filtering algorithm based on IMF algorithm.

The principle of IMF algorithm

IMF algorithm is an improved algorithm based on MTM algorithm, with both ideas of median filter algorithm and mean filter algorithm. The algorithm uses an adaptive method to calculate the weight and smoothes the noise points with weighted mean method, the idea is described as follows:

Let W is the filtering window, its center is every point (*i, j*) in noise image *f*, finds the gray median M of all pixels, than calculates the corresponding weight of every pixel in filtering window with M, the method is shown in Eq.1.

$$r_k(i,j) = \frac{\dfrac{1}{1+(f_k(i,j)-\mathrm{M})^2}}{\sum_{k=1}^{n}\dfrac{1}{1+(f_k(i,j)-\mathrm{M})^2}} \qquad (1)$$

In Eq.1, $r_k(i, j)$ is weight of every pixel in the filter window W, *k* is number of pixels in W. Eq.1 calculates the corresponding weight of every pixel with the variance of every pixel gray value and the median, and uses the normalization method to product the weights. Finally, uses every pixel gray value to multiply by its weight and adds them up, as the result of the filtering output of center point, the method is shown in Eq.2.

$$f(i,j) = \sum_{k=1}^{n} f_k(i,j).r_k(i,j) \qquad (2)$$

According to above principle, we can see that IMF algorithm bases on the median of all pixels in the filtering window, uses variance of every pixel and their median to calculate pixel weight, the algorithm is not restricted by threshold, and plays a certain effect for salt and pepper noise and Gauss noise in an image. But the IMF algorithm also has some disadvantages. Firstly, because there are salt and pepper noise points with extreme in filtering window, uses all pixels and their weights to get the filtering output, may influence the accuracy of result. Secondly, takes variance of pixels and their median gray to normalize the weights, some noise pixels whose gray value closes to median can get the greater weight, which expands the noise influence on filter results, the denoising ability will decrease. Therefore, this paper proposed an improved algorithm based on IMF algorithm, the denoising performance has been improved obviously.

Improved adaptive weighted mean filtering algorithm

The improvements of algorithm. Aiming at the shortcomings of IMF algorithm, this paper made the following improvements: (1) Uses median of all non-extreme pixels in the filtering window to calculate the weights. The method eliminates the impulse noise interference to the filtering results. (2) Calculates the weights with threshold optimization principle. The method is to carry out the average of absolution of difference between non-extreme pixels and their median, as a result of the threshold, then selects the maximum of these absolution and threshold to calculate the non-extreme pixel weight in the filtering window. (3) Uses window self adaptive strategy. If the number of non-extreme pixels in filtering window is less than five, expands the size of window to filters image.

Algorithm steps. (1) Counting the non-extreme pixels in the filtering window. Selects 3x3 filter window **W** of every pixel centered in noise image *f***,** and then removes those extreme pixels, establishes collection N, which stories the remaining pixels in the filtering window, the N is shown in Eq.3. If the number of pixels in N is less than five, then expands the size of filtering window to 5x5, and counts the non-extreme pixels. (2) Calculating weights of every pixel in N. Firstly, finds the median of pixels in N, calculates the absolution of difference between every pixel in N and the median, then uses the average of these absolutions as optimization threshold TH, the formula is shown in Eq.4, and then uses method in Eq.5 to calculate the corresponding weight of every pixel in N and normalize them.

$$N = \{\, f(i,j) \mid f(i,j) = \max(\mathrm{W}[f(i,j)])\ or\ f(i,j) = \min(\mathrm{W}[f(i,j)])\} \qquad (3)$$

$$\mathrm{TH} = \frac{\sum_{k=1}^{n} |\,\mathrm{N}(k) - Median(\mathrm{N}\{...\})\,|}{n} \tag{4}$$

$$r_k(i,j) = \frac{1/(1+\mathrm{Max}(|\,\mathrm{N}(k) - Median(\mathrm{N}\{...\})\,|, \mathrm{TH}))}{\sum_{k=1}^{n} 1/(1+\mathrm{Max}(|\,\mathrm{N}(k) - Median(\mathrm{N}\{...\})\,|, \mathrm{TH}))} \tag{5}$$

In Eq.5, r_k indicates corresponding weight of every pixel in N, k is the number of the pixels in N. The algorithm uses threshold optimization principle to calculate the weight of every pixel in N: if the absolution of difference between pixel in N and the median of pixels in N is greater than threshold TH, the weight is determined by the absolution, otherwise, the weight is determined by TH. (3) Weighting and filtering output. Carries out the weighted operation with the every pixel gray value in N and its corresponding weight, uses every pixel gray value to multiple by its weight and add up the results, the sum is as the filtering output of center pixel in filtering window, the formula is shown in Eq.6.

$$f(i,j) = \sum_{k=1}^{n} \mathrm{N}(k).r_k(i,j) \tag{6}$$

Verification experiment and the effect analysis

To verify the effectiveness of proposed algorithm, simulation experiments were performed on the Matlab platform. The subjects is eight bit standard gray image *lena* with 256x256 pixels, we add different density salt and pepper noise and Gauss noise in the image, uses traditional mean filtering algorithm(SMF), IMF algorithm in [3] and IAAF algorithm in [4] to filter the image respectively, the filtering effects contrast diagrams are shown in Fig.1 to Fig.3, the data of PSNR of these algorithms are shown in table1.

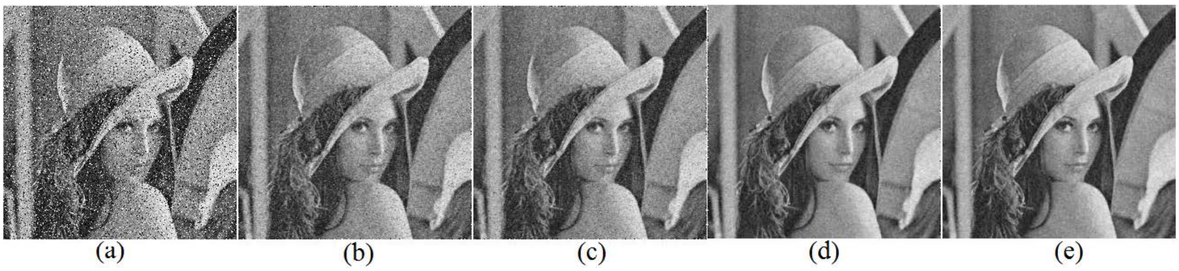

Fig 1 filtering image with low density Gauss noise and salt & pepper noise

Fig 2 filtering image with medium density Gauss noise and salt & pepper noise

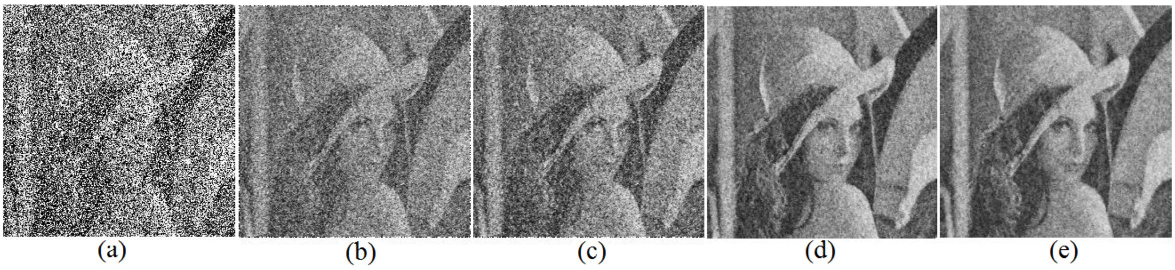

Fig 3 filtering image with high density Gauss noise and salt & pepper noise

In Fig.1-Fig.3, (a) is mixed noise image; (b) is SMF filtering image; (c) is IMF filtering image; (d) is IAAF filtering image;(e) is proposed algorithm image.

In Fig.1, the inital image is added with Gauss noise of variance is 0.01 (mean is 0) and salt and pepper noise of 10%. In Fig.2, the inital image is added with Gauss noise of variance is 0.02 (mean is 0) and salt and pepper noise of 30%. In Fig.3, the inital image is added with Gauss noise of variance is 0.05 (mean is 0) and salt and pepper noise of 50%. From Fig.1 to Fig.3, we can see when the density of mixed noise is low, SMF algorithm and IMF algorithm have better denoising effects, but with increasing of the mixed noise, their denoising performance decrease rapidly. IAAF algorithm and the proposed algorithm in this paper have stable denoising performance, both in low density and high density noise, their filtering effects are good, the output images are clear and the details are protected well, by contrast, the proposed algorithm is slightly better than IAAF algorithm in filtering efects.

Tabel 1 The PSNR comparitons of four algorithms

Gauss noise Salt & pepper noise	0.01 1%	0.02 10%	0.03 20%	0.04 30%	0.05 40%	0.06 50%	0.07 60%	0.08 70%	0.09 80%
SMF	27.32	22.32	19.73	18.15	16.74	15.80	14.71	13.97	13.25
IMF	27.71	23.35	20.80	19.21	17.61	16.81	15.16	14.25	13.29
IAAF	28.10	25.33	23.55	22.15	21.09	20.19	19.49	18.74	18.08
NEW	28.20	25.46	23.72	22.46	21.45	20.67	19.87	19.27	18.56

Table 1 is the PSNR comparisons of several algorithms, from these data in table1, we can see that the PSNR of proposed algorithm are greater than other algorithms in deferent density mixed noise image, which proves that the proposed algorithm has strong denoising performance and detail preserving ability objectively.

Summary

In order to eliminate the mixed salt and pepper noise and Gauss noise in an image, proposed an adaptive weighted mean filtering algorithm. The algorithm analyzes the defects of IMF algorithm, and makes some improvements based on IMF. Experiments show that the improved algorithm has strong denoising performance, and protects the details well, the overall performance is better than other algorithms.

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