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A Mean Filter With Adaptive Window Size

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Abstract: Removing the salt and pepper noise of an image is an essential step in digital image processing. In order to improve the effect of image denoising and obtain higher quality denoised images, this paper proposes a mean filter with adaptive window size. The filter can determine the appropriate window size according to the actual situation and restore the noise point's pixel value through the mean filtering method. Meanwhile, the filter uses a threshold comparison method to distinguish texture points and noise points more accurately. By testing on the data set, the superiority of the denoising method is verified. Furthermore, the value range of each parameter in the proposed method is determined through the experimental analysis.

1. Introduction

With computers and related mathematical theories and the growth of application requirements in the military, industry, and medicine, digital image processing technology has developed rapidly. However, in actual situations, digital images are often affected by imaging equipment and external environmental noise during digitization, transmission, and quantization and become noisy images. It is essential to reduce or eliminate noise in digital images and obtain clean original images.

A large number of researchers have made contributions in the field of image denoising. Based on the theory of compressed sensing, the researchers in [1] proposed an alternating direction method to remove salt and pepper noise, which improved image details. Researchers in [2] made improvements based on the current mainstream compressed sensing image restoration algorithms. They proposed a compressed sensing image restoration algorithm based on non-local similarity models, which extended the sparsity of two-dimensional image blocks into three-dimensional space. This method preserves the image texture better. [3] Moreover, [6] both did research on processing image features. Researchers in [3] proposed an improved fuzzy membership function adaptive type 2 fuzzy filter that performs better in preserving image features. Researchers in [6] proposed a denoising method based on a two-branch U-Net network, which shows superior infusion features. In [4], the researchers improved the standard median filter, using a median filter with a switching operator to remove salt and pepper noise, which can better maintain the undistorted pixels of the image. The self-supervised denoising method for single-noise images is mentioned in [5]. The neural network and training method is applied to image denoising, which improves the efficiency of network training. At the same time, the methods in [4] and [5] can retain helpful information to a greater extent. In [7], the wavelet threshold denoising method is studied. This method is based on wavelet transform and preserves the frequency information and spatial information of the image. The researchers in [8] are also based on wavelet transform [7] but improved the threshold function and used this function to process the fractional wavelet transform signal in the image. The methods in [7] and [8] can better preserve image details.

Although the above methods can achieve image denoising, the denoising effect is different, and it is far from the ideal denoising result. In order to improve the effect of image denoising, this paper proposes a perfect denoising method. This paper proposes a self-adaptive mean filter method. Firstly, the noise point is determined. Then the adaptive window size is determined, and the mean value method is used to restore the noise point pixels in the window. Through testing on a specific data set, it is found that applying this method to different images under different noise intensities can stably achieve better denoising effects, which demonstrates the superiority of this method. In the actual image processing process, the perfect denoising method proposed in this paper is used to make image denoising more efficient.

2. Experiment PROCEDURE

The process of removing salt and pepper noise by mean filter with adaptive window size is divided into two steps: determining noise points and eliminating noise. First of all, in order to determine whether a certain point is a noise point, it is necessary to compare the value size of the pixel at that point and the black or white pixel, and at the same time, it is necessary to analyze the pixel size of other points in a suitable range centered on the pixel point. Secondly, the pixel value of the central noise point is restored using the pixels of the non-noise point in this range. The detailed steps in the filtering method are analyzed below.

Since the same analysis method is used for each point in the image, the following analysis is aimed at a certain point (i,j).

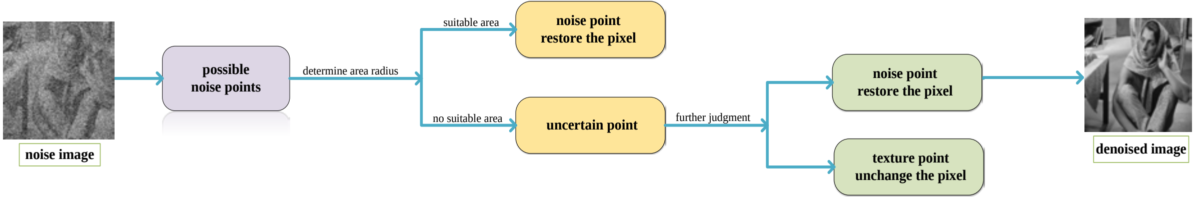

Fig 1. Experimental procedure of the mean filter with adaptive reference size.

2.1 Determine the noise point

Since the pixel of pepper noise in salt and pepper noise is 0, and the pixel of salt noise is 255, the comparison of (i,j) pixel with 0 and 255 can determine whether it may be a noise point. If the pixel x at this point is neither equal to 0 nor 255, that is, $x! = 0 \,\&\, x! = 255$, then the point is a non-noise point. Then this point is marked as $N(i,j) = 1$. If the pixel at this point is equal to 0 or 255, that is, $x == 0 \mid x == 255$, then the point may be a noise point. It is marked as $N(i,j) = 0$.

However, since the noise is a high-frequency signal, and edges or textures are also high-frequency information, a noise-free texture is easily misjudged as noise. A point with a pixel value of 0 or 255 is not necessarily a noise point. For possible noise points, it is necessary to determine whether they are real noise points further.

Firstly, it needs to determine a window of appropriate size with the point (i,j) as the center. The specific steps are as follows:

- ***Step 1:*** Initialize the window radius $s = 1$. Then calculate the total number of non-noise points in the are $S(max(i-s,1):min(i+s,xlen),max(j-s,1):min(j+s,ylen))$ and record it as sum.
- ***Step 2:*** Since this filter uses the pixels of the non-noise points in the window to restore the pixels at the central noise point, the number of non-noise pixels in the window should reach an appropriate standard. If the number of non-noise points is too small, the effect of restoring noise will be poor. If the number of non-noise points is too large, it is challenging to meet the standard in actual situations. In this paper, three are used as the minimum standard for the number of non-noise points if the total number of non-noise points in the existing area is less than 3. The area radius does not exceed the maximum limit, ($sum < 3 \,\&\&\, s < smax$ is satisfied), then the radius will add 1 to expand the area range, and count the number of non-noise points in the window again until the total number is not less than 3 or the area range has reached the maximum limit, that is, $sum < 3 \,\&\&\, s < smax$ is not satisfied.
- ***Step 3:*** At this point, a window of a specific size can be obtained. In this window, if there are no less than 3 noise points, the point (i,j) is determined to be the real noise point. If there are only fewer than 3 noise points, the nature of (i,j) is still uncertain. The point may be a texture point or a noise point.

For these still undetermined points, further judgment is needed. The specific judgment steps are as follows:

- ***Step 4:*** Calculate parameter $pd = length(find(S == x(i,j))) / length(S(:)$, and pd is the ratio of the number of points that are the same as the (i,j) pixel to the number of all points in the area S. Secondly, compare the value size of PD and self-set threshold B. If pd> B, the point is a texture point, and change the mark to $N(i,j) = 1$. Otherwise, the point is an actual noise point.

2.2 Eliminate noise

After completing the determination of the noise point, the next step is to eliminate the noise, that is, to restore the pixels at the noise point to obtain a denoised image.

For a non-noise point, the pixel value of the point in the denoised image M is equal to that of the noise image, that is, $M(i,j) = x(i,j)$. For noise points, the restored pixel value is obtained after the following processing,

Set the matrix $tmp = x(S)$. That is, the point of the window corresponds to the pixel matrix in the original image. Set the matrix Ws, and define $Ws = 0$ at noise points and $Ws = 1$ at non-noise points. It can be obtained that $\Sigma(\Sigma(tmp.* Ws))$ is the pixel sum of all non-noise points in the window, and $\Sigma(\Sigma(Ws))$ is the number of all non-noise points in the window.

Finally, the result of dividing the two is used as the restored pixel value at point (i,j), that is, $M(i,j) = \Sigma(\Sigma(tmp.* Ws))/ \Sigma(\Sigma(Ws))$, to achieve the purpose of eliminating noise.

Perform the above analysis on each point in the noise image to complete the image denoising.

Table 1. Use a non-local adaptive mean filter to process each pixel (i,j) in the noise image.

```
Algorithm    Mean Filter With Adaptive Window Size
/*Stage 1*/ Determinate the noise points
1) If $x\sim = 0$ & $x\sim = 255$, $N(i,j) = 1$, break;
   Otherwise, $N(i,j) = 0$, goes to step 2.
2) Initialize $s = 1$, $smax = 7$,
3) Calculate the number of non-noisy points, $sum = N(S)$,
   until $sum \geq 3$ or $s = smax$; Otherwise $s = s + 1$, and repeat step 3.
4) If $sum \geq 3$ and $s \leq smax$, break;
   Otherwise, go to step 5.
5) Calculate $pd$, if $pd > B$, $N(i,j) = 1$.

/* Stage 2*/ Eliminate the noise
6) If $N(i,j) = 1$, $M(i,j) = x(i,j)$.
   Otherwise $M(i,j) = \Sigma(\Sigma(tmp.* Ws))/ \Sigma(\Sigma(Ws))$
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3. Experimental RESULTS

Test the mean filter of the adaptive window size on a large number of image sets, and change the image noise intensity and the size of the parameter values in the filter. The experimental results are sorted below.

Table 2. Performance comparison of averaging filtering methods under different noise intensities (PSNR dB)

Image	Noise level				
	0.5	0.6	0.7	0.8	0.9
Barbara	22.4537	22.5064	22.5084	22.4697	22.4405
Elaine	27.6647	27.6371	27.7595	27.6066	27.6343
Goldhill	25.7848	25.7083	25.7095	25.6588	25.7314
Man	24.6780	24.6549	24.7253	24.7038	24.7117
Peppers	25.3129	25.5557	25.5357	25.6196	25.6218
Yacht	21.9491	22.0072	21.9623	22.0445	22.0219
Zelda	30.1509	30.1110	30.2554	30.1200	30.2333

Under the settings of B=0.7 and Smax=7, for different images under different noise intensities, the average filter method of adaptive window size is used to denoise, and the Peak Signal to Noise Ratio (PSNR dB) value of the denoised image is used as the standard to measure the image quality. Analyzing the data in the table shows that in different situations, the mean filtering method can achieve better denoising results, reflecting the superiority of this method.

Figure 2 lists the original images of the 7 images, and the added noise of different levels, and the denoised image. The picture name is listed below the original image, the noise level (Noise Level, abbreviated as NL) is listed below the noise image, and the quantitative PSNR (dB) is listed below the denoising image.

Table 3. Performance comparison of average filtering methods when parameter B takes different values (PSNR dB)

Image-Barbara	noise level				
B	0.75	0.8	0.85	0.9	0.95
0.3	23.4587	22.8410	21.9959	19.9909	14.0453
0.4	23.4587	22.8451	22.0016	20.0358	14.0002
0.5	23.4587	22.8494	22.0342	20.2835	14.0385
0.6	23.4587	22.8541	22.1525	21.2201	17.6920
0.7	23.4587	22.8541	22.2071	21.4511	20.2716
0.8	23.4587	22.8573	22.2098	21.4621	20.3604

Under the setting of Smax=7, for the same image Barbara, under a certain noise intensity, use the mean filtering method of adaptive window size to denoise, and then analyze the effect of changing the value of parameter B on the image quality after denoising (Use the PSNR (dB) value of the denoised image as a measure of image quality). The data in the longitudinal comparison table shows that under a certain noise intensity, when the parameter B=0.8, the image denoising effect is better. The data in the horizontal comparison table shows that when the parameter B=0.8, the image can achieve a better denoising effect under different noise intensities. Therefore, in this method, B=0.8 makes the denoising result superior.

Table 4. Performance comparison of the mean filtering method when the parameter Smax takes different values (PSNR dB)

Image-Barbara	noise level				
Smax	0.75	0.8	0.85	0.9	0.95
3	23.4620	22.8624	22.2211	21.4988	20.3430
4	23.4620	22.8624	22.2226	21.5122	20.4772
5	23.4620	22.8624	22.2226	21.5127	20.5103
6	23.4620	22.8624	22.2226	21.5128	20.5188
7	23.4620	22.8624	22.2226	21.5128	20.5201
8	23.4620	22.8624	22.2226	21.5128	20.5201

Under the setting of B=0.7, for the same image, Barbara, under a certain noise intensity, the mean filtering method of adaptive window size is used to denoise and change the value of the parameter Smax on the image quality after denoising is analyzed. (Use the PSNR (dB) value of the denoised image as a measure of image quality). The data in the longitudinal comparison table shows that under a certain noise intensity, the change of the parameter Smax has less influence on the image denoising effect. The data in the horizontal comparison table shows that when the parameters Smax=7 and 8, the image can achieve a better denoising effect under different noise intensities. Therefore, Smax=7 and 8 in this method make the denoising result superior.

4. Conclusion

To remove salt and pepper noise, this paper proposes a mean filter with adaptive window size. This method determines the adaptive window size, and averages the pixels of the non-noise points in the window, and restores the pixel values of the noise points with the average pixel value, which improves the effect of image denoising and obtains an ideal denoising result. This method also avoids the misjudgment that the texture points are regarded as noise points through threshold comparison, which better retains the texture characteristics of the original image. This paper conducts experiments on large data sets, constantly transforming images and changing the intensity of noise. The final experimental results prove the superiority of the mean filter with adaptive window size. Simultaneously, constantly change the value of each parameter in the filter for testing, and analyze the experimental results to determine the superior parameter value. Next, we will continue to study filters with adaptive window sizes, hoping to optimize the algorithm, improve the quality of denoised images on the existing basis, and reduce the time and space complexity of the algorithm.

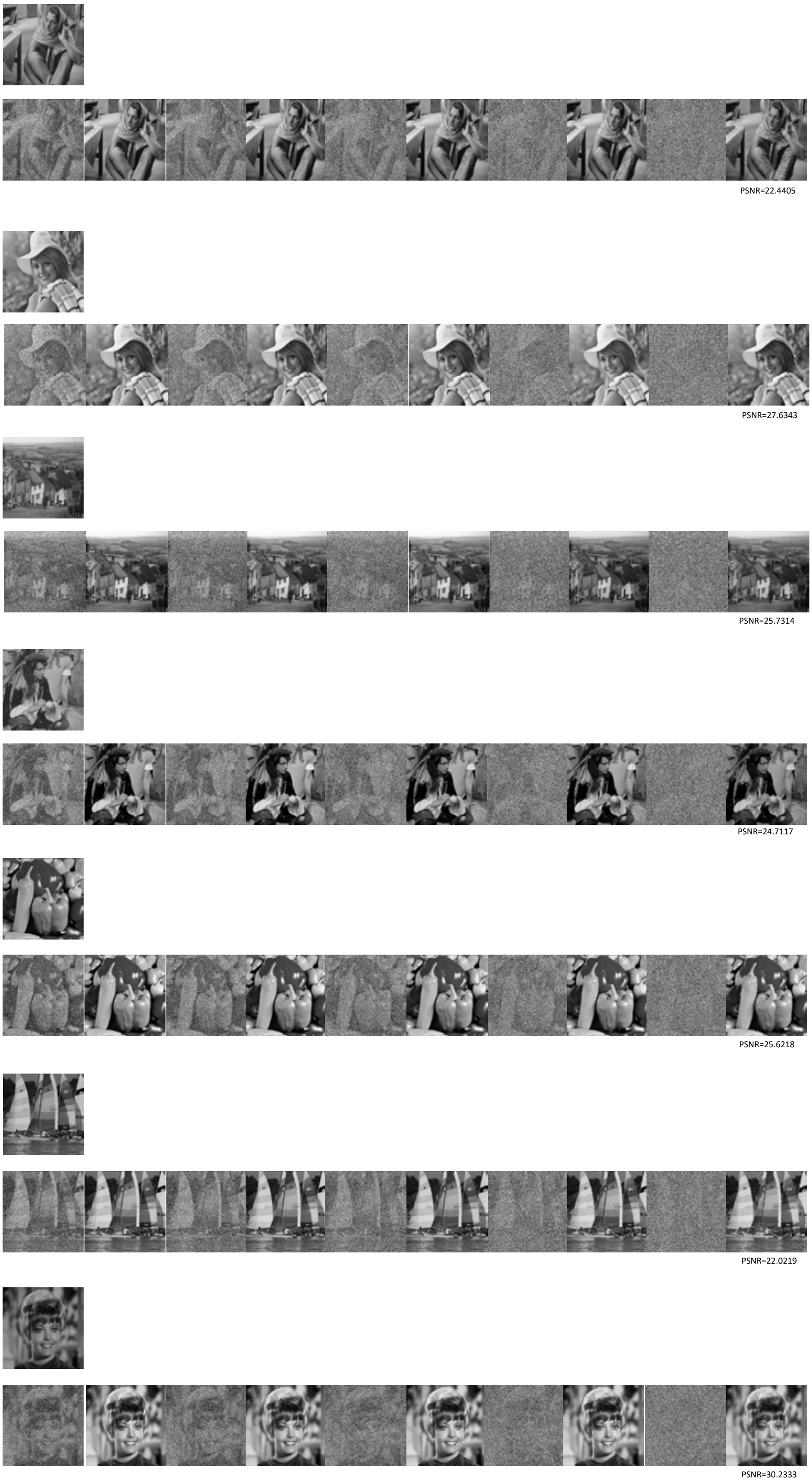

Fig 2. Original images, noisy images and denoised images.

References

[1] Qian Xue, Chengyi Yang, Huaxiang Wang. Alternate direction method to remove salt and pepper noise[J]. Acta Automatica Sinica, 2013, 39(12): 2071-2076.

[2] Yanfei Shen, Jintao Li, Zhenmin Zhu, Yongdong Zhang, Feng Dai. Compressed sensing image restoration algorithm based on non-local similarity model[J]. Acta Automatica Sinica, 2015, 41(02):261-272.

[3] Singh, Vikas, et al. "Improved Adaptive Type-2 Fuzzy Filter with Exclusively Two Fuzzy Membership Function for Filtering Salt and Pepper Noise." ArXiv Preprint ArXiv:2008.04114, 2020.

[4] Abdulsattar, Fatimah Shamsulddin. "A New Adaptive Filter for Eliminating Salt and Pepper Noise." IOP Conference Series: Materials Science and Engineering, vol. 928, 2020, p. 32001.

[5] Huang, Tao, et al. "Neighbor2Neighbor: Self-Supervised Denoising from Single Noisy Images." ArXiv Preprint ArXiv:2101.02824, 2021.

[6] Junrong Chen, Hanyang Lin, Yuzhong Chen. Texture-preserving image denoising method based on U-Net fusion [J]. Small Microcomputer System, 2021, 42(04): 791-797.

[7] Guangyu Liu, Yi Huang, Zhiyong Zeng, Yu Cao, Enming Zhao, Chuanxi Xing. Research on image denoising method based on wavelet threshold [J]. Journal of Xinxiang University, 2021, 38(03): 42-47.

[8] Chunmeng Li, Yanhua Cao, Xiaozhong Yang. Fractional wavelet image denoising based on improved threshold function [J]. Measurement and Control Technology, 2020, 39(08): 97-101+107.

[9] Xiaoxiao Xing, Hailong Wang, Jian Li, Xuande Zhang. Asymptotically non-local average image denoising algorithm. Acta Automatica Sinica, 2020, 46(9):1952−1960 doi: 10.16383/j.aas.c190294.

[10] Yefei Chen, Guangshe Zhao, Guoqi Li, Dingheng Wang. Unsupervised multiple non-local fusion image denoising method. Acta Automatica Sinica, 2020, 45(x):1−16 doi: 10.16383/j.aas.c200138.