An improved image denoising algorithm based on Fourier transform

1.Introduction

As a classic problem of image processing,image noise reduction. Since the beginning of the research, various algorithms emerge one after another. The Fourier transform[1] is one of the more classical ones in image processing.At present, image denoising algorithm based on Fourier transform has attracted people's attention. This paper attempts to obtain an improved scheme based on fourier transform, and makes a quantitative evaluation of the denoising effect with wavelet denoising, mean denoising and median denoising methods by analyzing the differences in MSE and SSIE between the original noiseless image and the denoised image.

Fourier transform can be used in image processing to convert the time domain into the frequency domain and process its high and low frequencies. The edge signal and noise signal in the image are often high frequency signals, while the image contour and background signals which change frequently are often low frequency signals. At this time, relevant operations can be carried out on the image, such as image denoising, image enhancement and sharpening.

Non-local mean filtering algorithm[2]was first proposed in 2011. Its core idea is very similar to Gaussian filtering: calculate the weighted sum of pixel values of all pixels in a rectangular window, and the weight follows Gaussian distribution. The difference is that the Gaussian filtering uses the Euclidean distance between the current filtering point and other points in the rectangular window to calculate the weight, and the closer the distance is, the greater the weight is. In non-local mean filtering, the similarity between the neighborhood block of the current filtering point and the neighborhood block of other points in the rectangular window is used to calculate the weight. The greater the similarity, the greater the weight. This algorithm can realize image filtering in local area.

2 .algorithm

Our algorithm has three main modules: 1. Non-local mean noise reduction 2. Fourier transform 3. Median filtering.

The reason why we use Non-local mean filtering before Fourier transform is that in the second step, we directly set all high frequency noise to 0 in the Fourier transform, which leads to the connection between high and low frequency parts of the image is not smooth enough, which loses a lot of detail information and may form false edges and contours. The advantage of the non-local mean method is that it can retain our detailed information to a large extent, which makes up for the lack of details caused by the Fourier transform on the image, so a Non-local mean filter is used first in the Fourier transform, which retains the image details and also provides a preliminary noise reduction on our noisy image. Fourier transform is mainly aimed at the noise reduction of high frequency noise, by setting a threshold to filter out high frequency information to achieve the purpose of noise removal. The median filter is mainly aimed at salt and pepper noise. We can observe our noise images and see that the main noise is salt and pepper noise, so we use the median filter to further optimize our algorithm in the end.

The algorithm flow chart is shown in the figure:

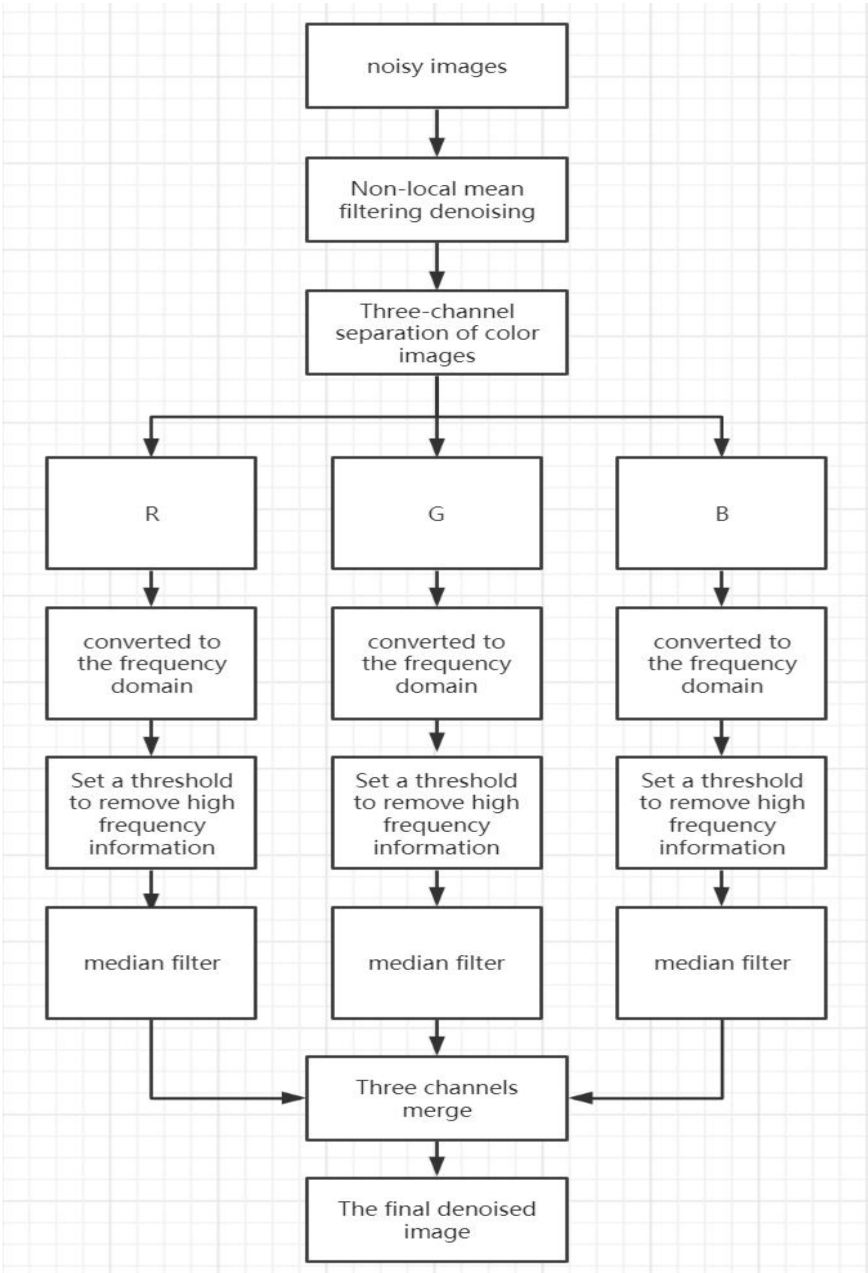
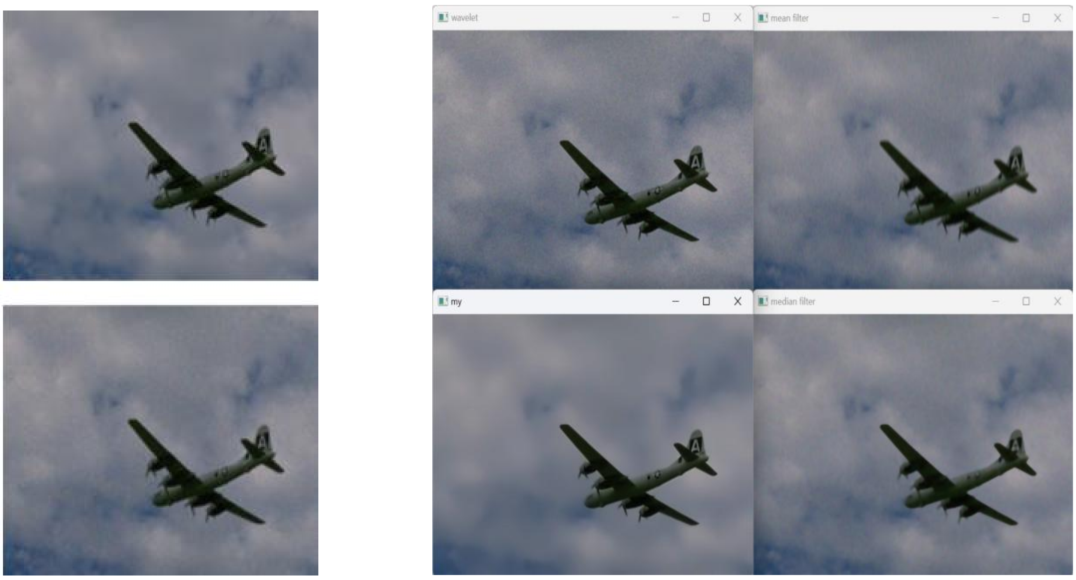


Figure1 algorithm flow chart

1. Use the fastNlMeansDenoisingColored in cv2 for the initial overall denoising of the image.
2. Divide the denoised image into three channels, RGB.
3. Fourier transform is used to convert the time domain into the frequency domain, which is divided into high frequency and low frequency.

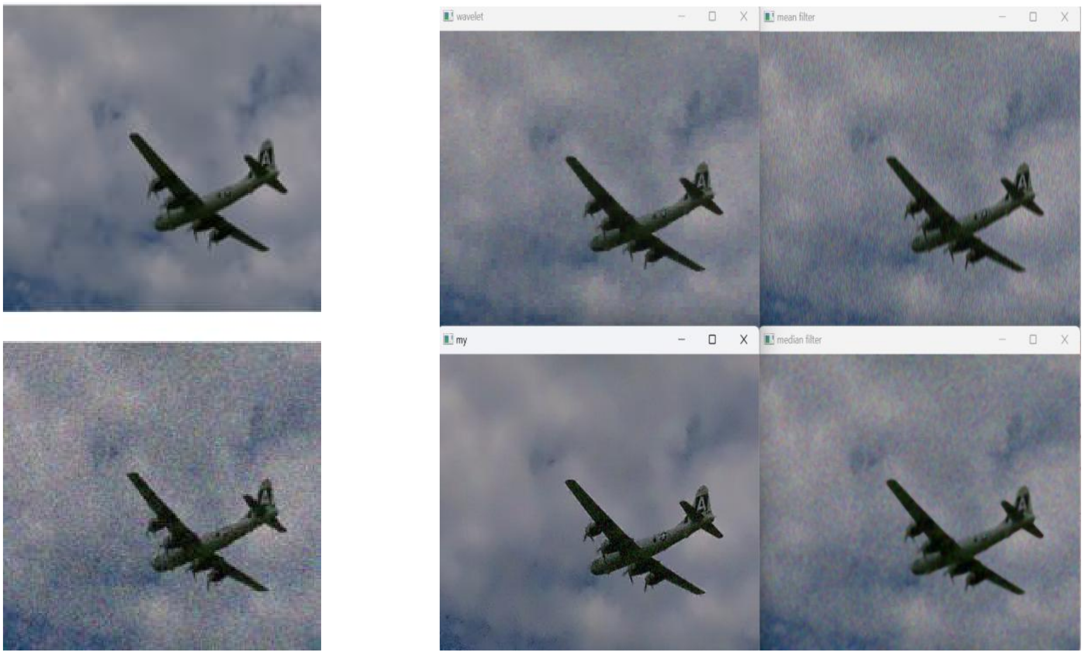
4. The high frequency corresponds to the noise information, so we need to remove the high frequency and set a threshold. We can think of it as high frequency information and filter it out.
5. Use median filtering to carry out median filtering on the three channels respectively. Because the advantage of median filtering is to protect the edge of the signal from being blurred, if the adjustment of parameters in non-local mean noise reduction is too large, they can be adjusted back through median filtering.
6. The 3 channels are combined to form the final noise reduction image.

3.Result



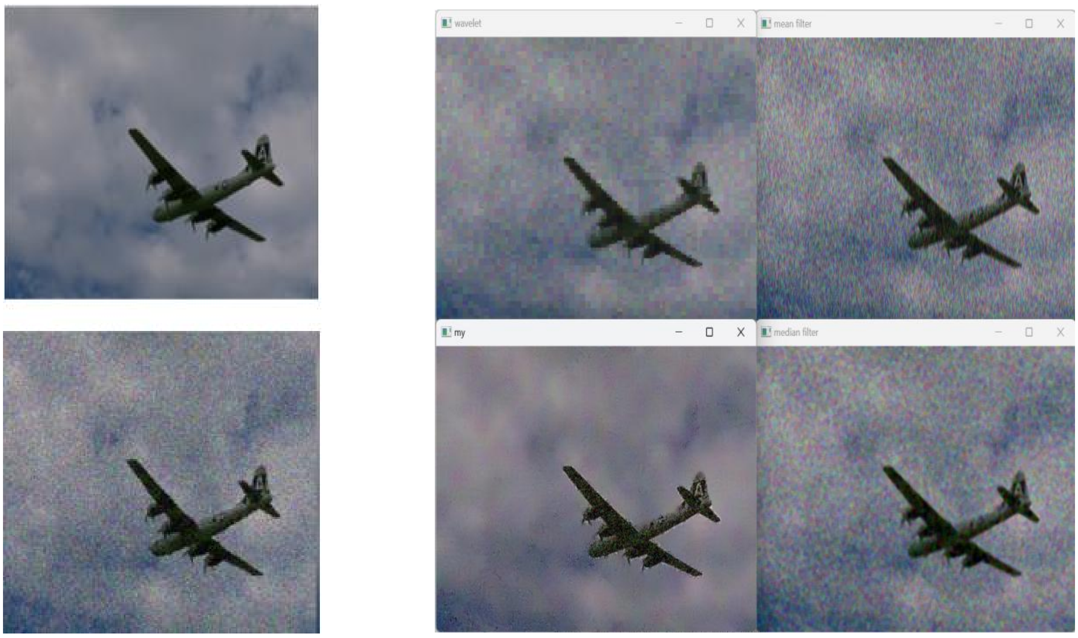
(Above is the noise plot, below is the original plot)

Figure2 noisy10



(Above is the original plot， below is the noise plot)

Figure3 noisy25



(Above is the original plot， below is the noise plot)

Figure3 noisy50

The above three groups of drawings correspond to noisy10, noisy25, and noisy50 respectively. Each group of noise has 4 algorithms to reduce its noise It is obvious from the processing effect that the image denoising effect is better when all kinds of algorithms remove the noise under the condition of low signal-to-noise ratio. The larger the noise signal-to-noise ratio is, the worse the denoising effect is.

		SSIM				MSE			
		My	Means	Median	Wavelet	My	Means	Median	Wavelet
noisy10	0000	**0.953703376**	0.872237308	0.936051812	0.821506691	**11.49773641**	28.93094604	15.23660253	19.23092035
	0001	0.678448357	0.789552805	0.70734441	0.899836114	183.6246548	124.9098732	177.0227049	43.86105012
	0002	**0.852306766**	0.808375594	0.843322793	0.844101817	36.62166048	46.58424276	36.77044406	25.18751822
	0003	0.698831216	0.728694911	0.709446029	0.876604371	144.3316062	145.8796079	158.5806202	69.13983502
	0004	0.732673611	0.763605012	0.708699642	0.875851489	139.9661207	161.7235726	189.8955987	61.96883656
noisy25	0000	**0.866331718**	0.391007592	0.695519259	0.823501895	44.13457167	144.6081178	55.11080239	39.08697914
	0001	0.614792356	0.621038587	0.626453952	0.740626074	312.5563435	228.5342625	222.4309299	148.6365179
	0002	0.539478989	0.469132085	0.658077768	0.747058065	232.6409825	147.9542253	77.74485053	62.57825619
	0003	0.562993344	0.542402162	0.612459838	0.735567784	310.7743516	254.2418551	208.8194766	149.7426873
	0004	0.586697726	0.564126051	0.601775469	0.731496466	324.791627	265.7664264	239.9548254	171.6370576
noisy50	0000	0.69282147	0.164423116	0.404725469	0.720173462	127.8102581	505.585415	178.7925661	94.34262731
	0001	0.455734797	0.419635123	0.500757396	0.575704682	571.4534297	553.1535439	347.5591026	297.1150791
	0002	0.373121174	0.230047143	0.429831723	0.596775529	571.4534297	478.4719659	187.7525038	171.2928198
	0003	0.410729686	0.356636094	0.473195831	0.582156318	610.3642938	574.3918347	335.5475979	278.3000391
	0004	0.403735163	0.37249819	0.456129253	0.576338421	730.2955184	579.6949631	370.3714203	299.2802162

Table1 MSE and SSIM are compared in different algorithms

In addition, MSE and SSIM index were used to analyze the denoised image and the original image. As shown in the curve in FIG. 4 drawn in Table 3, the algorithm we designed has certain advantages compared with the current popular algorithms when the noise is low. However, when the noise becomes louder and louder, our algorithm becomes worse and worse compared with other algorithms.

Among them，the best performance is wavelet algorithm.

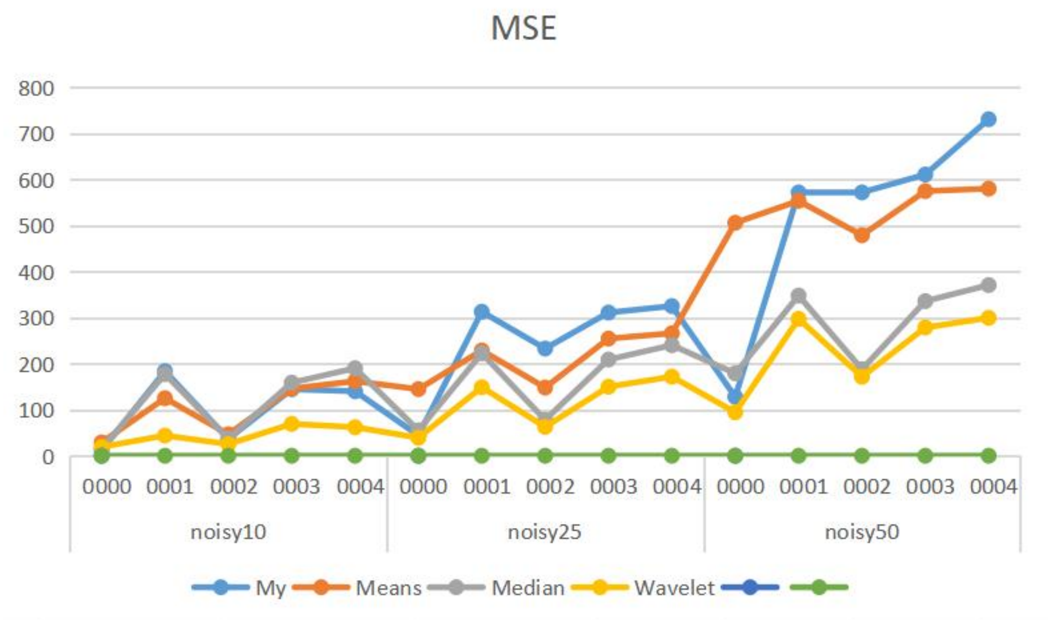


Figure4 MSE

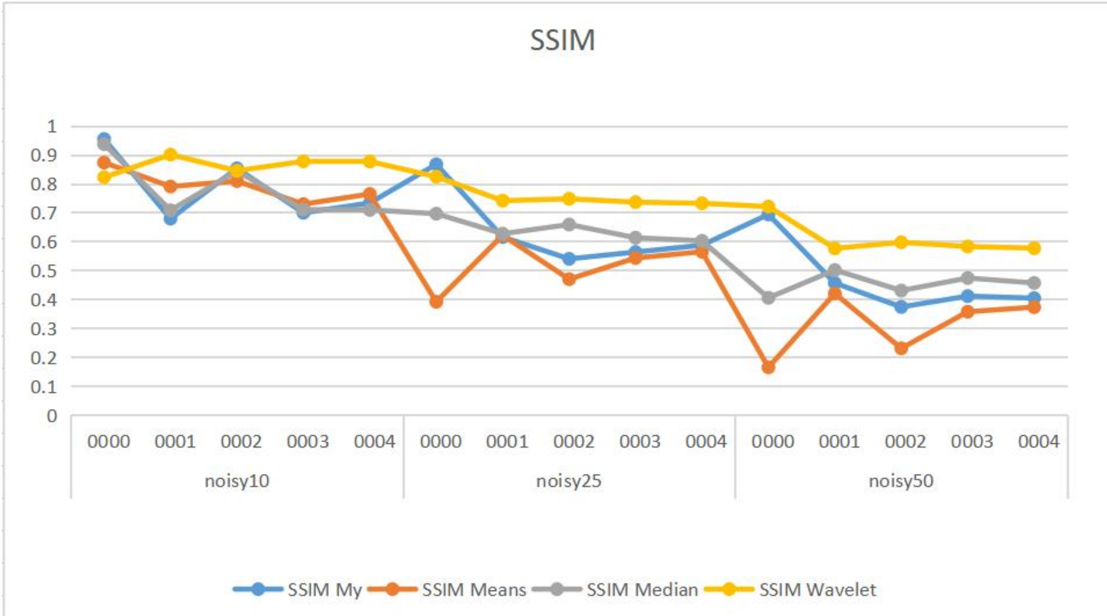


Figure5 SSIM

Through SSIM curve, we can observe that wavelet filtering is the most stable among the four algorithms, while the effect of mean filtering is not very ideal. Our algorithm has certain advantages in low signal-to-noise ratio. Meanwhile, we can see the noise reduction effect of our first drawing, which is well performed in noisy10, noisy25 or noisy50. The first drawing is a drawing with a relatively simple background, indicating that our algorithm is better than the other four algorithms in dealing with the noise of simple drawing. When dealing with slightly complex graphs, the results are similar to those of the other three algorithms.

To sum up, our algorithm has certain advantages in processing low signal-to-noise ratio images, but is slightly weak in processing high signal-to-noise ratio images compared with the current algorithm.

4.Conclusion

Compared with traditional Fourier algorithm or traditional mean denoising, our algorithm has better denoising effect. After adding non-local mean denoising to Fourier transform, the details of the image can be preserved, which greatly improves the disadvantage of Fourier denoising unsmoothness. However, the disadvantage is that the calculation takes a long time, because the non-local mean noise reduction is to operate the whole graph. At the same time, we cannot adjust our parameters through the noise intensity adaptively, so sometimes we need to manually modify the parameters to achieve the desired effect.

Reference

[1]Z. Wang and S. Li, “Discrete fourier transform and discrete wavelet packet transform in speech denoising,” *2012 5th International Congress on Image and Signal Processing*, 2012.

[2] A. Buades, B. Coll, and J.-M. Morel, “Non-local means denoising,” *Image Processing On Line*, vol. 1, pp. 208–212, 2011.