An Improved Filtering Method Applied in Digital Mobile Terminal for Images Getting from Wireless Network Remote Transmission

Guoxiang Tong[1,2], Lingling Mei[1], Naixue Xiong[1], Chunxue Wu[1]

[1] School of Optical-Electrical & Computer Engineering, Univ. of Shanghai for Science & Technology, China
[2] Shanghai Key Laboratory of Modern Optical Systems, China
tonggx@usst.edu.cn, 1090685874@qq.com, xiongnaixue@gmail.com, tyfond@126.com

Abstract

Images transmitted through wireless network or imaged by digital mobile devices usually contain a lot of noise against information acquisition. The improved nonlocal means (NLM) filtering algorithm proposed in this paper is suitable for digital mobile terminals in order to filter the noise mentioned above and obtain denoised images which details in them can be easily picked out for the field: the internet of things. It inherits some excellent ideas from several improved NLM denoising algorithms: abandon gaussian kernel function, utilize correlation of color components and compensate the pixels' hue for color denosing image. Besides above, we select an optimal value of the parameter h after experiments and analyzing a lot of data and we put forward a reprocessing mode based on Rough Set theory. The proposed method is intended to improve signal-to-noise ratio (SNR) of images and effectively solve the problem that the details in image are blurred. And the improved color-image denoising method can remove motle in the denoising image better than most state-of-the-art methods. The conclusion shows that it can preserve images' hue and details availably.

Keywords: Wireless network remote transmission, Digital mobile terminal, Nonlocal means denoising, Rough reprocessing, Correlation between RGB channels

1 Introduction

Transmiting images to digital mobile terminals through wireless network, staffs can obtain images of job sites and complete information acquisition directly without attending there. The connection environment of wireless network is very complicated, such as the wireless sensor network (WSN) [1-2], images which transmitted through it may suffer a serious noise pollution if the transmitting distance is too far because of light, atmospheric factors or restraints of different specifications. Digital mobile terminals as the main tools of capturing and processing image today, images which taken by them also may contain noise because of its internal sensor, imaging system and some physical factors such as shooting environment. Among many applications of this technology, some of them such as remote monitoring, unmanned aerial vehicle (UAV) recorder, remote consultation and vehicle-borne image recorder require that the image after transmitting must have a high SNR and unambiguous details. In order to preserve details and improve images' quality, we must solve the problem that detail-preserving and denoising effect can't balance. In addition, this kind of images generally contain unpredictable random noise, only probability analysis is available, fortunately, typical Gaussian noise and impulse noise account for most of them. In this paper, we mainly commit to eliminating Gaussian noise, because the algorithm in [3] and a variety of other algorithms already have excellent denoising effect to impulse noise. The difficulty of filtering Gaussian noise is that the Gaussian noise causes different extent of pollution to each pixel in the image.

We analyzed the features of various mainstream denoising algorithms, found that the eliminating noise effect of the nonlocal means (NLM) algorithm is better than a variety of image denoising methods in the present and can preserve structure information in images. However, digital mobile equipments require the denoising algorithm have features of less code, real-time performance and low computational complexity. In order to meet requirements above and get high-quality images, we propose an improved nonlocal means filtering algorithm in this paper, which is based on a recent work [4]. In addition, color images processed by our algorithm all have fine hue and less motle, the filtering result is better than most plans in the past.

The remainder of this paper is organized as follows. Section 2 discusses related work. In Section 3, we discuss the NLM algorithm and propose two improved

*Corresponding Author: Lingling Mei; E-mail: 1090685874@qq.com
DOI: 10.3966/160792642018051903002

methods accorded with requirements. Next section, we verity the effect of our proposed methods and compare to some state-of-the-art methods with experimental results. Finally, Section 5 concludes the findings of this paper.

2 Related Work

Based on the feature of noise caused by wireless network remote transmission, Wang et al. [5] proposed a filtering method based on fuzzy mathematics and a filtering method based on genetic algorithm, both of them can fulfil a great filtering task, but they are not suitable for digital mobile devices because of their features and computational complexity. Previously, many scholars have put forward image filtering algorithms which are suitable for digital mobile devices. Earlierly, Chen et al. [6] filtered noise in images by setting threshold of spatial frequency, this way may easily filter important signals and cause information loss. Gao et al. [3] filtered noise in images which affected noise pollution seriously using an improved fast median filtering method, although it's filtering effect for impulse noise is remarkable and it has a fast speed, but it may cause unsmooth edges of objects in denoised images which affected Gaussian noise pollution before. Wang et al. [7] proposed a denoising algorithm based on neuron models, the filtering effect is better but the complexities both of time and space are so high, does not necessarily apply to all the digital mobile terminals. Later, Yang et al. [8] proposed a threshold based Area-Average method which equals to an ideal band-pass filter, it not only has a lower computational cost but also can protect details in images better. Furtherly, Cheng et al. [4] raised a nonlocal means algorithm based on principal component analysis (PCA), it protects structure information of images effectively using the redundancy of a image and has a short computing time, but the filtering effect is compromised, relative to the NLM algorithm. We suspect that if we can improve the NLM algorithm using other reasonable ways, may get a better denoising effect.

3 Algorithm Theory

3.1 A Method for the Noisy Grayscale Image

Using a improved NLM filtering algorithm for the initial filtering. Digital mobile devices require algorithms have the feature of low computational complexity. In the NLM filtering process, weight calculation takes up most of the time, almost 70% of the whole filtering time, improving its weight calculational method can quickly improve its real-time performance. So, the improved algorithm we proposed abandons the component of Gaussian kernel function when calculating its weight. After many times tests and calculations, we found that the way of weight calculation in the work [9] can be replaced with the following equation(1), and we just need to explore the value of h-parameter again in order to obtain images which can be picked out details easily. The computation formula of $w(k,l)$ is as follow:

$$w(k,l) = \exp(-\frac{\sum_{l \in S_k} (\mathbf{z}_{k+s} - \mathbf{z}_{l+s})^2}{h}) \quad \textbf{(1)}$$

The weight meets with two conditions: $0 \le w(k,l) \le 1$ and $\sum_{S_k} w(k,l) = 1$, among the formula, S_k represents the window region, k represents the center pixel in the window and l represents each pixel in the window.

Then, we begin to explore the optimal value of parameter h. Shown in Figure 1 is the influence of parameter h to the effect of detail-preserving in the image at σ=25. It is known from the comparison that when h<0.3, details in image are too sharpening and the filtering effect is poor; when h>40, the effect is better but details in the image tend to be fuzzy and adverse to observe; in contrast, when h=0.35, the effects of denoising and detail-preserving both can be taken care.

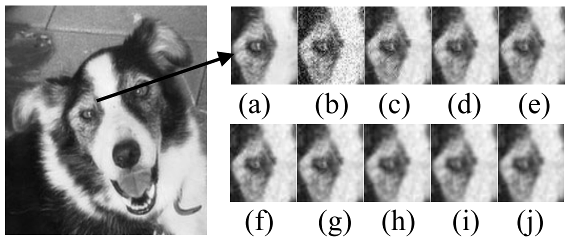


Figure 1. The left is the original image, (a) is some details of the original image, (b) is the noisy image of σ =25, (c) is the denoising result when h=0.2, (d) is the denoising result when h=0.3, (e) is the denoising result when h=0.35, (f) is the denoising result when h=0.4, (g) is the denoising result when h=0.5, (h) is the denoising result when h=10 σ, (i) is the denoising result when h=10 $\sqrt{2}\sigma$, (j) is the denoising result when h=15σ.

In Figure 2, function curves present the influence of different value of h-parameter to the output PSNR results when the parameter σ equals to 10, 25 and 45 respectively. We can uncover that at the same value of σ, the function curves of different images always trend to accordance: after h being larger than a certain value, the curve which was sharp originally would become gentle gradually. Combining the conclusion of Figure 1 we can find that the value of the turning-point on the each curve can not only ensure a high output SNR value of denoised image but also preserve details excellently. It would seem, when 0<σ<15, we can set the value of h as 0.45, when 15<σ<35, set the value of h as 0.35, and when $35<\sigma$, set it as 0.20. Then, we calculate an estimated value of the center pixel in the window as the original algorithm, its normalized expression is:

$$\hat{\mathbf{y}}(k)=\frac{\sum_{l\in S_k} w(k,l)\mathbf{z}(l)}{\sum_{l\in S_k} w(k,l)} \quad \textbf{(2)}$$

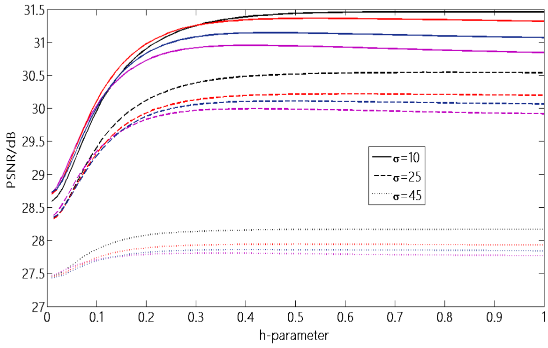


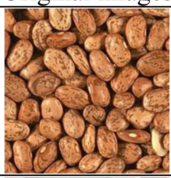
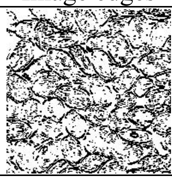
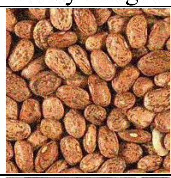
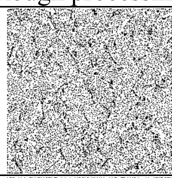
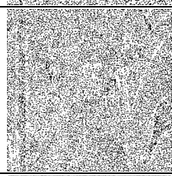
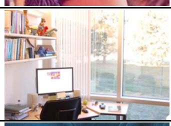
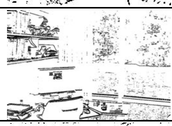
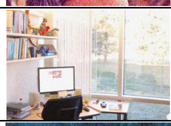
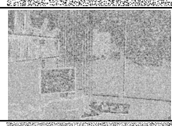
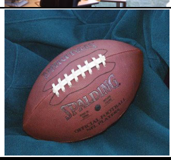
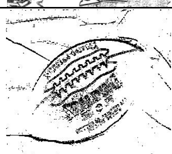
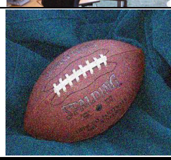
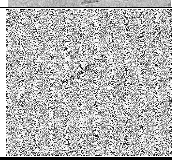
Figure 2. The influence of parameter h to PSNR from denoised image with different value of σ

Reprocessing based on the rough set theory. For a distinct image which can be identified information easily, edges of objects in it are also an important part of details. An image filtering method can't preserve edges also doesn't conform to the requirement of this article. We find a way only to reprocess the pixels which contain a large amount of noise and little edges. Based on Rough Set Theory [10], we select out grayscale maximum and minimum in each window regin and group them as a set of pixels for special processing. In Table 1, the "edge-content rate" we calculated means the proportion of edge pixels in the set of pixels selected based on Rough Set Theory. We find that the edge-content rate is quite low, and after comparing of multiple images in Table 1, we also find these sets include a lot of noise and very little edge, pollution levels of most pixels in them are relatively high. We denoise these pixels again, the filter we used is defined as follow:

$$\hat{\mathbf{y}}(k)=\frac{\sum_{l\in S_k} w(k,l)(\mathbf{z}(l)+\mathbf{z}(k))}{2\cdot\sum_{l\in S_k} w(k,l)} \quad \textbf{(3)}$$

Among them, the center-weighted method is used to calculate the difference between the value of center pixel and one of its adjacent pixels in the window. This filter is better for keeping the value of center pixel and makes every effort to weaken serious noise and preserve edges and details in images.

Table 1. The edge-content rate of the pixel set obtained from rough processing

	Original images	Image edges	Noisy images	Rough processing	Edge-content rate
BEANS					0.1270
LENA					0.0396
OFFICE					0.0425
FOOTBALL					0.0528

3.2 A Method for the Noisy Color Image

A improved color image filtering method. In color images, in order to using the correlation of three channels in RGB space, Wang et al. [11] put forward a concept of calculating two pixels' Euclidean distance in the window of each channel and fusing them to obtain the weight of NLM denoising method, then filtering three channels respectively with it. The algorithm suggested by us inherits this excellent idea to obtain the weight. This novel algorithm bases the improved grayscale-image NLM denoising algorithm proposed in this paper. The equation of weight calculation is as follow:

$$w^c(k,l)=\exp\left(-\frac{\sum_{l\in S_k}(z_{k+s}^R-z_{l+s}^R)^2+\sum_{l\in S_k}(z_{k+s}^G-z_{l+s}^G)^2+\sum_{l\in S_k}(z_{k+s}^B-z_{l+s}^B)^2}{3h}\right) \quad \textbf{(4)}$$

Although the weight calculation of the fusion method above has taken the impact of the correlation into account and the denoising effect in the aspect of SNR is better than the method which compound RGB image after processing each single-channel, but in terms of vision, denoised images are all very messy and still have much motle.

In literature [12], the algorithm which combines the thought of compensating pixel value can significantly reduce much motle contained in denoised image. Taking the channel R and channel G as a representative, the expression is:

$$p_R(k) = z_G(k) + \Delta \quad \textbf{(5)}$$

among them, $p_R(k)$ is the predicted estimate of pixel in channel R, and Δ is a compensation for the pixel in this channel. In addition,

$$\Delta = \bar{z}_R^{S_k} - \bar{z}_G^{S_k} \quad \textbf{(6)}$$

thereinto, $\bar{z}_R^{S_k}$ and $\bar{z}_G^{S_k}$ are the average values of all pixels in each window of channel R and G. In order to improve the filtering effect furtherly, we use the generated value from the Gaussian low-pass filter to replace the average value of all pixels in the window, it can highlight details in the image while sacrificing a little PSNR.

Taking the channel R as an example, the calculational method of improved color-image NLM denoising algorithm combining with the self-correlation [13] of channel R and the compensation values from channel G and channel B is as follow:

$$\hat{\mathbf{y}}_R(k) = \frac{\sum_{l \in S_k} w^c(k,l)\mathbf{z}_R(l)}{\sum_{l \in S_k} w^c(k,l)} \quad \textbf{(7)}$$

$$\hat{\mathbf{y}}_{Rg}(k) = \frac{\sum_{l \in S_k} w^c(k,l)(\mathbf{z}_G(l) - \mathbf{z}_G^L(l) + \mathbf{z}_R^L(l))}{\sum_{l \in S_k} w^c(k,l)} \quad \textbf{(8)}$$

$$\hat{\mathbf{y}}_{Rb}(k) = \frac{\sum_{l \in S_k} w^c(k,l)(\mathbf{z}_B(l) - \mathbf{z}_B^L(l) + \mathbf{z}_R^L(l))}{\sum_{l \in S_k} w^c(k,l)} \quad \textbf{(9)}$$

thereinto, $\mathbf{z}_R^L(l), \mathbf{z}_G^L(l), \mathbf{z}_B^L(l)$ are the Gaussian low-pass filtering values of channel R, channel G and channel B respectively.

Integrating the denoising results of the three equations above to obtain filtering estimates of channel R. The other two channels imitate it in turn, then we integrate the filtering estimates for color image.

A multichannel-joint rough reprocessing. The noise which polluted single component may have implicative effects on the others. We assume that if a pixel in one component has been polluted, the corresponding pixels of other two components are as same as it approximatively. In order to address this issue, this paper puts forward a rough reprocessing method for color images of multi-channel combination after a first filtering. Similar to the grayscale-image denoising method, we select out all the maximum and minimum in each window as a set of pixels from one component, then, we have a second filtering to the three sets of pixels obtained from the three color components and get the final result.

3.3 Main Steps of the Two Denoising Methods

The process of grayscale-image filtering:

Step 1. use the estimation formula of σ to obtain the value and then pick out the corresponding h-parameter

Step 2. carry on a initial filtering to the noisy image with our algorithm to increase the denoising result

Step 3. carry on a reprocessing based on Rough Set theory to distinguish noise and details.

The process of color image filtering:

Step 1. obtain the value of σ and pick out the correct h-parameter as above.

Step 2. carry on a first filtering combining with channels' correlations to the noisy color image for a high SNR.

Step 3. compensate each channel with Gaussian low-pass filtering values from other two channels in order to eliminate much motle in the image.

Step 4. compound each channel's denoising result and then carry on a multichannel-joint rough reprocessing to filter out residual noise and increase the image's visual quality.

4 Experimental Results

4.1 Experimental Settings

In this section, we present and discuss the experimental results obtained by the improved algorithms. Grayscale images we used in Figure 3 are obtained from MATLAB sample library and color images in Figure 4 are taken in four different situations by digital mobile terminals. The digital mobile terminal captures images using a CMOS sensor of Sony 800W pixels and its light-sensing surface area is 1/3.2 of an inch. The light-sensitive chip is imx179, and the lens of it is 5P spherical lens and the aperture size is F2.0 with a LED light-compensating lamp. The noise in experimental images are all the Gaussian White Noise added by MATLAB to simulate the noise which caused by wireless network remote transmission and shooting. The block sizes of the NLM filter are all setas 7 * 7, the window size is set as 5 * 5 (increasing the window size can effectively promote the algorithm performance but it is at the cost of details in images and the computational complexity will be quite higher). The choice criterion of the h-parameter in this experiment is according to the new conclusion.

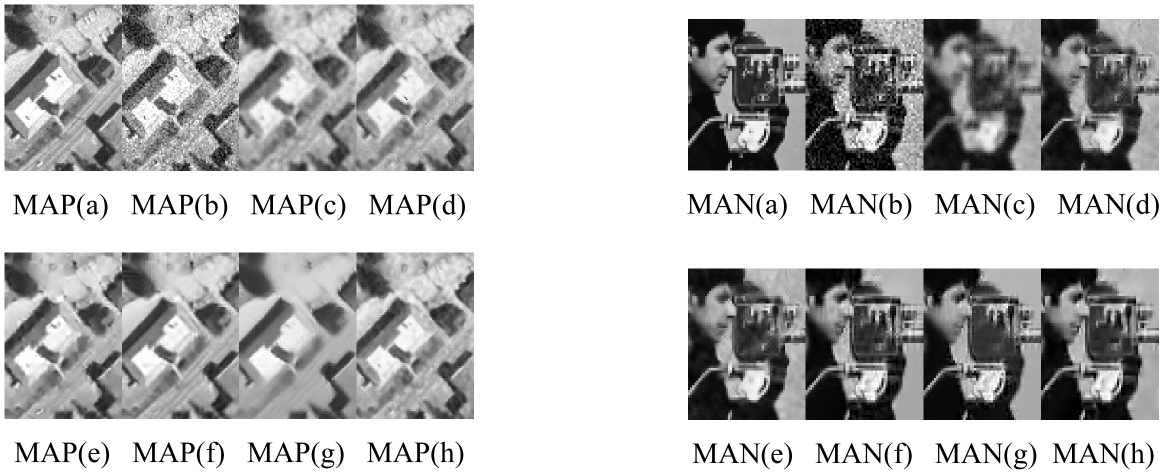


Figure 3. The visual comparison of filtering results obtained by the six denoising methods, (a) is the original image, (b) is a image added noise at $\sigma = 25$, (c) is the filtering result of Area-Average method, (d) is the filtering result of PCA-NLM, (e) is the filtering result of BLS-GSM, (f) is the filtering result of BM2D, (g) is the filtering result of NLM, and (h) is the filtering result of our method

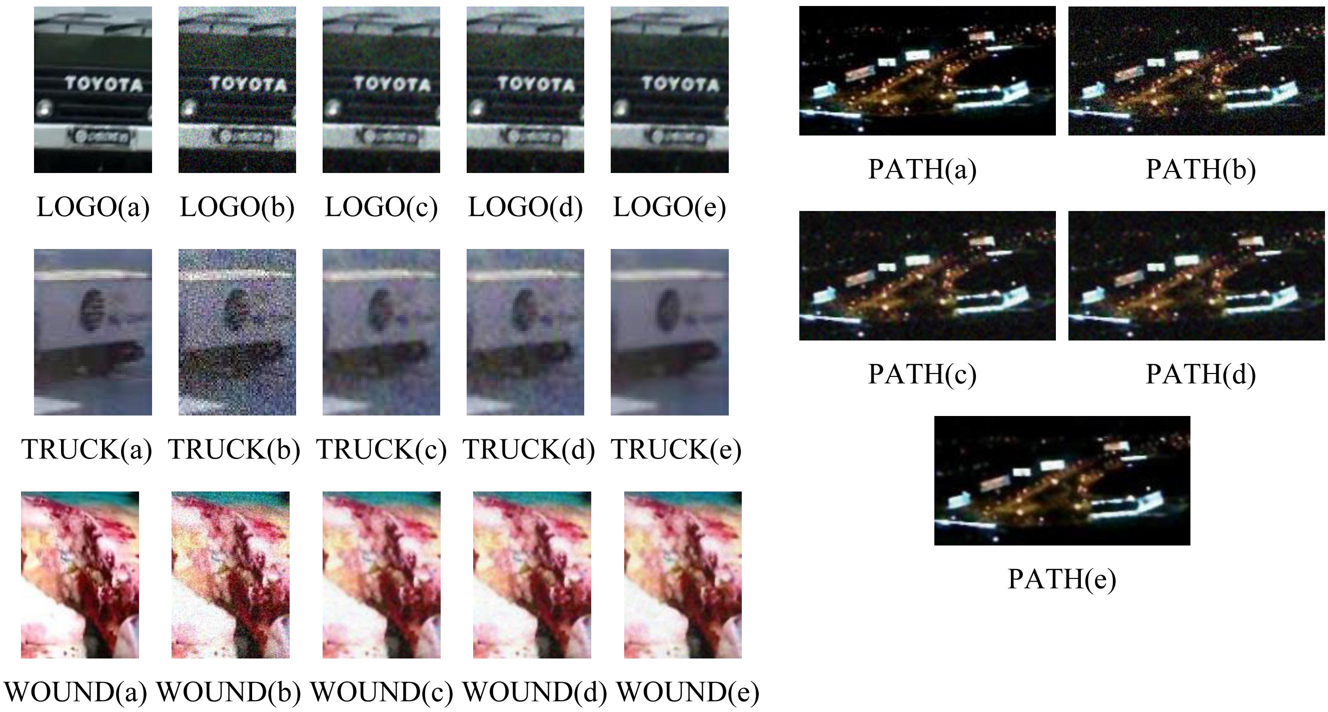


Figure 4. The visual comparison of filtering results obtained by the three denoising methods, (a) is the original color image, (b) is a color image added noise with $\sigma = 45$, (c) is the filtering result of PR, (d) is the filtering result of CNLM, (e) is the filtering result of our method

4.2 Results

Grayscale-image denoising. First of all, we compare the output PSNR results of the proposed algorithm with those of the state-of-the-art methods Area-Average [8], PCA-NLM [4] in Table 2. It shows that the filtering ability of our algorithm in this paper is a little higher than the other two algorithms and it can still maintain a certain advantage when $\sigma = 55$, which means it has a strong robustness. Many experimental results show that the value of PSNR can not be completely consistent with the visual quality, and the image which has a high PSNR result may have a worse visual performance than a low one, so the effect of a filtering algorithm also need a visual test.

The denosing performances of our algorithm and the other five methods Area-Average [8], PCA-NLM [4], BLS-GSM [14], BM2D [15] and NLM [9] at $\sigma = 25$ are illustrated in Figure 3. Among them, MAP(c) and MAP(d) still have obvious residual noise, the building's edge in MAP(e) appears as jaggies, and the noise in MAP(f) and MAP(g) are filtered out neatly but the two images lose much details, especially MAP(g), it's not conducive to identify information. MAN(c) and MAN(d) have low SNR results and at the same time, the character's facial feature and the camera's external detail in MAN(c) are both missing, the background color of MAN(e) is not pure, and details in MAN(g) are also lost seriously although structure information is maintained excellently. The comprehensive effect of MAN(f) is better. The denoising effect and the effect of detail-preserving are balanced in MAP(h) and MAN(h), the edges of objects in the two images are smooth, and they also keep the advantage of retaining structure information. Combining with above comparisons and evaluations, we found that the BM2D method and our algorithm are slightly better than the other four algorithms.

Table 2. The comparison in PSNR of processing results from three denoising algorithms

Noise standard deviation	Denoising methods	MISS PSNR/dB	RICE PSNR/dB	MAN PSNR/dB	COINS PSNR/dB	MAP PSNR/dB
$\sigma = 10$	Area-Average	31.3355	31.1227	30.8402	32.0488	30.1028
	PCA-NLM	31.3810	31.1727	30.9761	31.9988	30.2656
	our algorithm	**31.5109**	**31.3429**	**31.1163**	**32.0801**	**30.4781**
$\sigma = 25$	Area-Average	30.2276	30.1097	29.9309	30.7875	29.3735
	PCA-NLM	30.2257	30.1378	30.0165	30.7433	29.4829
	our algorithm	**30.3056**	**30.2527**	**30.1079**	**30.7886**	**29.6449**
$\sigma = 45$	Area-Average	27.9365	27.8447	27.7524	28.1096	27.7754
	PCA-NLM	27.9437	27.8649	27.7900	28.1099	27.8162
	our algorithm	**27.9646**	**27.8922**	**27.8289**	**28.1163**	**27.8710**
$\sigma = 55$	Area-Average	26.6161	26.7136	26.5705	26.7504	26.8881
	PCA-NLM	26.6426	26.7344	26.5892	26.7678	26.8968
	our algorithm	**26.6387**	**26.7376**	**26.6091**	**26.7721**	**26.9007**

Color-image denoising. The denosing performance of our algorithm and the state-of-the-art techniques PR [16] and CNLM [9] at $\sigma = 45$ are illustrated in Figure 4. The four kinds of color images respectively simulate the images transmitted from vehicle-borne image recorder, remote monitoring, remote consultation and UAV recorder. Among them, color of vehicles' bodies in LOGO(c) and LOGO(d) both contain a lot of motle, each "TOYOTA" is not clear and their color change a lot. The recovery effect of LOGO(e) is the best. TRUCK(c) and TRUCK(d) have too much motle and lose details seriously, those may lead to distinguish objects difficultly in images. WOUND(c) and WOUND(d) also contain much motle and noise. The visual effect of WOUND(e) is better and the color's fidelity is higher, relative to the first two images. PATH(a) contains night scene, this may require a high-level denoising algorithm. After comparing PATH(c), PATH(d) and PATH(e), we find that the advantage of our algorithm is more obvious and it can be conveniently used for image recording in UAV at night.

We compare the output PSNR results of the images from Figure 4 in Figure 5. The three kinds of algorithms all improve the SNR of LOGO(b), TRUCK(b) and WOUND(b), and we can clearly find that the denoising ability of our algorithm is the best. It's a low illumination scene in PATH(b), the image contains a large amount of random noise, dark current noise and shot noise [7], from Figure 5 we find numerical computation results of three algorithms are all not ideal, but the output PSNR result of our algorithm proposed in this paper is still better than the other two algorithms.

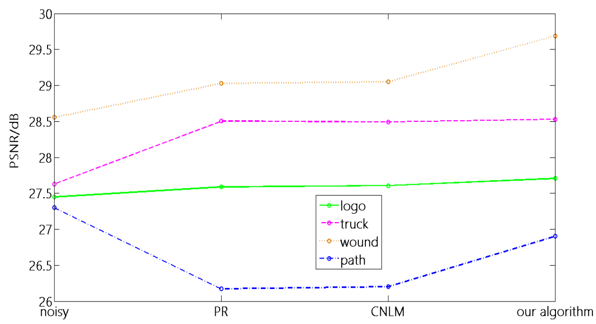


Figure 5. The influences of three methds to output PSNR results after filtering noisy images at $\sigma = 45$

Several experimental results show that the grayscale-image denoising method we proposed has an evident filtering effect and fine robustness. And the color-image denoising method we proposed based on foregoing method is very suitable for a variety of applications in the field of wireless remote transmission. Images processed by it all have high-fidelity color, clear structures and are

easy to pick out details. In addition, we make our algorithms to have smaller computational complexity, less code and higher instantaneity through simplifing computation approach of weight in algorithms, choosing the appropriate window size and abandoning tedious iterations. In later work, we will continue to optimize our algorithm: make the algorithm more suitable for images taken in low illumination and night scene; make the algorithm more suitable for filtering random noise caused by remote transmission; develop the proposed method combining with self-tuning property [17-18]; improve method combining with the transmission features of wireless multimedia sensor network [19-20]; use cloud computing services [21-22] to deal with complex calculations, etc.

5 Conclusion

Wireless network data transmission makes message passing more convenient, the combination with intelligent terminal technology can promote the rapid development of Internet of Things technologies. In this paper, we present a new image filtering algorithm for digital mobile terminal, can filter out noise pollution in images caused by wireless remote transmission and imaging system. We compare and analyze the algorithm with multiple filtering methods recently used in this field. The results show that the computing complexity of our algorithm is small, images all have fine hue and less motle after its processing. The balance between detail-preserving and denoising in image is outstanding. It is very suitable for picking out details in images and can be used for image transmission in the fields of remote monitoring, UAV recorder, remote consultation, vehicle-borne image recorder and others in emerging internet of things technology [23-24].

References

[1] Y. Liu, N. Xiong, Y. Zhao, A. V. Vasilakos, J. Gao, Y. Jia, Multi-layer Clustering Routing Algorithm for Wireless Vehicular Sensor Networks, *IET Communications*, Vol. 4, No. 7, pp. 810-816, April, 2010.

[2] Y. Sang, H. Shen, Y. Inoguchi, Y. Tan, N. Xiong, Secure Data Aggregation in Wireless Sensor Networks: A Survey, *2006 Seventh International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT'06)*, Taipei, Taiwan, 2006, pp. 315-320.

[3] C. Gao, Y.-C. Guo, K. Ren, H. Yang, Detecting Technology of Cable Surface Defect Based on Embedded System and Image Recognition, *Opto-Electronic Engineering*, Vol. 35, No. 2, pp. 40-44, February, 2008.

[4] G. Chen, Z. Qian, S. Wang, Implementation of Non-local Means Image Denoising on Embedded System, *Video Engineering*, Vol. 37, No. 7, pp. 1-3, July, 2013.

[5] X. Wang, Design and Implementation of Remote Network Monitoring Image Filtering System, *Electronic Technology & Software Engineering*, No. 4, pp. 109-109, February, 2015.

[6] S. Chen, Design and Implementation of Embedded Multimedia Network Control Equipment, *Microcomputer Applications*, Vol. 23, No. 4, pp. 36-37, April, 2007.

[7] J. Wang, *Design of the Tube Sampling Robot based on Embedded Video System and Research on Video Denosing Algorithm*, Master Thesis, Zhejiang University, Hangzhou, China, 2010.

[8] B. Yang, *Research of the Video Monitoring Forensics System Base on ARM9*, Master Thesis, Xi'an Technology University, Xi'an, China, 2013.

[9] J. Dai, O. C. Au, L. Fang, C. Pang, F. Zou, J. Li, Multichannel Nonlocal Means Fusion for Color Image Denoising, *IEEE Transactions on Circuits & Systems for Video Technology*, Vol. 23, No. 11, pp. 1873-1886, November, 2013.

[10] L.-F. Chen, C.-T. Tsai, Data Mining Framework Based on rough Set Theory to Improve Location Selection Decisions: A Case Study of a Restaurant Chain, *Tourism Management*, Vol. 53, pp. 197-206, April, 2016.

[11] W.-N. Wang, L. Shi, H.-J. Li, New Approach of Color Images coder in RGB Color Spaces, *Application Research of Computers*, Vol. 26, No. 1, pp. 395-397, January, 2009.

[12] Q. Zhao, D. Chen, E. Jiang, Z. Fang, Improved Weighted Non-local Mean Algorithm Filter for Image Denoising, *Journal of Electronic Measurement & Instrumentation*, Vol. 28, No. 3, pp. 334-339, March, 2014.

[13] P. F. Wang, Y. Jin, Z. Liu, Study on Components of Color Space and Their Auto-correlation of Image, *China Printing and Packaging Study*, Vol. 3, No.5, pp. 34-39, October, 2011.

[14] L. Li, N. Kasabov, J. Yang, L. Yao, Z. Jia, Poisson Image Denoising Based on BLS-GSM Method, *22nd International Conference on Neural Information Processing (ICONIP 2015)*, Istanbul, Turkey, 2015, pp. 513-522.

[15] H. Zhong, K. Ma, Y. Zhou, Modified BM3D Algorithm for Image Denoising Using Nonlocal Centralization Prior, *Signal Processing*, Vol. 106, pp. 342-347, January, 2015.

[16] J. Ji, *Experimental Study of the Color Recognition System Based on Embedded Vidio Technology*, Ph.D. Thesis, 2014.

[17] N. Xiong, A. V. Vasilakos, L. T. Yang, C.-X. Wang, R. Kannane, C.-C. Chang, Y. Pan, A Novel Self-tuning Feedback Controller for Active Queue Management Supportig TCP flows, *Information Sciences*, Vol. 180, No. 11, pp. 2249-2263, June, 2010.

[18] N. Xiong, X. Défago, X. Jia, Y. Yan, Y. He, Design and Analysis of a Self-tuning Proportional and Integral Controller for Active Queue Management Routers to support TCP flows, *25TH IEEE International Conference on Computer Communications (INFOCOM 2006)*, Barcelona, Spain, 2006, pp. 1-12.

[19] L. Shu, Y. Zhang, L.T. Yang, Y. Wang, M. Hauswirth, N. Xiong, TPGF: Geographic Routing in Wireless Multimedia Sensor Networks, *Telecommunication Systems*, Vol. 44, No. 1-2, pp. 79-95, June, 2010.

[20] H. Cheng, N. Xiong, A. V. Vasilakos, L. T. Yang, G. Chen, X. Zhuang, Nodes Organization for Channel Assignment with Topology Preservation in Multi-radio Wireless Mesh Networks, *Ad Hoc Networks*, Vol. 10, No. 5, pp. 760-773, July, 2012.

[21] G. Wei, A. V. Vasilakos, Y. Zheng, N. Xiong, A Game-theoretic Method of Fair Resource Allocation for Cloud Computing Services, *The Journal of Supercomputing*, Vol. 54, No. 2, pp. 252-269, November, 2010.

[22] J. Yin, X. Lu, C. Pu, Z. Wu, H. Chen, JTangCSB: A Cloud Service Bus for Cloud and Enterprise Application Integration, *IEEE Internet Computing*, Vol. 19, No. 1, pp. 35-43, January-

February, 2015.

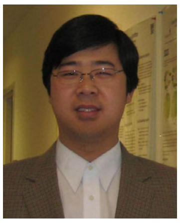
[23] L. Tan, N. Wang, Future Internet: The Internet of Things, *2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE)*, Chengdu, China, 2010, pp. V5-376-V5-380.

[24] B. Hu, Z.-H. Guan, N. Xiong, H.-C. Chao, Intelligent Impulsive Synchronization of Nonlinear Interconnected Neural Networks for Image Protection, accepted for publication in the *IEEE Transactions on Industrial Informatics*.

Biographies

Guoxiang Tong is Ph.D./Assistant Professor in School of Optical-Electrical and Computer Engineering at University of Shanghai for Science and Technology (USST). Her major research interests include application of computer control, design and develop of embedded system, design for programable of ASIC.

Lingling Mei reveived the B.Sc. engineering degree in Automation Engineering from Sanjiang University in 2013, and working toward the M.Sc in USST. Her major research interests include algorithm of image noise reduction, embedded technology.



Naixue Xiong is current a Professor at School of Computer Science, Colorado Technical University, Colorado Spring, CO, USA. He received his both Ph.D. degrees in Wuhan University (about software engineering), and Japan Advanced Institute of Science and Technology (about dependable networks), respectively. Before he attends Colorado Technical University, he worked in Wentworth Technology Institution, Georgia State University for many years. His research interests include Cloud Computing, Security and Dependability, Parallel and Distributed Computing, Networks, and Optimization Theory.

Chunxue Wu is Ph.D./Professor in School of Optical-Electrical and Computer Engineering at University of Shanghai for Science and Technology (USST). His major research interests include application of computer control, design and develop of embedded system, design of application software.