A kind of Image De-noising Method Based on Improved Intersecting Cortical Model

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Abstract. The article analyzed the impulse noise characters of the image, proposed an improved Intersecting Cortical Model. The model has to rely on the concept in the respective processing time (node) independent information, threshold function related with the number of iterations. We will introduce the timed matrix. When forming the matrix contains space-related information and determine the number of iterations. The computer simulation results show that use of the information provided by T, and use of the relevant algorithm can effectively remove impulse noise in the image. In the meantime, the proposed algorithm can effectively preserve the details of image.

Keywords: Impulse noise; Intersecting Cortical Model; Time matrix; Image de-noising.

1. Introduction

De-noising is an important part of image processing, Wavelet threshold is widely used in Gaussian noise process [1-4]. Literature [2] proposed de-noising based on SURE unbiased estimate of adaptive wavelet threshold. But, Wavelet transform lack of multi-directional, but Contourlet Transform has many advantages, such as Multi-resolution, Time-frequency localization, multi-directionality and anisotropy, etc [5, 6]. Literature [6] proposed an Adaptive De-noising Algorithm Based on Contourlet. But Contour let Transform also has its disadvantages, for example Gibbs appears angiography when used Contourlet in image de-nosing. Nonsubsampled Contourlet transform not only has the advantage of Contourlet transform but also has Shift invariance [7, 8]. Literature [8] proposed a new image de-noising method combining Nonsubsampled Contourlet adaptive total variation.

Impulse noise is a common image noise, in 1999, John L Johnson put forward a third-generation artificial neural network PCNN (*pulse-coupled neural network*). But because of its complex structure of neurons and a large number of parameters to be determined, when a neuron firing, the certain conditions around neurons activated simultaneously firing, let these neurons to achieve the same gray value, in the meanwhile weakening some useful information [9-13]. Literature [10-12] proposed a series of impulse noise de-noising based on PCNN. Literature [13] proposed an improved PCNN model.

ICM (*Intersecting Cortical Model*) is a kind of important biological background Visual cortex model. Compared with PCNN, It has fewer parameters to be determined and Low Computational Complexity [14-18].But its iterations, Attenuation coefficient and Constant amplitude are the main constraint on its performance. Literature [17] proposed an image de-noising method based on CIM. Literature [18] proposed an improved model of ICM. It reduced parameters determined. Although the threshold function is monotonically decreasing, but after a certain period of time will inevitably decline down due to the sudden increase in neuronal activation caused.

In this paper, from the above mentioned, Proposed an Improved Intersecting Cortical Model. Its dendrite only partially related to its own, Threshold function related to the number of iterations and make it a monotonically decreasing. In the meanwhile, timed matrix positioning the noise point and determining process at the same time period and the number of iterations.

2. Improved intersecting cortical model

2.1 Original intersecting cortical model

ICM is a biology background Artificial Neural Network. Figure 1 shows a basic structure of neurons ICM, its discrete mathematical expression is:

$$F_{ij}(n) = fF_{ij}(n-1) + I_{ij} + W_{ij}\{Y(n-1)\} \tag{1}$$

$$Y_{ij}(n) = \begin{cases} 1, & F_{ij}(n) > \delta_{ij}(n-1) \\ 0, & \text{other} \end{cases} \tag{2}$$

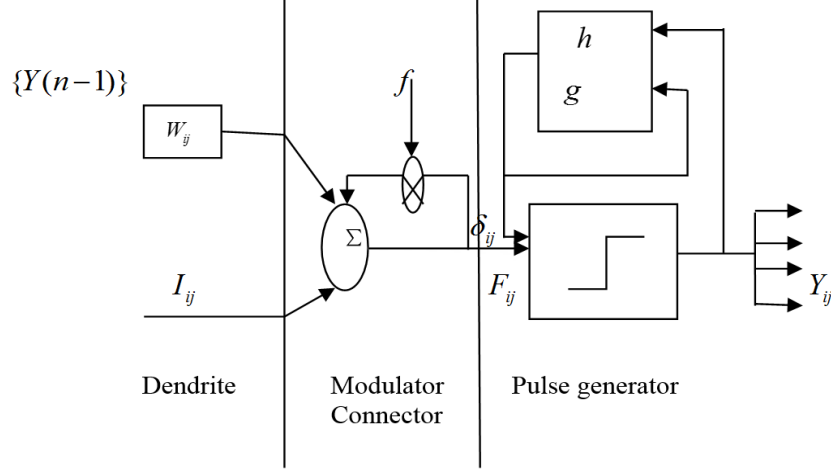$$\delta_{ij}(n) = g\delta_{ij}(n-1) + hY_{ij}(n) \tag{3}$$

Figure 1 ICM neurons Chart

Wherein: Subscript $_{ij}$ is the coordinates of the pixel, I_{ij} is corresponding to Pixel values, W_{ij} is Connection matrix between neurons; Y_{ij} is corresponding to Binary Output(0 or 1); F_{ij}, δ_{ij} respectively, for the state of neuron dendrites and dynamic threshold; f, g, respectively corresponding to the iterative dendrite attenuation coefficient and the attenuation coefficient threshold value; h is the amplitude threshold value constant, f, g, h are the scalar coefficients, in the meanwhile $g<f<1$,n is Iterations.

In the course of ICM work, External input of each neuron is corresponding to the corresponding pixel in the image. In the Nonlinear pulse modulation section, Neuron internal state F_{ij} is from External excitation I_{ij} adding Neighboring neurons $Y(n-1)$. F_{ij} with the increasing number of iterations and increasing. In Pulse generating section include threshold constantly changing δ_{ij}.

When $F_{ij} > \delta_{ij}$, $_{ij}$ corresponding neuron firing, at this time, The value of Y_{ij} is 1, δ_{ij} Sudden increase , corresponding neuron is not in the ignition. Decreasing the threshold in the attenuation factor g role, until $F_{ij} > \delta_{ij}$, neurons firing again. In the meanwhile, Produced by the action of firing neurons link their neighborhood neuronal function, Enable those neurons are successively captured ignition, again and again.

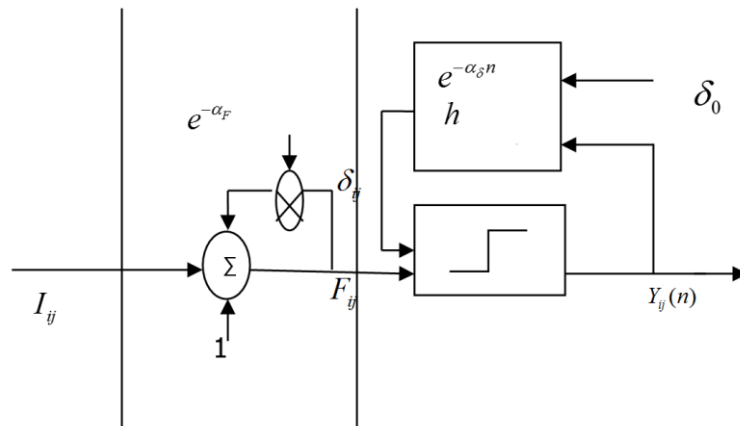## 2.2 A kind of Improved intersecting Cortical Model

Figure 2 Improved ICM neurons Chart

In the original model, although ICM threshold function is monotonically decreasing, after a period of decay, the threshold value will rise, because the neurons firing again. Further, determine iterations and four undetermined coefficients w, f, g, h is from human subjective experience and the large number of simulation experiments (Fig. 2).

To overcome original Intersecting Cortical Model shortcomings, this paper presents an improved Intersecting Cortical Model. Its discrete mathematical expression of formula (4)-(6):

$$F_{ij}(n) = e^{-\alpha_F} F_{ij}(n-1) + I_{ij} + 1 \tag{4}$$

$$Y_{ij}(n) = \begin{cases} 1, & F_{ij}(n) > \delta_{ij}(n-1) \\ 0, & \text{other} \end{cases} \tag{5}$$

$$\delta_{ij}(n) = \delta_0 e^{-\alpha_\delta n} + h Y_{ij}(n) \tag{6}$$

In the formula (4): $e^{-\alpha_F}$ is Regulators, α_F is Constant Coefficient and its satisfy $0 < \alpha_F < 1$, I_{ij} is ij neurons corresponding pixel values, n is Iterations. In the formula(6): Threshold function adjusted to the number of iterations n related functions, δ_0 is the initial threshold value, $e^{-\alpha_\delta n}$ ensure that each neuron dynamic threshold value is always monotonically decreasing trend, $\delta_0 e^{-\alpha_\delta n}$ Guarantee threshold does not appear iteration repeatedly rising and falling state after a long period, α_δ is a constant coefficient and $0.1 < \alpha_\delta < 0.2$, Threshold amplitude constant h is an integer constant, usually chosen large values to ensure that a limited number of iterations of each neuron activation (ignition) once.

$$\because \ 0 < e^{-\alpha_F} < 1, \quad I_{ij} > 0$$

$$\therefore \ F_{ij}, F_{ij}(n-1) \geq 0 \text{ and } \uparrow$$

$$\because \ 0 < e^{-\alpha_\delta n} < 1, 0.1 < \delta_0 < 0.2$$

$$\therefore \ \delta_0 e^{-\alpha_\delta n} \ \downarrow \to 0$$

When n increasing, $F_{ij}(n) > \delta_{ij}(n-1)$, so the Neuron firing.

With respect to the original model, the improved ICM has the following points of improvement:

(1) In the improved Intersecting Cortical Model processing time mainly depend on independent information.

(2) Threshold function are about to the number of iterations n, because of it will not be a sudden rise and fall of phenomena.

(3) To determine the processing cycles and iterations n, we will introduce timed matrix.

(4) In order to make the model capable of processing each pixel, given its fixed external excitation 1.

(5) In the processing time, in order to let each neuron only firing once, the threshold is set to a constant amplitude h (h usually is a large integer constant amplitude).

3. Timed matrix

When all neurons are firing, firing timing of each neuron is timed matrix of Improved Intersecting Cortical Model. The larger number of timed matrix is iterations. Its discrete mathematical expression is following:

$$T_{ij}(n) = \begin{cases} n, & Y_{ij}(n) = 1 \\ T_{ij}(n-1), \text{other} \end{cases} \tag{7}$$

In formula (7): if neurons ij never firing, the corresponding T_{ij} is 0; if neurons ij firing, the corresponding T_{ij} is the current number of iterations.

Noise let neurons firing advance or delay, so if one neurons firing time is different from other surrounding neurons, so this neurons corresponding pixel is noise.

4. Image de-noising based on Improved intersecting cortical model

When the image is pulsed noise pollution, it can cause some pixel grayscale value is the maximum (255) or minimum (0). Image de-noising based on Improved intersecting cortical model is following:

(1) Impulse noise image processing by ICM, produced a timed matrix (T) and calculated minimum $T_{\min}$ and maximum $T_{\max}$.

(2) For T in the original image corresponding to the point of use (2m + 1) * (2m + 1) matrix full k window mask, whose elements are sorted to generate vector elements u, Compute $T_{\min}$ and $T_{\max}$ proportion n_{ij} in the u.

(3) Timed matrix T and u to determine how to filtering:

  (a) If $T(i,j) \neq T_{\min}$ and $T(i,j) \neq T_{\max}$, Direct output $I'(i,j)$.

  (b) If $T(i,j) = T_{\min}$ or $T(i,j) = T_{\max}$ and $n_{ij} \neq 1$, in the U that not equal to $T_{\min}$ and not equal to $T_{\max}$ pixels are Mean filter, And the result is assigned $I'(i,j)$.

  (c) If $T(i,j) = T_{\min}$ or $T(i,j) = T_{\max}$ and $n_{ij} = 1$, so expansion of the mask k until the u $n_{ij} \neq 1$, in this U, that not equal to $T_{\min}$ and $T_{\max}$ not equal to $T_{\max}$ pixels are Mean filter, and the result is assigned $I'(i,j)$.

(4) All elements of the image processing does not finish, redirect to (3).

5. Experimental results and analysis of image

In order to verify the effectiveness of the method is reasonable, use matlab 2013a, Standard test image Lena, Mandrill pulse noise processing simulation (table 1 and table 2). Image size is 512×512 pixels. In the experiment, the parameters used are $\delta_0 = 245$, $\alpha_\delta = 0.04$, $\Delta\delta = 8$. Figure 3 and figure 4 show the result of different algorithms.
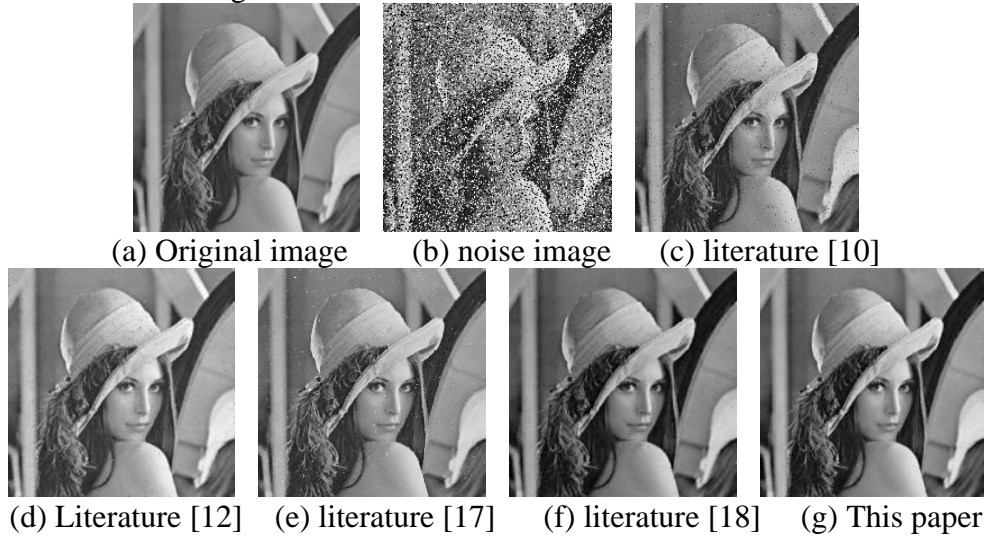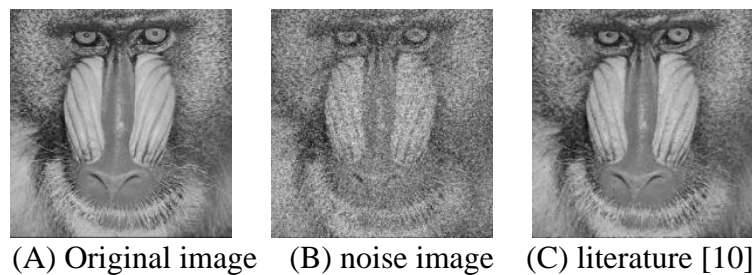

(a) Original image   (b) noise image   (c) literature [10]
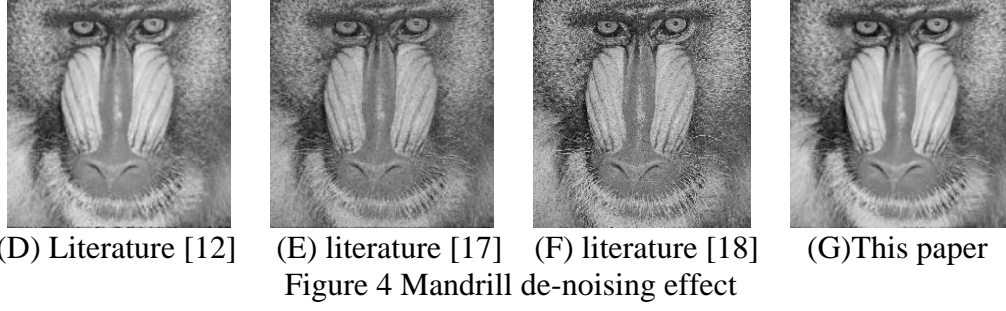

(d) Literature [12]   (e) literature [17]   (f) literature [18]   (g) This paper

Figure 3 Lena de-noising effect

(A) Original image   (B) noise image   (C) literature [10]

(D) Literature [12]   (E) literature [17]   (F) literature [18]   (G)This paper

Figure 4 Mandrill de-noising effect

Table 1: Different methods of Lena image de-noising parameters

		0.15	0.25	0.3
Literature [10]	SNR	27.7592	24.7583	23.9706
	PSNR	33.4099	30.4090	29.6213
Literature [12]	SNR	28.2478	26.0123	25.9210
	PSNR	33.1985	31.8568	31.2718
Literature [17]	SNR	28.7932	26.4523	25.6524
	PSNR	34.3761	32.0219	31.3032
Literature [18]	SNR	29.6488	28.0562	27.5023
	PSNR	35.2996	32.8214	32.4531
This Paper	SNR	**30.7723**	**29.3089**	**28.3483**
	PSNR	**36.4231**	**34.9597**	**33.9990**

Table 2: Different methods of Mandrill image de-noising parameters

		0.15	0.25	0.3
Literature [10]	SNR	17.6183	16.8188	16.3652
	PSNR	23.0848	22.2853	21.8317
Literature [12]	SNR	20.0578	19.0123	18.3114
	PSNR	26.0243	24.2368	23.7779
Literature [17]	SNR	20.7475	19.3354	18.6799
	PSNR	26.2141	24.7412	23.9464
Literature [18]	SNR	20.7511	19.3562	19.2992
	PSNR	26.2177	24.8714	24.1657
This Paper	SNR	**21.2094**	**20.2760**	**19.9284**
	PSNR	**26.6760**	**25.7425**	**25.1949**

6.   Conclusion

In this paper, we proposed an Improved Intersecting Cortical Model, and proposed an Image De-noising Method based on this model. This algorithm only deal with contaminated pixels. Simulation results show that: this paper algorithm has more advantages superior than the conventional classical impulse noise filtering algorithm.

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