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Research of Pulse Coupled Neural Network on Image Processing

Zhenyu Han, QingE Wu

***Abstract*—This paper proposes a new adaptive pulse coupled neural network simplified models. The parameters of the model are not artificially outside interference, the decision by the pixel itself. On this basis, this paper focuses on the use of pulse coupled neural network ignition matrix for the impulse noise detection and location, and clearly pointed out that the study emphasis in the future. Moreover, the noise filtering algorithms have been ported to Field Programmable Gate Array (FPGA) hardware platform for implementation compare to the implementation of software. The implementation of FPGA hardware platform possesses high-speed, reconfiguration and other advantages.**

***Index Terms*—Pulse-coupled neural network, Synchronous oscillation, Noise testing.**

I. INTRODUCTION

The pulse coupled neural network (PCNN) is a new artificial neural network model which was formed and developed according to the phenomenon of the cat's visual cortex neurons burst synchronous oscillation. PCNN compared with the traditional neural network, its biology background determines it more accord with human visual system. It showed a greater superiority in image processing compared to conventional algorithms. Noise is formed by all kinds of interference in the process of the image generation, codec processing, transmission, and etc. According to the influence of the signal, noise can be divided into two categories, additive noise and multiplicative noise. The common noise characteristics are in accordance with additive noise in the digital image processing, which is divided into impulse noise and Gauss noise. Image de-noising has been the research focuses in the field of image processing continuously break. Abroad started the research earlier in the use of PCNN[1] for image de-noising processing, Plesser HE and Gerstner W studied the time-varying signal noise on neuronal firing PCNN impact in the literature [3]; Burkitt introduced the relationship between neuronal synchronization pulse excitation and neuronal excitation frequency [4];By optimizing the traditional PCNN model of internal activities item, Forac got the simplified PCNN model in the literature [5],which is convenient for engineering application. According to Gauss noise in the literature [6],a new method was put forward based on the timed matrix of the basic PCNN model, through the analysis and processing of data correlation matrix, Gauss noise can be effectively suppressed. The domestic started late.

For impulsive noise in the literature [7], on the basis of simplified PCNN model a new way was proposed for removing impulse noise; Literature [9] combined the PCNN theory and mathematical morphology, some new breakthroughs was made in impulse noise removal. In the Literature [8] for the current image binarization application issues such as narrow range of applications, some parameters require manual intervention, and then a new method was proposed which takes into account a variety of evaluation criteria to analyze the effect of image segmentation. T hose mentioned studies provide a good reference on PCNN image processing applications and development, and promote the rapid development in image de-noising, image filtering, and many other areas. For the above, this paper presents a simplified adaptive PCNN model, on the basis of the nature of PCNN, which has a similar neurons synchronous excitation pulse sequence, Using of the properties that noise Pixel has a poor correlation with the surrounding image, judging the location of noise points quickly, To the next filtering process. The experiment results show that this method has a distinct advantage in de-noising, edge preserving image detail.

II. PCNN MODEL

A. PCNN basic model

PCNN is a new type of neural network which was proposed in 1998, with other neural network the biggest distinction is that constitute a network of neurons, Its single neuron structure and function of neurons has great differences with the general. PCNN model has the features such as sync pulse excitation phenomena, threshold attenuation, parameters controllable and capture, and it has a linear addition, nonlinear modulation, automatic transmission and other characteristics, widely used in image processing, image recognition, network public opinion analysis and other aspects. Eckhorn proposed the standard model of PCNN [10], its single neuron model is composed of three parts, Receiving domain part, modulation and pulse generation section .as figure 1.

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Prof. Zhenyu Han, College of Electric and Information Engineering, Zhengzhou University of Light Industry, Zhengzhou, China.

Dr. QingE Wu, College of Electric and Information Engineering, Zhengzhou University of Light Industry, Zhengzhou, China.

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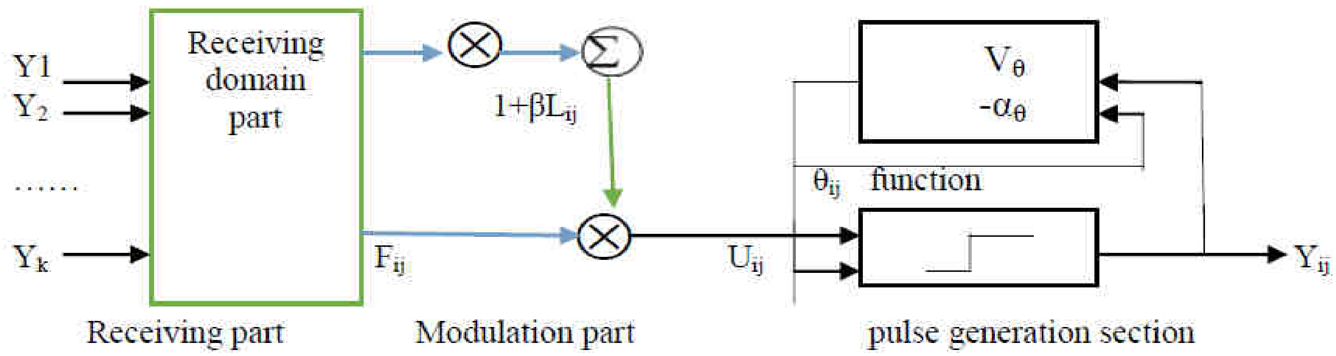

Fig. 1. Standard PCNN neuron model

The receiving part is used to receive from other neurons and external input. The receptive field transmits the receiving input through two paths. One is feedback channel F, which is used for receiving external input signal. The formula is:

$$F_{ij}(k) = e^{-\alpha_F} F_{ij}(k-1) + V_F \sum_n M_{nj} Y_{ij}(k-1) + S_{ij}$$

The other one is for receiving the connecting input from other neurons, and its relationship is:

$$L_{ij}(k) = e^{-\alpha_L} L_{ij}(k-1) + V_L \sum_n W_{nj} Y_{ij}(k-1)$$

In formula (1), (2), where: M and W are internally connected matrix; $Y(k)$ is for the information that neurons ignition or not, α_F and α_L is the decay time constant of $F_{ij}(k)$ and $L_{ij}(k)$ respectively, VF and VL is the reset voltage of $F_{ij}(k)$ and $L_{ij}(k)$ respectively, S_{ij} is for the stimulation which the (i, j) neurons receiving from the output. In the modulation section L_{ij} and adding an offset, and multiplied by F_{ij}, and then through the modulation, the internal status signal U_{ij} were generated of the first (i, j) neurons, its relation is:

$$U_{ij}(k) = F_{ij}(k)[1 + \beta_j L_{ij}(k)]$$

The neuron threshold relation is

$$\theta_{ij}(k) = \exp(-\alpha_\theta)\theta_{ij}(k-1) + V_T \sum Y_{ij}(k-1)$$

The importation of Y(i,j) is:

$$Y_{ij}(k) = Step[U_{ij}(k) - \theta_{ij}(k)] = \begin{cases} 1, U_{ij}(k) > \theta_{ij}(k) \\ 0, Others \end{cases}$$

When the neuron threshold $\theta(i,j) < U(i,j)$, the pulse generator is opened, the neurons is in the state of ignition, the pulse output is $Y(i,j)=1$, the threshold function is adjusted accordingly at the same time. Otherwise, $Y(i,j)=0$.

B. Unidirectional threshold attenuation model

When PCNN was used for image noise detection, it is a single two-dimensional network, And all the parameters of neurons is in exactly the same. The number of neurons and the number of pixels in the image are equal, and keep the one - to - one relationship. The gray value neuron and its of each pixel is input to the feeding domain of the corresponding neurons, each neighborhood are connected by a link field. The neurons ignition correspond to the pixels ignition, and the output of each neuron is only 1 and 0 of two. In the detection of noise, the parameters are needed to be determined: the decay time constant (α_F, α_L), reset voltage (V_F, V_L), the connection weights (M, W) and the modulation parameters β. There is a close relationship between the test results and parameters selection. But it obviously reduces the adaptive characteristics of PCNN. Therefore, it is needed to further simplify the PCNN model. The principle structure and the original PCNN model are the same. Take the V_F as 0, α_F and α_L as infinity, V_L as 1, and the internal bias β_j is defined as the mean of adjacent threshold, In the iterative process, the bias in each iteration will be adaptive. The formula is simplified as followed.

$$F_{ij}(k) = S_{ij}$$

$$L_{ij}(k) = \left(\sum_{p \in W} \sum_{q \in W} W_{qp} Y_{pq} - W_{ij} Y_{ij}\right)$$

$$U_{ij}(k) = F_{ij}(k)[1 + \beta_j L_{ij}(k)]$$

$$\theta_{ij}(k) = \exp(-\alpha_\theta)\theta_{ij}(k-1)$$

Among them, $\theta(0) = 255$.

The threshold of the model start attenuation from the maximum gray value in exponentially state, The simplified model has a better adaptive characteristics, Through calculating and analyzing of the image of PCNN firing matrix to locate the noise pixels, and then to filter the noise pixels.

III. IMAGE DE-NOISING METHOD ANALYSIS

The traditional noise removal is achieved by using filtering method. The median filter algorithm and the improved median filter is widely used filtering method. The median filtering has the characteristics of simple operation, fast speed, and good effect. But it uses the same filtering window to deal with the entire image which contaminated by different noise intensity. When the noise intensity increases and removing the noise in the meantime, the image of normal pixels will also be affected, so that the image becomes blurred. The reason is that the median filtering can't determine the real point, but uses the same filtering operation on the image. Therefore, the key issue of noise filtering is to first determine the noise points, and then use the median filter, the noise can be filtered in the case of without losing image details and protect the image edge information. PCNN has the characteristics of neurons synchronize with similar excitation, adaptive, generating an output pulse train. By using these attributes the impulse noise can be detected exactly. In order to filter noise, and meanwhile preserve image details and edge information effectively, the PCNN ignition matrix was adopted to detect and locate the noise in this paper. Through improving the output of PCNN neurons, the initial ignition

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timing can be got of neurons (i, j) .

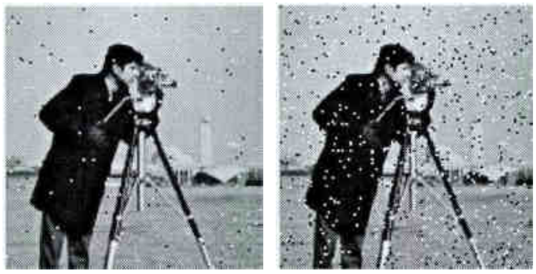
$$Y_{ij}(k) = Step[U_{ij}(k) - \theta_{ij}(k)] = \begin{cases} 1, U_{ij}(k) > \theta_{ij}(k) \\ 0, Others \end{cases}$$

This ignition has the same two-dimensional matrix with the detected image. It means that the initial ignition time of each neuron. Because the PCNN neighborhood neurons has an coupling relationship, thus the neighboring neurons groups which the pixel is similarity in the network released pulse simultaneously. When one of the neuron (i, j) firing, if its neighborhood neurons (p, q) meet the certain conditions that $U_{pq}(1+\beta L_{pq}) > \theta_{pq}$, then the neurons were captured and ignition, the ignited neurons perform the same operation to capture the neighborhood other neurons. the lager the βof the simplified model, the wider the area range that the neurons captured, the stronger the ability to detect noise, but this is at the expense of image detail and edge information. When the neurons (i, j) igniting, if most of the neurons in its neighborhood has advance ignited, this indicates that the firing of neurons is not caused by captured, thus it is defined as the noise pixel. There is a certain correlation between the image brightness of a certain pixel and its neighboring pixels. The pixel brightness values contaminated by noise has a poor relation with its surroundings, also because there are significant differences between impulse noise point and its surrounding pixel gray, and the impulse noise points mainly include bright and dark pixels, based on the nature of PCNN synchronous excitation generating pulse, the neurons that the noise points correspond are the first or the last ignite, so it can quickly determine the location of noise points. When the detected image with noise were input PCNN network, according to the nature which the similar brightness neurons sync firing and pulse capturing. Setting the appropriate threshold, the noise pixels and the image pixel will ignite at the different times, so it can accurately distinguish the noise pixels and the image pixel. According to the results of the noise pixel detection, the gray value of image pixel remains the same before and after filtering, but the gray value of the noise pixel equal to the median value of all the pixel gray values which the noise pixel as the center of the neighborhood window. The median filtering and other filtering methods were alone adopted in the detected noise point, while the non-noise points without being processed and output directly.

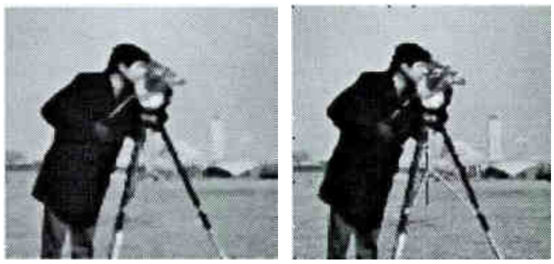
IV. EXPERIMENTAL ANALYSIS

In this study, the Xilinx Spartan-3E development board were adopted, completed the design and implementation of the entire experiment by the XC3S250E chip. By using Matlab software to read 256 ×256 gray-scale images, and add different intensity impulse noise to the image. To compare with the two methods, first, through PCNN detect the noise, then using the median algorithm filtering the image. The second is the direct use of median filtering algorithm for image. The image data is downloaded to the FPGA[11][12] development board for processing, and then the filter results are exported to a computer, so as to compare and validate the filtering effect. Among them, the filter window was adopted in the text and median filtering method is the same size. the parameter is: N=10,β=0.01.The filtering performance were described by the normalized mean square error (MSE).

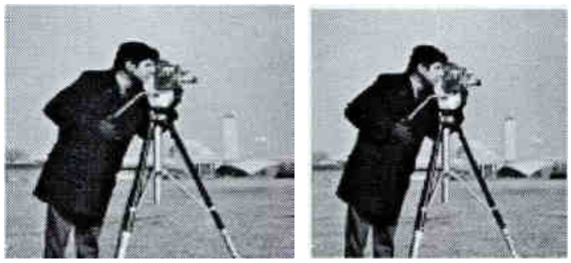
(1) Original image



(2) Image processing with noise



(3) Filtering results based on the median algorithm



(4) Filtering results based on the proposed method

Fig. 2. Comparison of filtering by the proposed and existing methods

Table 1. Comparison of common image filtering algorithm NMSE (×10-3)

Filtering method	Noise intensity					
	0.1	0.2	0.3	0.4	0.6	0.7
Median filter	3.8	10.7	15.6	19.2	71.3	107.6
Extreme median filter	0.43	0.99	3.3	10.1	17.3	23.9
The proposed method	1.9	2.5	5.6	9.5	15.9	19.8

From the photos and the table above, we can conclude that using the method of combining PCNN and median filtering for image processing has more obvious filtering advantages in this paper. It not only can protect the image detail better, and also can effectively filter noise. In the case of increasing noise intensity, the filtering performance of median filtering and extreme median filtering is poor. The method described has a better de-noising performance in a variety of noise intensity in this paper.

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V. CONCLUSION

For the impulse noise characteristics, the method was proposed that the use of PCNN ignition matrix for detecting and locating the noise pixel, and then take the median filter. This algorithm can effectively filter noise and protect the image without distortion, leaving the overall image details. And when the intensity of the noise is larger, the performance is also very clear. At present, the domestic and international research shows that, PCNN in image processing has a distinct advantage because of its biological background. However, due to the complexity of PCNN model. In the future it is need to strengthen the theoretical study of PCNN and the combination with other methods to expand the scope of application, and design the PCNN image noise filter based on FPGA in the context of this paper.

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Prof. Zhenyu Han, male; Professor. He is doing research work in Zhengzhou University of Light Industry, China. His main research interests include pattern recognition, computer theory, and software engineering.

Dr. QingE Wu, female, associate Professor, Ph.D. Her main research interests include image processing, pattern recognition, computer theory and intelligent control.

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