2020 RISP International Workshop on Nonlinear Circuits,
Communications and Signal Processing (NCSP 2020)
Honolulu, Hawaii, USA, February 28 - March 2, 2020

Edge Detection and Noise Removal in Cellular Neural Networks Using Switching Two-Type Templates

Sosuke Nakano, Kodai Kitamura, Yoko Uwate and Yoshifumi Nishio

Department of Electrical and Electronic Engineering, Tokushima University
2-1 Minami-Josanjima, Tokushima 770–8506, Japan
E-mail: {nakano, kitamura, uwate, nishio}@ee.tokushima-u.ac.jp

Abstract

In 1998, Cellular Neural Networks (CNN) were developed by Chua and Yang. The main characteristics of the CNN are the local connection and the parallel signal processing. The CNN consists of cells connected each other. The performance of the CNN depends on the parameters which is called the template. When the template has a good influence for processing, the CNN can perform complex processing. In this study, we propose Switching Two-Type Templates CNN. In our proposed method, Edge Detector template and Proposed template with reference to Small Object Remover template are switched according to the output values around a cell in processing. Then edge detection and noise removal template process from a certain number of calculation. We investigate the performance of our proposed method by some simulations.

1. INTRODUCTION

Recently, many information have been existed in our life. Therefore, processing method is demanding the performance of parallel signal and high speed processing of large amount of data. In general, digital circuits are used for information processing. However, digital circuits cannot process many information in real time. Therefore, in order to conduct parallel signal and flexible processing like human, Neural Networks were proposed. The Neural Networks was based on the human's nervous system. Then, Cellular Neural Networks (CNN) was introduced by L. O. Chua and L. Yang in 1988 [1]. The idea of CNN was inspired from the architecture of the cellular automata and Neural Network. Differences between the conventional neural network and CNN are local connectivity property and high speed parallel processing. Moreover, CNN resembles the structure of the retina. CNN has been successfully used for various high-speed parallel signal processing applications such as image processing, pattern recognition and so on [2]. CNN is composed of the basic analog circuit unit called cell. Each cell is connected to its neighboring cells, according to the parameter called the template. Each cell is influenced from its neighboring cells and its value is updated by the template. The performance of CNN depends on the template. Thus, various applications for image processing and pattern recognition of CNN have been reported [3]- [6].

In this study, we propose switching two-type templates CNN. In our proposed method, Edge Detector template and Proposed template similar to Small Object Remover template are switched. We investigate this method in edge detection and noise removal. In CNN processing, Edge Detector template and Small Object Remover template have merit and demerit. Processing with Edge Detector template can detect edge lines but noise remains. On the other hand, processing with Small Object Remover template can remove noise but cannot detect edge lines. In order to confirm the effectiveness of our proposed method, we perform edge detection and noise removal with our proposed method.

2. CELLULAR NEURAL NETWORKS

In this section, we explain the structure and processing flow of CNN. Basic unit circuit of CNN is called cell. The cell consists of linear capacitors, linear resistors, linear and nonlinear controlled sources. The CNN contains an array in a reticular pattern of many cells. We show a two dimensional array composed of $M \times N$ identical cells arranged in M rows and N columes. Figure 1 shows the circuit of cell. The array of the CNN is shown in Fig. 2.

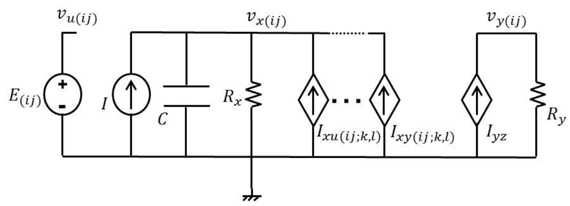


Figure 1: The circuit of cell.

A cell is coupled with only adjacent cells. Adjacent cells interact with one another. Cells which do not couple with

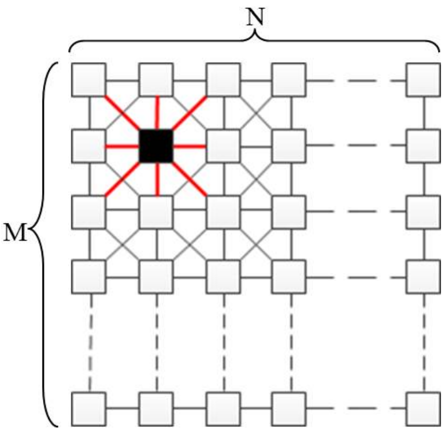


Figure 2: The structure of CNN.

only adjacent cells have an indirect influence. The range which some cells have influenced one cell is defined by neighborhood. We describe state equation of cell and output equation of cell below.

State Equation :

$$\frac{dv_{x(ij)}}{dt} = -v_{x(ij)} + \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} A_{(i,j;k,l)} v_{y(kl)}(t) + \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} B_{(i,j;k,l)} v_{u(kl)}(t) + T. \quad (1)$$

Output Equation :

$$v_{y(ij)}(t) = \frac{1}{2}(|v_{x(ij)}(t) + 1| - |v_{x(ij)}(t) - 1|). \quad (2)$$

v_x, v_y and v_u are state value, output value and input value. Output equation represents piece-wise nonlinear function is shows in Fig 3.

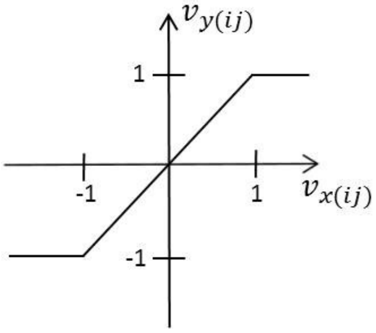
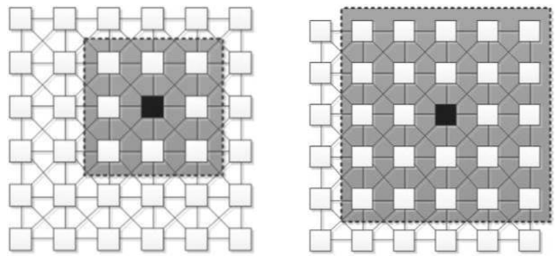


Figure 3: Piece-wise nonlinear function.

In Eq (1), A is feedback template, B is feedforward template, T is threshold. These value determine performance of CNN.



(a)3×3 (b)5×5

Figure 4: System of neighborhood.

When we process the image with CNN, we should determine the size of system of neighborhood. When this size is big, the amount of information in system of neighborhood is increasing. However, noise works easily. Figure 4 shows the size of system of neighborhood, 3×3, and 5×5. Generally, the size which is used for image processing is 3×3. In this study, we use 3×3. Figure 5 shows block diagram of image processing with CNN.

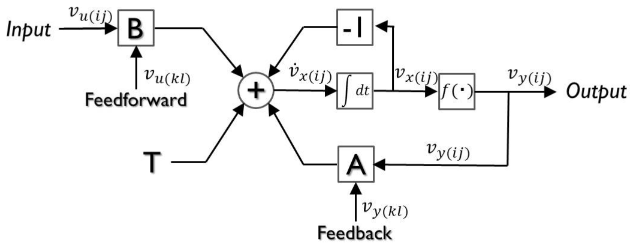


Figure 5: Block diagram.

3. PROPOSED METHOD

Our proposed method is switching two-type templates CNN. First, we calculate the state value of the all cells in the output image. Second, we calculate the output value of the center cell y_{ij} and the output value of the cells around it y_{kl}. Third, we calculate the difference value $|y_{ij} - y_{kl}|$ in 5×5 neighborhood. Fourth, compare the difference value with the threshold and increase the count. Then switch Edge Detector template and proposed template according to the count. Last, process y_{ij} using the chosen template. This process is conducted in all cells every number of calculation n. Switching condition depends on the difference value between the output value of the center cell and the output value of the cells around it y_{ij} and y_{kl} of each 5×5 neighborhood and is given as follows:

$$|y_{ij} - y_{kl}| > a. \quad (3)$$

$$b \leq count < c. \quad (4)$$

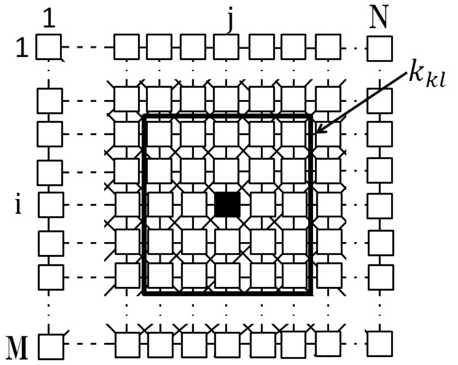


Figure 6: Process of calculation.

We fix certain threshold a, b and c. Equation (3) is used to determine the color difference between y_{ij} and y_{kl}. Equation (4) is used to determine whether y_{ij} is noise, edge, or other. When the inequality of Eq. (3) is satisfied, the difference value $|y_{ij} - y_{kl}|$ become more than a, we increase the count by one. When the inequality of Eq. (4) is satisfied, the count become b or more and less than c, process y_{ij} using Edge Detection template. Otherwise, process y_{ij} using the proposed template. This switching process is conducted in all cells every certain number of calculation n. In this study, the number of calculations is defined 50000 in this simulation. Switching process with our proposed method is conducted in all cells every number of calculation 10 until the number of calculation 25000. Then proposed template processes until the number of calculation 50000.

4. SIMULATION RESULTS

In this section, we show simulation results of the edge detection and noise removal for using our proposed method and the conventional CNN. The proposed template is modified to reduce the amount of noise removed than Small Object Remover template. Using Edge Detection template, Small Object Remover template and proposed template of the edge detection and noise removal is described as follows.

Edge Detection template :

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}, I = -1. \quad (5)$$

Small Object Remover template :

$$A = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix},$$

$$B = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I = 0. \quad (6)$$

Proposed template:

$$A = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix},$$

$$B = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 6 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I = 0. \quad (7)$$

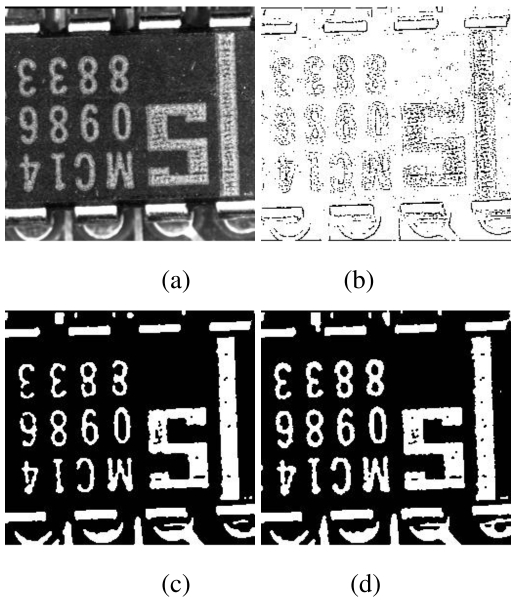


Figure 7: Simulation results 1. (a) Input image. (b) Simulation result of using Edge Detector template (c) Simulation result of using Small Object Remover template. (d) Simulation result of using the proposed method (a = 0.32, b = 6, c = 17, n = 50000).

In one instance, Fig. 7 shows images which are processed with CNN. Figure 7(a) shows an input image. The input image has the indistinct portions and noise. Indistinct portions are the vertical line on the right-side, numbers and letters. Noise are inside them. Figure 7(b) shows the simulation result of using Edge Detector template. Figure 7(b) shows to detect edge lines of rectangle positioned up and down. However, noise remains inside numbers and letters. Figure 7(c) shows the simulation result of using Small Object Remover template. Figure 7(c) shows to remove noise inside numbers and letters. However, edge line of numbers and letters

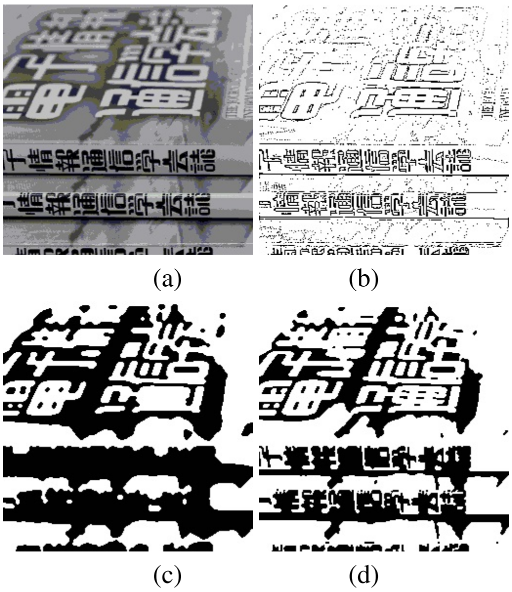


Figure 8: Simulation results 2. (a) Input image. (b) Simulation result of using the Edge Detector template (c) Simulation result of using the Small Object Remover template. (d) Simulation result of using the proposed method (a = 0.32, b = 6, c = 17, n = 50000).

is indistinct and some noise remains inside big letter. Figure 7(d) shows the simulation result of the proposed method. Figure 7(d) shows to remove noise the vertical line, numbers and letters compared to Fig 1(b). In addition, Fig 7(d) shows to detect edge lines of indistinct portions of numbers compared to Fig. 1(c). Still, some noise remains inside big letter.

We process another image for edge detection and noise removal with our proposed method. Figure 8(a) shows an input image. The input image has indistinct portions and noise. Indistinct portion is back side letters on book cover. Noise is inside letters. Figure 8(b) shows the simulation result of using Edge Detector template. Figure 8(b) shows to detect edge lines of front letters in book cover. However, on distinct points remains in the back side letters on book cover. Figure 8(c) shows the simulation result of using Small Object Remover template. Figure 8(c) shows to remove noise inside letters on book cover. However, the letters are crushed on book cover. Figure 8(d) shows the simulation result of the proposed method. Figure 8(d) shows to detect edge lines of indistinct portions and to remove noise on book cover letters compared to Fig. 8(b) and Fig. 8(c). However, the backside letters are crushed on book cover. From the simulation results, our proposed method is more effective than the conventional CNN in edge detection and noise removal.

5. CONCLUSION

In this study, we proposed new method of switching two-type templates by the magnitude of difference values in cells and the certain number of calculation n for CNN. In order to confirm the effectiveness of our proposed method, we applied our proposed method to edge detection and noise removal. As a result, our proposed method is more effective than the conventional CNN in edge detection and noise removal. In future work, we will confirm that the proposed method is effective for noise removal. In addition, we will confirm switching three-type templates.

References

[1] L. O. Chua and L. Yang, "Cellular Neural Networks Theory." IEEE Trans. Circuits Syst., vol. 35, pp. 1257-1272, 1988.

[2] Z. H. Yang, Y. Nishio and A. Ushida,"Image processing of twolayer CNNs applications and stability," IEICE Trans. Fundamentals, vol. E85-A, no. 9, pp. 2052-2060, 2002.

[3] M. Hänggi and G. S. Moschytz, "Cellular Neural Networks Analysis, Design and Optimization." Kluwer Academic Publishers Norwell, 2000.

[4] F. Dirk and T. Ronald, "Coding of Binary Image Data using Cellular Neural Networks and Iterative Annealing," Proc. of ECCTD'03, vol. 1, pp. 229-232, Sep. 2003.

[5] Z. H. Yang, Y. Nishio and A. Ushida,"Image processing of twolayer CNNs applications and stability," IEICE Trans. Fundamentals, vol. E85-A, no. 9, pp. 2052-2060, 2002.

[6] T. Kozek, K. R. Crounse, T. Roska and L. O. Chua, "Smart Image Scanning Algorithms for the CNN Universal Machine," Proc. of NOLTA95, vol. 2, pp. 707-712, 1995.

[7] T. Ando, Y. Uwate and Y. Nishio "Cellular Neural Networks with Switching Two-Type Templates for Image Peocessing." TJCAS. Aug. 2016.