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Cellular Neural Networks with Switching Three Templates for Image Processing

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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 three templates CNN. In the proposed method, 3×3 template, 5×5 template and noise removal template are switched according to the output values around a cell in processing. We investigate the performance of the proposed method by some simulations.

1. INTRODUCTION

Recently, many information have been existed in our life. In general, digital circuits are used for information processing. However, digital circuits cannot process many information in real time. Therefore, Neural Networks were proposed. The Neural Networks was based on the human's nervous system. The Cellular Neural Networks (CNN) is introduced by replacing neuron with cell. Hence, the CNN has been successfully used for various high-speed parallel signals processing applications such as image processing, pattern recognition and so on [1]. The CNN was paired Neural Networks with the Cellular Automata by L.O.Chua in 1998 [2]. The CNN consists of cells connected each other and the structure of CNN resembles the structure of the animal's retina [3]. Thus the CNN has been suitable for various image processing. The performance of CNN depends on the parameters which is called the template. The template represents strength of connection between cells. If the template influences exactly, CNN can perform complex processing. Additionally, various applications for image processing and pattern recognition of CNN have been reported.

In previous study, we have proposed the method of switching two-type templates CNN [4]. Two-type templates are 3×3 template and 5×5 template. In CNN processing, 3×3 template and 5×5 template have merit and demerit. Processing with 3×3 template is quick but the delicate process is difficult. On the other hand, processing with 5×5 template is brady and easy to receive noise effect but the delicate process is possible. In simulation results with switching two-type templates, noise effect was observed.

In this study, we propose switching three templates CNN. In the proposed method, noise removal template is added to the previous method. In order to confirm the effectiveness of the proposed method, we perform edge detection.

2. CELLULAR NEURAL NETWORKS [2]

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 element and nonlinear element. The CNN contains an array in a reticular pattern of many cells. We show a two dimensional array composed of M × N identical cells arranged in M rows and N columes. The array of the CNN is shown in Fig. 1. Figure 2 shows the circuit of cell.

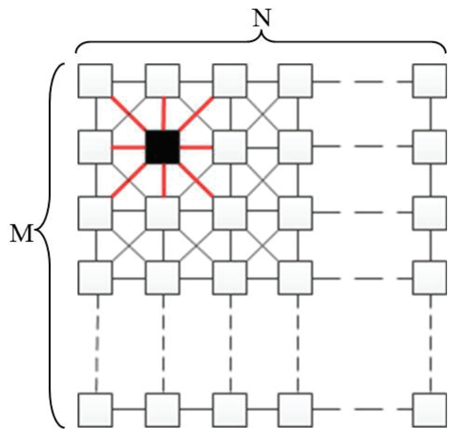


Figure 1: The structure of CNN.

A cell couples with only adjacent cells. Adjacent cells interact with one another. Cells which don't couple with only adjacent cells have an indirect influence. The range which

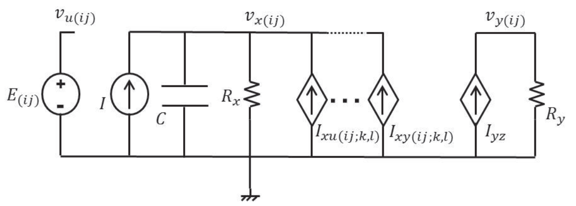


Figure 2: The circuit of cell.

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. State equation is solved by Runge-Kutta method (step size h = 0.005). Output equation represents piece-wise nonlinear function Fig 3.

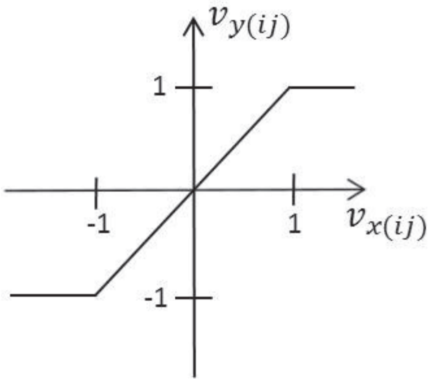
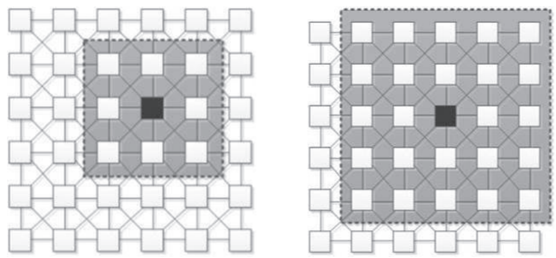


Figure 3: Piece-wise nonlinear function.

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

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. Generally, the size which is used for image processing is 3×3. In this study, we use 3×3 and 5×5 in combination. Figure 5 shows block diagram of image processing with CNN.



(a)3×3 (b)5×5

Figure 4: System of neighborhood.

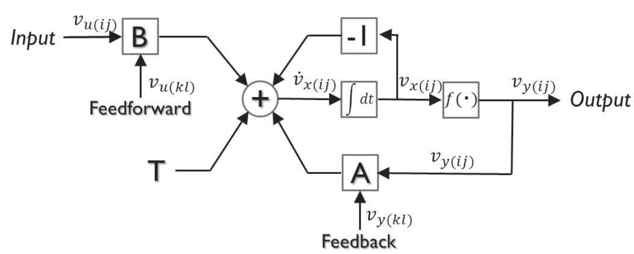


Figure 5: Block diagram.

3. PREVIOUS METHOD [4]

In this section, we show the previous method. The previous method is switching two-type templates CNN. Two-type templates are 3×3 and 5×5 templates. Switching templates is conducted in the way hereinafter prescribed First, we calculate cell's output value. Second, we calculate cell's maximum output value v_{ymax} and minimum output value v_{ymin} in 5×5 neighborhood. Third, we calculate the difference value $|v_{ymax} - v_{ymin}|$. Figure 6 shows this process which calculates the difference value $|v_{ymax} - v_{ymin}|$. In the end, 3×3 and 5×5 templates are switched according to the output values around cells in processing. This process is conducted for all cells every number of calculation 10. Switching condition depends on the difference value between the maximum and minimum output values v_{ymax} and v_{ymin} of each 5×5 neighborhood and is given as follows :

$$\begin{cases} |v_{ymax} - v_{ymin}| \le a \\ |v_{ymax} - v_{ymin}| > a. \end{cases} \quad (3)$$

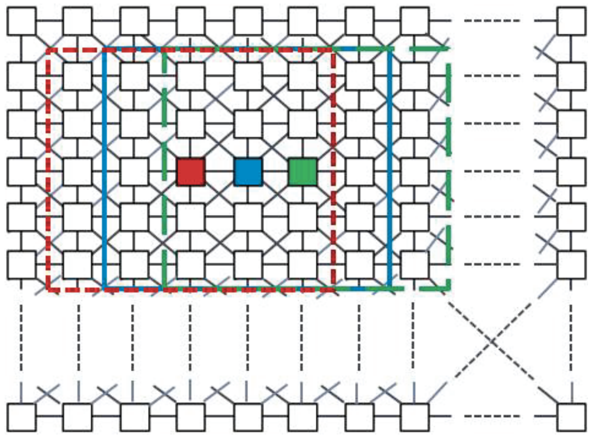


Figure 6: Process of calculation $|v_{ymax} - v_{ymin}|$.

We fix a certain value a as threshold about switching template. When the top inequality of (3) is satisfied, 3×3 template is used. In the other case, 5×5 template is used.

4. PROPOSED METHOD

In this section, we show the proposed method. In the proposed method, noise removal template is added to the previous method. Switching condition is given as follows.

$$\begin{cases} |v_{ymax} - v_{ymin}| > a \\ b \le |v_{ymax} - v_{ymin}| \le a \\ |v_{ymax} - v_{ymin}| < b. \end{cases} \quad (4)$$

When the top inequality of (4) is satisfied, 5×5 template is used. When the middle inequality of (4) is satisfied, 3×3 template is used. When the bottom inequality of (4) is satisfied, noise removal template is used. For all cells, this switching process is conducted every 10 repetition of the Runge-Kutta method.

5. SIMULATION RESULTS

In this section, we show simulation results of the edge detection by using the proposed method and threshold value a is defined to obtain results which can be observed edge line and noise effect. We show two examples. Using templates of the edge detection and noise removal are described as follows.

Edge detection template :

3×3 *template* :

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

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

5×5 *template* :

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

$$B = \begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & 0 & 0 & 0 & -1 \\ -1 & 0 & 16 & 0 & -1 \\ -1 & 0 & 0 & 0 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix}, T = -1. \quad (6)$$

Noise removal template:

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix},$$

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

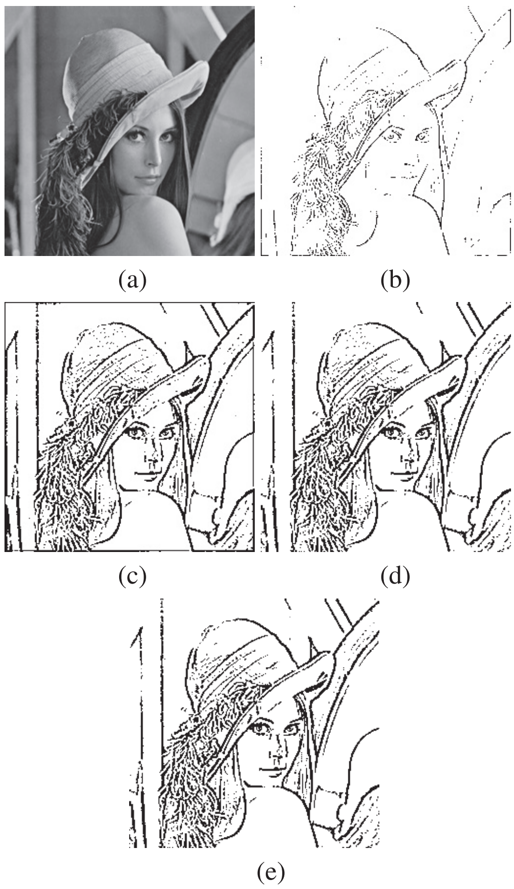


Figure 7: Simulation results 1. (a) Input image. (b) Simulation result of the 3×3 CNN. (c) Simulation result of the 5×5 CNN. (d) Switching two-type (3×3 and 5×5) templates CNN (a = 0.6). (e) The proposed method (a = 0.6, b = 0.5).

In one example, Fig. 7 shows images which are processed with CNN. Figure 7(a) shows an input image. The input image has the indistinct portions. Indistinct portions are the pillar of the left-side and an outline of a woman's face. Figure 7(b) shows the simulation result of the 3×3 CNN. The 3×3 CNN cannot detect edge lines of indistinct portions. Figure 7(c) shows the simulation result of the 5×5 CNN. The 5×5 CNN can detect edge lines of indistinct portions, however output image receives the noise effect. Figure 7(d) shows the simulation result of switching two-type templates CNN (a = 0.6). Switching two-type templates CNN can detect edge lines of indistinct portions and receive less noise effect compared to Fig. 7(c). Figure 7(e) shows the simulation result of switching three templates CNN (a = 0.6, b = 0.5). In Fig. 7(e), dots which are caused by noise effect are rarely found, especially woman's hat compared to Fig. 7(d).

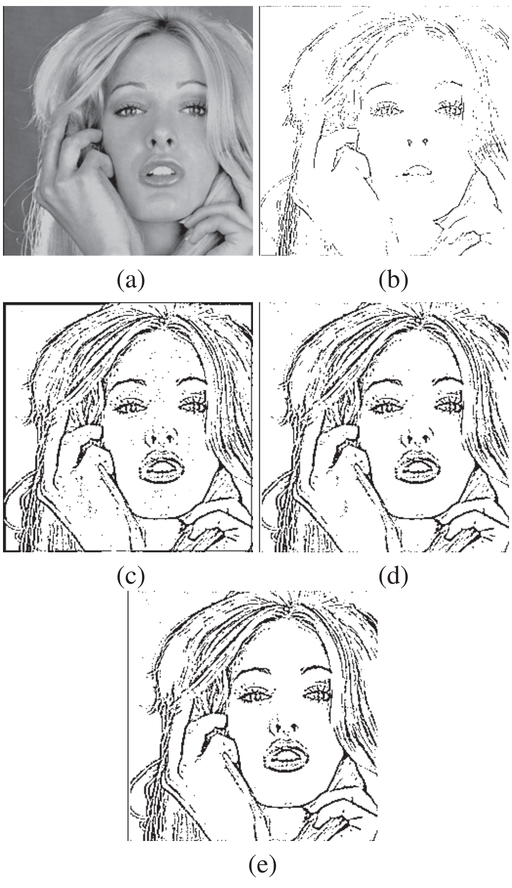


Figure 8: Simulation results 2. (a) Input image. (b) Simulation result of the 3×3 CNN. (c) Simulation result of the 5×5 CNN. (d) Switching two-type ($3{\times}3$ and $5{\times}5$) templates CNN (a = 0.6). (e) The proposed method (a = 0.6, b = 0.4).

We process another image for edge detection with the proposed method. Figure 8(a) shows an input image. The input image is woman's face. Figure 8(b) shows the simulation result of the 3×3 CNN. The 3×3 CNN cannot detect edge lines of woman's face. Figure 8(c) shows the simulation result of the 5×5 CNN. The 5×5 CNN can detect edge lines of woman's face, however output image receives the noise effect. Figure 8(d) shows the simulation result of switching two-type templates CNN (a = 0.6). In Fig. 8(d), switcing two-type templates CNN can detect edge lines of woman's face and receive less noise effect compared to Fig. 8(c). Figure 8(e) shows the simulation result of switching three templates CNN (a = 0.6, b = 0.4). In Fig. 8(e), dots which are caused by noise effect are rarely found compared to Fig. 8(d). From the simulation results, the proposed method is more effective than the conventional CNN and the previous method.

6. CONCLUSION

In this study, we proposed a new method of switching three templates CNN. Three templates are $3{\times}3$ template, $5{\times}5$ template and noise removal template. $3{\times}3$ template, $5{\times}5$ template noise removal template are switched by the threshold a and b. In order to confirm the effectiveness of the proposed method, we tried the proposed method as a method of edge detection. In output image, the proposed method has detected edge of indistinct portions in the input image. Moreover, noise removal effect can be observed compared to the conventional CNN. As a result, the proposed method is more effective than the conventional CNN and the previous method in edge detection.

Acknowledgment

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