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Cellular Neural Networks with Changing Templates for Edge Detection and Half-Toning

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Abstract

In 1998, Cellular Neural Networks (CNN) were introduced. The performance of the CNN depends on the parameters called the template. If the template is influenced by the spacially and the temporally variation, CNN can perform complex processing. In this study, we propose a new method of changing templates. We apply the pseudoramdom numbers to template, the template is changed spacially and temporally. We investigate the performance of the proposed method by some simulations.

1. Introduction

In recent years, many information has been increasing. Generally, the von Neumann machine is used for many information processing. However, the von Neumann machine cannot process information at a time. The Neural Networks were proposed to solve this problem. This idea was based on the human's nervous system. The Neural Network is used in every direction, such as an associative memory, pattern recognized, and so on. In 1998, the idea of CNN (Cellular Neural Networks) was inspired from the architecture of the Neural Networks and the Cellular Automata by L. O. Chua and L.Yang. [1]. The structure of CNN resembles the structure of animal retina. Therefore, CNN has been suitable for various image processing. The performance of CNN depends on the parameters called the template. [2]- [5] The template has a feature that is not influenced by the spatially and temporally variation. This feature causes that CNN cannot complex processing. If the template is influenced by the spacially and the temporally variation, CNN can perform complex processing.

In this study, we propose a new method of changing template of the CNN. We apply the pseudoramdom numbers to templates in our method. We fix the range of the pseudorandom numbers and every constant additional number of times. In order to confirm the effectiveness of the proposed method, we perform some simulations in image processing by using the proposed method. We compare our method with the conventional method for edge detection and half-toning.

2. Cellular Neural Networks

A basic unit circuit of CNN is called a cell. The cell contains linear elements and nonlinear elements. CNN is formed from 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.

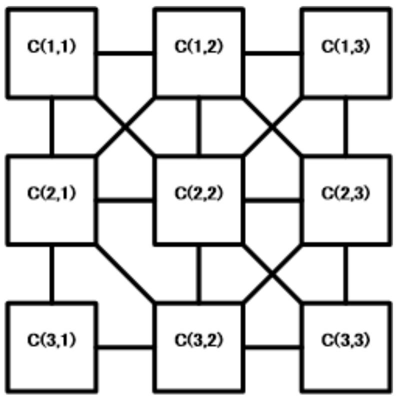

Figure 1: Structure of CNN (3 × 3).

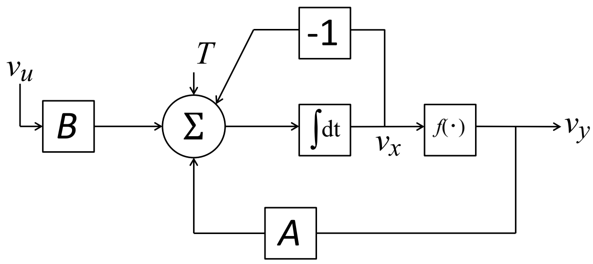

Figure 2: Block diagram of the conventional CNN.

A cell couples with only adjacent cells. Adjacent cells interact with one another. One cell receives information from adjacent cells and indirect cells. The neighborhood determines the range, which one cell receives information. We describe a state equation of the cell and an output equation of the cell below.

State Equation :

$$\frac{dv_{xij}}{dt} = -v_{xij} + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} A_{(i,j;k,l)}v_{ykl}(t) + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} B_{(i,j;k,l)}v_{ukl}(t) + T. \quad (1)$$

Output Equation :

$$vyij(t) = \frac{1}{2}(|v_{xij}(t)+1| - |v_{xij}(t)-1|). \quad (2)$$

v_x, v_y and v_u are the state value, the output value and the input value. In Eq (1), A is a feedback template, B is a feedforward template, T is a threshold. These values determine the performance of CNN.

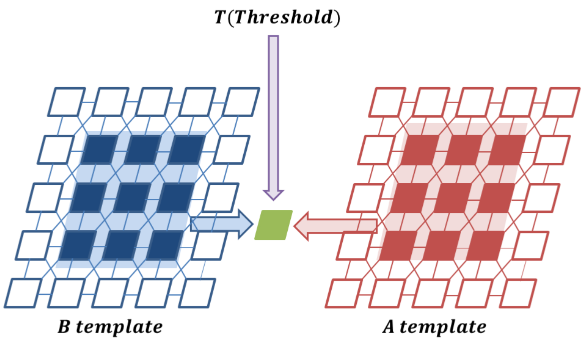

Figure 3: Strucure of CNN.

The template has a feature that the spatial and the temporal influence cannot effect the template. Therefore, the template cannot perform complex processing. The template can perform complex processing in the adverse feature. We focus on that feature.

3. Proposed Method

In this section, we explain CNN with changing templates. The pseudorandom number is added to templates every the constant number of times for changing templates. The range and the adding number of times differ the kind of image processing. The example of the proposed method templates shows Eq. (3),

The example of the proposed method templates :

$$A = \begin{bmatrix} a_{11}+\alpha_{11} & a_{12}+\alpha_{12} & a_{13}+\alpha_{13} \\ a_{21}+\alpha_{21} & a_{22}+\alpha_{22} & a_{2n}+\alpha_{23} \\ a_{31}+\alpha_{31} & a_{32}+\alpha_{32} & a_{33}+\alpha_{33} \end{bmatrix}$$

$$B = \begin{bmatrix} b_{11}+\beta_{11} & b_{12}+\beta_{12} & b_{13}+\beta_{13} \\ b_{21}+\beta_{21} & b_{22}+\beta_{22} & b_{23}+\beta_{23} \\ b_{31}+\beta_{31} & b_{32}+\beta_{32} & b_{33}+\beta_{33} \end{bmatrix} \quad (3)$$

α_{mn} and β_{mn} are pseudorandom numbers. T_p is every the constant number of times. There are some problems to fix the range and the constant number of times.

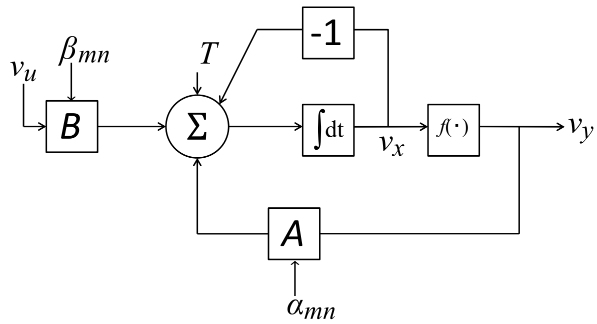

Figure 4: Block diagram of the proposed method.

4. Simulation Results

4.1 Edge Detection

In this section, we show simulation results of the edge detection by using our proposed method. Using templates of the edge detection is described as follows.

Edge detection template :

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

$$B = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}, T = -1. \quad (4)$$

Edge detection template of the proposed method :

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

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

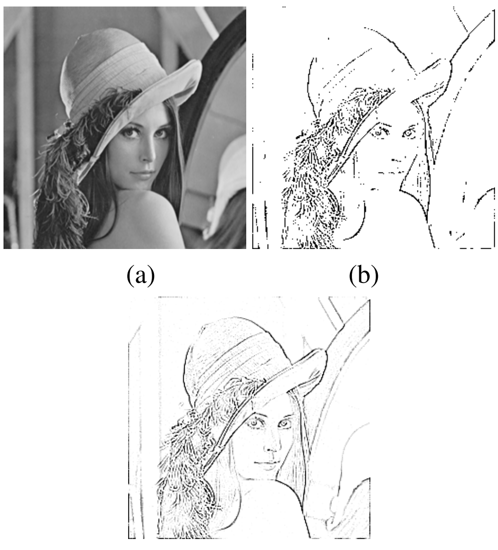

Figure 5: Simulation results. (a) Input image. (b) Simulation result of the conventional CNN. (c) Simulation result of the proposed method (T_α = 1, -0.2 $\leq \alpha \leq 0$, T_β = 5, $0 \leq \beta \leq 0.1$.).

Figure 5(a) is an input image. The input image has indistinct portions. Indistinct portions are the pillar of the left-side and an outline of a woman's face. Figure 5(b) shows the simulation result of the conventional CNN. The conventional CNN can not detect edge lines of indistinct portions. Figure 5(c) shows the simulation result of the proposed method. In Fig. 5(c), the proposed method can detect edge lines of indistinct portions.

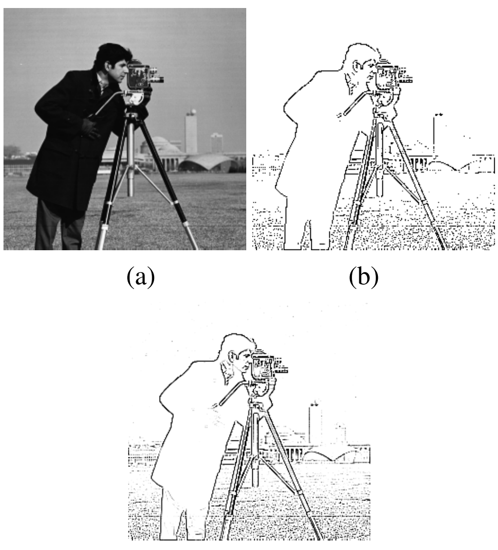

Figure 6: Simulation results. (a) Input image. (b) Simulation result of the conventional CNN. (c) Simulation result of the proposed method (T_α = 1, -0.16 $\leq \alpha \leq 0$, T_β = 5, $0 \leq \beta \leq 0.1$).

Figure 6(a) is an input image. To detect buildings in the lower right of the image is difficult for the conventional method of CNN. In the Fig 6(b) cannot detect buildings by the conventional method of CNN. However, the proposed method of CNN can detect buildings in the Fig 6(c).

4.2 Half-toning

In this section, we show simulation results of the half-toning by using our proposed method. Using templates of the half-toning is described as follows. ($0 \leq \xi \leq 1$)

Half-Toning template :

$$
\begin{aligned}
A &= \begin{bmatrix} -0.07 & -0.1 & -0.07 \\ -0.1 & 1+\xi & -0.1 \\ -0.07 & -0.1 & -0.07 \end{bmatrix}, \\
B &= \begin{bmatrix} 0.07 & 0.1 & 0.07 \\ 0.1 & 0.32 & 0.1 \\ 0.07 & 0.1 & 0.07 \end{bmatrix}, \ T = 0.
\end{aligned} \tag{6}
$$

Half-Toning template of the proposed method :

$$
\begin{aligned}
A &= \begin{bmatrix} -0.07 & -0.1 & -0.07 \\ -0.1 & 2+\alpha & -0.1 \\ -0.07 & -0.1 & -0.07 \end{bmatrix}, \\
B &= \begin{bmatrix} 0.07+\beta & 0.1+\beta & 0.07+\beta \\ 0.1+\beta & 0.32+\beta & 0.1+\beta \\ 0.07+\beta & 0.1+\beta & 0.07+\beta \end{bmatrix}, \ T = 0
\end{aligned} \tag{7}
$$

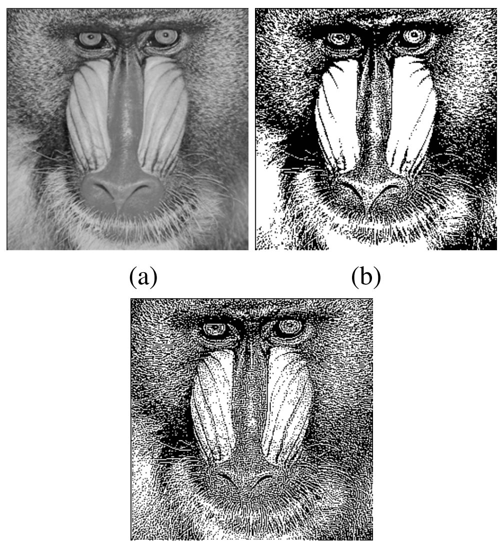

Figure 7: Simulation results. (a) Input image. (b) Simulation result of the conventional CNN. (c) Simulation result of the proposed method (T_α = 4, -1.0 $\leq \alpha \leq 0$, T_β = 4, -0.01 $\leq \beta \leq 0$).

Figure 7(a), around of the eyebrow and the whisker are difficult to express the continuous tone imagery through the use of dots by the proposed method of CNN. The proposed method of CNN cannot express shades of color in the Fig 7(b). However, Fig 7(c) can express clearly shades of color by the proposed method of CNN.

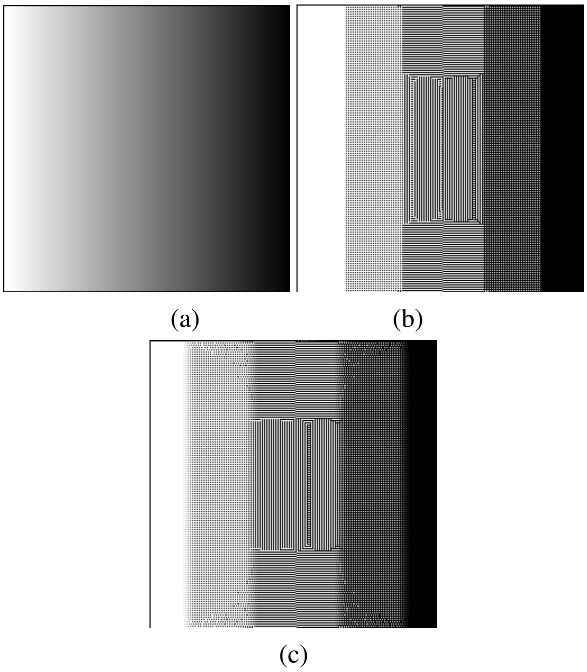

Figure 8: Simulation results. (a) Input image. (b) Simulation result of the conventional CNN. (c) Simulation result of the proposed method (T_α = 3, -0.7 $\leq \alpha \leq$ 0, T_β = 3, -0.06 $\leq \beta \leq$ 0).

Figure 8(a) is a specialty image, which gray scale is expressed clearly in one image. Therefore, we can evaluate whether to express clearly shading of color or not. The conventional method of CNN can express white zone and black zone widely in the Fig 8(b). In the Fig 8(c), white zone and black zone are expressed narrow by the proposed method. From those results, the proposed CNN is more effective than the conventional method of CNN in edge detection and half-toning.

5. Conclusion

The template is the most important for the CNN. If the template is influenced by the spacially and the temporally variation, CNN can perform complex processing. Therefore, we focus on template to improve CNN. In this study, we have proposed the new method of changing templates. We applied the pseudoramdom numbers to templates in our method. In order to confirm the effectiveness of the proposed method, we investigated the proposed method in image processing. We performed the edge detection and the half-toning. From the results of the edge detection, our method can detect many indistinct portions. Our method can express shades of color from the results of the half-toning. Hence, the proposed method is more effective than the conventional CNN in image processing.

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