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Combination of Two Neurons for a Cell in Cellular Neural Networks

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Abstract

In this paper, we propose a new structure of the Cellular Neural Networks (CNN) which combines two kinds of neurons for one cell. The proposed structure is inspired from the two-layer CNN. Compared with the two-layer CNN, the data from each neuron are sent using templates A_1 and B_2. We apply this structure to image processing of gray scale image and binary image. From two examples in simulation, we confirm that the proposed structure has a great potential in image processing.

1. Introduction

Cellular Neural networks (CNN) were introduced by Chua and Yang in 1988 [1]. The idea of the CNN was inspired from the architecture of cellular automata and neural networks. Unlike the conventional neural networks, the CNN has local connectivity property and since the structure of CNN resembles the structure of animals' retina, they have been successfully developed in various image processing applications [2][3]. Wiring weights of the cells are established by parameters called a template. The template is used to decide the performance of CNN. A template has its own characteristic and the values do not change during the processing.

In previous studies of CNN, single-layer and two-layer CNNs have been introduced with many kinds of templates. In single-layer CNN, one set of templates are used. For using two or more templates, a lot of processing is necessary and implementation becomes difficult. For high performance processing, two-layer CNN has been proposed. The two-layer CNN is a combination of two sets of single-layer CNNs and the data from both layers are connected by coupling templates C. In this study we are not using parameter "template C" to carry the data between both layers. As a new approach, we propose a combination of two neurons for one cell in CNN. The proposed method is inspired from the two-layer CNN. In the propose method, two templates are used simultaneously. In order to investigate the process, we apply the method to gray scale image and binary image. For the simulation, we used two sets of different templates. Also, we consider that it is important to investigate the behavior of this new type of CNN and the characteristic of image processings achieved by the new architecture which transfers the data to the other layer directly.

The rest of this paper is structured as follows. In Sec.2, we describe about the basic CNN models which are single-layer and two-layer. In Sec.3, we explain the proposed method. In Sec.4, we show some examples of simulation results from the combination of two kinds of templates. Finally in Sec.5, we conclude the paper.

2. Cellular Neural Networks

In this section, we explain about the structure of single-layer CNN and two-layer CNN.

2.1. Single-layer CNN

The basic circuit unit in the CNN is called a cell. It contains linear and nonlinear circuit elements such capacitors, resistors, linear and nonlinear controlled sources. The circuit size in the CNN is consider as $M \times N$ cells that arranged in M rows and N columns. Each cell in the CNN only takes interaction communication with the cell in neighborhood. The values of each cell change according to the neighbor cells. In the CNN, output value also depends on parameters called a template. The CNN contains with three templates which are feedback template A, control template B and constant bias I. The state equation and the output equation in the single-layer CNN are described as follows.

State Equation :

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

Output Equation :

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

2.2. Two-layer CNN

In previous studies, the two-layer CNN has been introduced. The two-layer CNN has been confirmed to have more efficient structure for image processing [4]. The two-layer CNN is a combination of two sets of the single-layer CNNs. The different point from the single-layer CNN is that the two-layer CNN has coupling templates C_{12} and C_{21}. The templates are used to connect and transfer the data between first and second layers. The block diagram of the two-layer CNN is shown in Fig. 1.

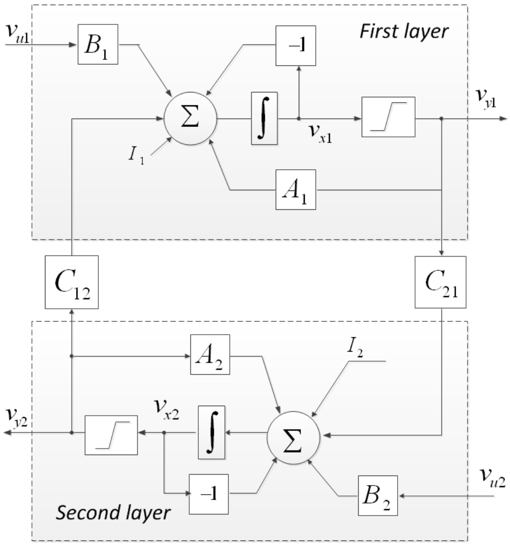


Figure 1: Block diagram of the two-layer CNN.

The state equations and the output equations for the two-layer CNN are given as follows.
State equation :

$$\begin{aligned}\frac{dv_{x1ij}}{dt} &= -v_{x1ij} + \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} A_1(i,j;k,l)v_{y1kl}(t) \\ &+ \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} B_1(i,j;k,l)v_{u1kl}(t) \\ &+ \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} C_{12}(i,j;k,l)v_{y2kl}(t) + I_1, \\ &(|i-k| \le 1, |j-l| \le 1). \end{aligned} \tag{3}$$

$$\begin{aligned}\frac{dv_{x2ij}}{dt} &= -v_{x2ij} + \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} A_2(i,j;k,l)v_{y2kl}(t) \\ &+ \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} B_2(i,j;k,l)v_{u2kl}(t) \\ &+ \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} C_{21}(i,j;k,l)v_{y1kl}(t) + I_2, \\ &(|i-k| \le 1, |j-l| \le 1). \end{aligned} \tag{4}$$

Output equation :

$$v_{y1ij}(t) = \frac{1}{2}(|v_{x1ij}(t)+1| - |v_{x1ij}(t)-1|). \tag{5}$$

$$v_{y2ij}(t) = \frac{1}{2}(|v_{x2ij}(t)+1| - |v_{x2ij}(t)-1|). \tag{6}$$

3. Proposed Method

In this section, we explain the algorithm of the proposed structure. The proposed structure provides two neurons with two types of templates for one cell in CNN. The proposed structure is inspired from the two-layer CNN. In the proposed structure, coupling templates are dismissed and the connection between two layers are accomplished by A_1 and B_2. This is the different point between the proposed structure and the two-layer CNN. By not using coupling templates, the structure becomes simpler compared with the two-layer CNN.

Figure 2 shows the block diagram of the proposed structure. We define the input and the output values as v_{u1}, v_{u2}, v_{y1} and v_{y2}. At first the initial states for the neuron α and the neuron β are the same. The input value v_{u1} is carried out with template B_1 in the neuron α. The output from the neuron α is directly transfered into the neuron β as the input value v_{u2}. In the neuron α, v_{y2} is carried out with template A_1, and in parallel v_{y2} is also carried out with template A_2 in the neuron β. These processes continue until the output converges. The state equations and the output equations are given as follows.

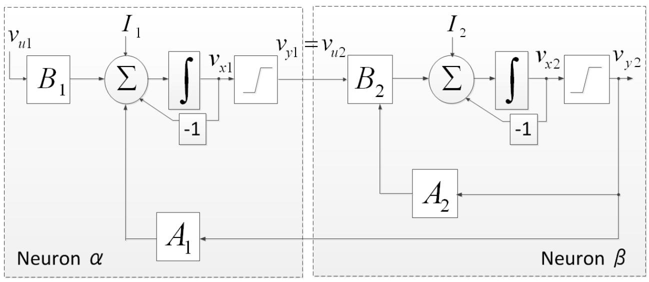


Figure 2: Block diagram of the proposed structure.

State equation in the neuron α :

$$\begin{aligned}\frac{dv_{x1ij}}{dt} &= -v_{x1ij} + \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} A_1(i,j;k,l)v_{y2kl}(t) \\ &+ \sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1} B_1(i,j;k,l)v_{u1kl}(t) + I_1, \end{aligned}$$

$$(|i-k| \leq 1, |j-l| \leq 1). \quad (7)$$

State equation in the neuron β :

$$\frac{dv_{x2ij}}{dt} = -v_{x2ij} + \sum_{k=i-1}^{i+1} \sum_{l=j-1}^{j+1} A_2(i,j;k,l) v_{y2kl}(t) + \sum_{k=i-1}^{i+1} \sum_{l=j-1}^{j+1} B_2(i,j;k,l) v_{y1kl}(t) + I_2,$$
$$(|i-k| \leq 1, |j-l| \leq 1). \quad (8)$$

Output equation :

$$v_{u2ij}(t) = v_{y1ij}(t) = \frac{1}{2}(|v_{x1ij}(t)+1| - |v_{x1ij}(t)-1|). \quad (9)$$

$$v_{y2ij}(t) = \frac{1}{2}(|v_{x2ij}(t)+1| - |v_{x2ij}(t)-1|). \quad (10)$$

4. Simulation Results

In this section, we show two examples of the simulation results using the proposed method.

4.1. Logic NOT operation

In single-layer CNN, when the *"Logic NOT"* template [5] in Eq. (11) is used to the Fig. 3(a), the output image becomes binary image like Fig. 3(b).
Logic NOT template :

$$A_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; B_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; I_1 = 0. \quad (11)$$

Also Fig. 3(c) shows the simulation result using the fuzzy CNN (FCNN) [6]-[8]. By applying the logic NOT template and fuzzy template to FCNN, the output image of the logic NOT operation becomes gray scale image. However the feature of some parts in the input image with the similar gray scale value are lost. For example the texture of pants worn by the cameraman with the different color of gray scale is disappeared.

For logic NOT operation using the proposed structure, we apply the template as follow.
Template in the neuron α :

$$A_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1.2 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; B_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -0.4 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; I_1 = -1. \quad (12)$$

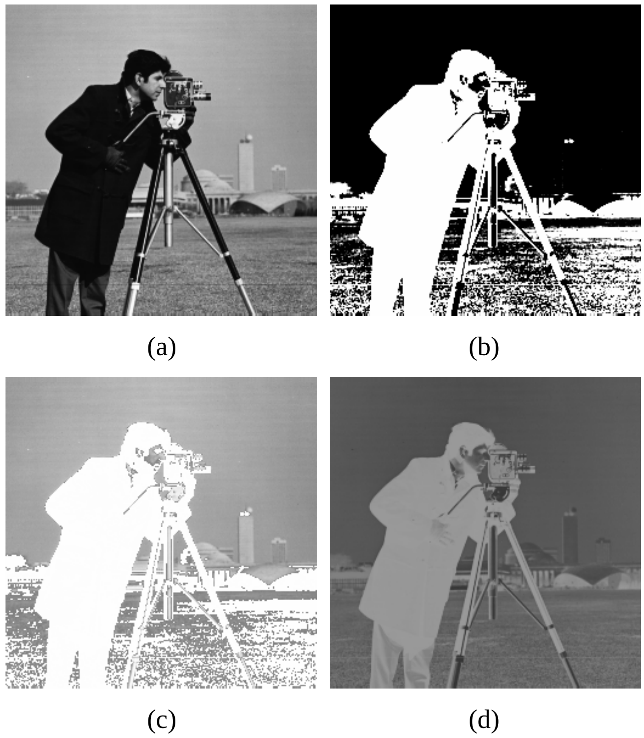


Figure 3: Simulation results of logic NOT operation. (a) Input image (256×256). (b) Output result using the basic CNN. (c) Output result using the fuzzy CNN. (d) Output of neuron α using the proposed method.

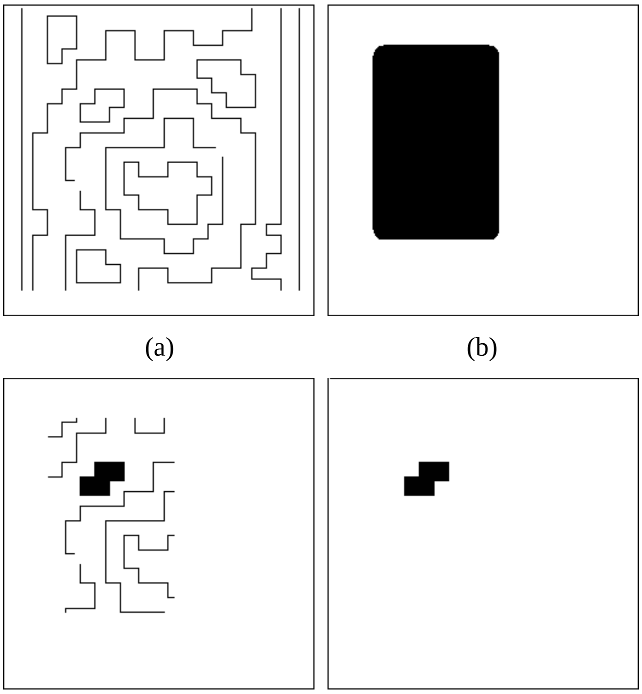
Template in the neuron β :

$$A_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; B_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1.2 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; I_2 = -1. \quad (13)$$

Figure 3(d) shows the simulation result using the proposed structure. The result using the proposed structure shows some parts with the similar gray value are performed the logic NOT operation well. For the neuron β, the output becomes whole white. From the result, we can say that the proposed structure performs the Logic NOT operation more finely than the FCNN.

4.2. Combination of "Hole filling" and "White propagation"

For second simulation example, *"Hole filling"* template [5] is used in the neuron α and a new *"White propagation"* template is used in the neuron β.



(a) (b) (c) (d)

Figure 4: Simulation results. (a) Input image (256×256). (b) Initial state. (c) Output image of neuron α. (d) Output image of neuron β.

"Hole filling" template :

$$A_1 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 3 & 1 \\ 0 & 1 & 0 \end{bmatrix}, \; B_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad I_1 = -1. \tag{14}$$

New *"White propagation" template* :

$$A_2 = \begin{bmatrix} 0 & 0.5 & 0 \\ 0.5 & 3 & 0.5 \\ 0 & 0.5 & 0 \end{bmatrix}, \; B_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad I_2 = -2.75. \tag{15}$$

The results are shown in Fig. 4. The output of the neuron α is obtained as Fig. 4(c). It is the same as the case of the basic CNN with *"Hole filling"* template. The connection between v_{y1} and v_{u2}, enable the value from the neuron α directly process to the neuron β in the same loop. Figure 4(d) is the output of the neuron β. Only enclosed shape that exists in a black area of the initial state in Fig. 4(b) is detected as the output of neuron β. From these results, we can say that both templates can be used simultaneously.

From both simulation results, we can say that the proposed structure has the distinctive output feature.

5. Conclusions

In this study, we have proposed a combination method of two neurons for a cell in CNN. We can say that the data from each neuron still can be sent to each other by only using templates A_1 and B_2. In our proposed structure, two types of templates can be confirmed to effect in one output value. The proposed structure was also approved to have a great ability in image processing.

In the future works, we would like to change the size of template and circuit implementation to investigate the effects for output feature. Besides gray scale and binary images, we also would like to try to use the proposed structure for motion pictures.

References

[1] L. O. Chua and L. Yang, "Cellular Neural Networks: Theory," IEEE Trans. Circuits Syst., vol. 32, no. 10, pp. 1257-1272, Oct. 1988.

[2] H. Koeppl and L. O. Chua, "An Adaptive Cellular Nonlinear Network and its Application," Proc. of NOLTA'07, pp. 15-18, Sep. 2007.

[3] L. O. Chua and L. Yang, "Cellular Neural Networks: Applications," IEEE Trans. Circuits Syst., vol. 35, no. 10, pp.1273-1290, Oct. 1988.

[4] Z. Yang, Y. Nishio and A. Ushida, "Templates and Algorithms for Two-Layer Cellular Neural Networks," Proc. of IJCNN'02, vol. 3, pp. 1946-1951, May 2002.

[5] L. Kek, K. Karacs and T.Roska, "Cellular Wave Computing Library (Templates, Algorithms, and Programs), Version 2.1," Cellular Sensory Wave Computers laboratory, Hungarian Academy of Sciences, Budapest, Hungary, 2007.

[6] T. Yang and L.B. Yang, "Fuzzy Cellular Neural Network: Theory, "Proc. of CNNA'96, pp. 181-186, 1996.

[7] T. Yang and L.B. Yang, "Fuzzy Cellular Neural Network: Applications, "Proc. of CNNA'96, pp. 225-230, 1996.

[8] K. Nishizono and Y. Nishio, "Image Processing of Gray Scale Image by Fuzzy Cellular Neural Network" Proc. of NCSP'06, pp.90-93, Mar. 2006.