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Combination of Two Neurons in Cellular Neural Networks

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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 structure of CNN resembles the structure of animals' retina, CNN can be used for various image processing applications. Wiring weights of the cells are established by parameters called the template. In the basic CNN, one template is used in one process. For using two or more templates, lots of processing are necessary and processing time becomes longer. We desired the simplest and proper size of CNN to apply them to image processing. In this study, as a new approach we propose a combination method of two neurons for one cell in CNN. In our propose method, two templates are used in one time. As a result, both templates' effects appear in output image.

2. Proposed Method

In this section, we explain the algorithm of the proposed method. Our proposed method provides two neurons with two different templates for one cell. The state equations and the output equations are described as follows.

State Equation :

Neuron α :
$$\frac{dv_{x1ij}}{dt} = -v_{x1ij} + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} A_1(i,j;k,l)v_{y2kl}(t)$$
$$+ \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} B_1(i,j;k,l)v_{u1kl}(t) + I_1, \quad (1)$$

Neuron β :
$$\frac{dv_{x2ij}}{dt} = -v_{x2ij} + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} A_2(i,j;k,l)v_{y2kl}(t)$$
$$+ \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} B_2(i,j;k,l)v_{y1kl}(t) + I_2,$$
$$(|i-k|\leq 1 \ , \ |j-l|\leq 1). \quad (2)$$

Output Equation :
$$v_{u2ij}(t) = v_{y1ij}(t) = \frac{1}{2}(|v_{x1ij}(t)+1|-|v_{x1ij}(t)-1|). \quad (3)$$
$$v_{y2ij}(t) = \frac{1}{2}(|v_{x2ij}(t)+1|-|v_{x2ij}(t)-1|). \quad (4)$$

We define the input and the output values as v_{u1}, v_{u2}, v_{y1} and v_{y2}. The initial states for Neurons α and β are the same. v_{u1} is carried out with B_1 template and sent to Neuron β. The output value v_{y2} is carried out with A_1 and A_2 templates in the feedback loops. In Neuron α, v_{y2} is carried out with A_1, and in parallel, v_{y2} is also carried out with A_2 template in Neuron β. This processes continue until the output converges. Our proposed method can be expressed by the block diagram shown in Fig. 1.

3. Simulation Results

In this section, we show a simulation result using our proposed method. We use *"Hole filling"* template in Neuron α and a new template based on *"White propagation"* template in Neuron β .

"Hole filling" template :
$$A_1 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 3 & 1 \\ 0 & 1 & 0 \end{bmatrix}, B_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I_1 = -1. \quad (5)$$
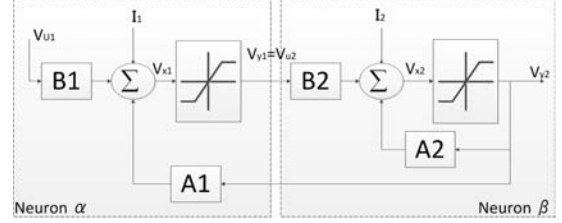

Figure 1: Block diagram.

New *"White propagation" template* :

$$A_2 = \begin{bmatrix} 0 & 0.5 & 0 \\ 0.5 & 3 & 0.5 \\ 0 & 0.5 & 0 \end{bmatrix},$$
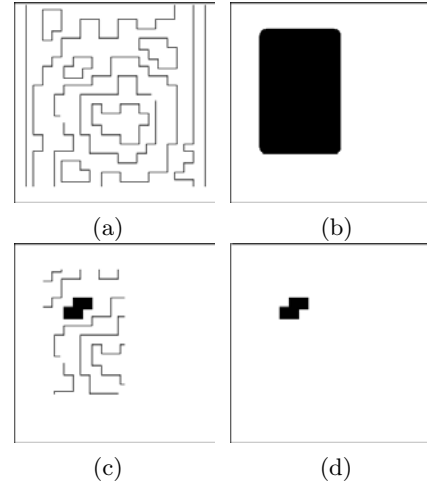$$B_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I_2 = -2.75. \quad (6)$$

Figure 2: Simulation result. (a) Input image. (b) Initial state. (c) Output Neuron α. (d) Output of Neuron β.

From the simulation results, the output of Neuron α is obtained as Fig. 1(c) and it is the same as the case of the basic CNN with *"Hole filling"* template. The connection between v_{y1} and v_{u2} let the value from Neuron α directly process to Neuron β in the same loop. Figure 1(d) is the output of Neuron β when the input value v_{u2} is processed with the initial state in Fig. 1(b). Only enclosed shape that exists in a black area of the initial state in Fig. 1(b) is detected as the output. From the results we can say that both templates can be used simultaneously.

4. Conclusions

In this study, we have proposed combination of two neurons for one cell in CNN. In our proposed method, two types of templates can be confirmed to effect in one output value because of the bond between two neurons. From the results, we can say that our proposed method can combine two processes in one time because of the combination of two neurons in one cell.

References

[1] L.O. Chua and L. Yang, "Cellular Neural Networks: Theory," IEEE Trans. Circuits Syst., vol. 32, pp. 1257-1272, Oct. 1988.