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Improvement of Two-Layer Cellular Neural Networks for Edge Detection

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1. Introduction

Cellular Neural Networks (CNN) were introduced by Chua and Yang in 1988. The idea of the CNN was inspired from the architecture of the cellular automata and the neural networks. The CNN has local connectivity property.

The former two-layer CNN had a feedforward multilayer CNN structure. The first layer and the second layer influenced reciprocally.

In this study, we propose an improvement of two-layer CNN for edge detection. We show effective edge detection using the proposed two-layer CNN. Also, we obtain interesting result by feeding back the edge detection image to another layer.

2. Proposed Two-Layer CNN Model

The state equation of the cell in the proposed two-layer CNN are described as follows.

State equation of the first-layer :

$$\begin{aligned}\frac{dv_{x1ij}}{dt} &= -v_{x1ij} + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} A_1(i,j;k,l)v_{x1kl}(t) \\ &+ \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} B_1(i,j;k,l)v_{u1kl}(t) \\ &+ \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} C(i,j;k,l)v_{y2kl}(t) + I_1. \quad (1)\end{aligned}$$

State equation of the second-layer :

$$\begin{aligned}\frac{dv_{x2ij}}{dt} &= -v_{x2ij} + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} A_2(i,j;k,l)v_{x2kl}(t) \\ &+ \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} B_2(i,j;k,l)v_{u2kl}(t) + I_2. \quad (2)\end{aligned}$$

In our two-layer CNN, we input an image to the first layer. Next, we calculate difference of output values of the first layer at different times, and the calculated value is inputed to the second layer.

Difference of output value in the first layer :

$$v_{u2ij} = v_{y1ij}|_{t=\Delta\tau} - v_{y1ij}|_{t=0}. \quad (3)$$

Finally, the output of the second layer is feedbacked to the first layer via the coupling template C. Namely, our two-layer CNN has two features. The first feature is that the coupling template is used only from the second layer to the first layer. The second feature is that the calculation start time of the second layer is later than that of the first layer.

3. Simulation Results

In this section, we show effective edge detection result and interesting result using our two-layer CNN. In this simulation, $\Delta\tau$ in Eq.(3) is set to 0.05.

Diffusion template in the CNN :

$$A = \begin{bmatrix} 0.1 & 0.15 & 0.1 \\ 0.15 & 0 & 0.15 \\ 0.1 & 0.15 & 0.1 \end{bmatrix}, B = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I = 0. \quad (4)$$

Edge detection template in our two-layer CNN :

The first layer template

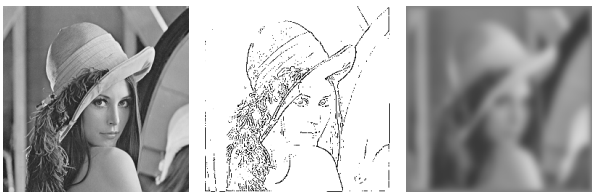
$$A_1 = \begin{bmatrix} 0.1 & 0.15 & 0.1 \\ 0.15 & 0 & 0.15 \\ 0.1 & 0.15 & 0.1 \end{bmatrix}, B_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I_1 = 0$$

The second layer template

$$A_2 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 3 & 1 \\ 1 & 1 & 1 \end{bmatrix}, B_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I_2 = 0.1$$

Coupling template

$$C = \begin{bmatrix} 0.05 & 0.05 & 0.05 \\ 0.05 & -0.4 & 0.05 \\ 0.05 & 0.05 & 0.05 \end{bmatrix}. \quad (5)$$



(a) (b) (c)

(d) (e)

Figure 1: Simulation results. (a) Input image. (b) Edge detection result using the CNN. (c) Diffusion result using template (4). (d) Output image of second layer in our two-layer CNN. (e) Output image of first layer in our two-layer CNN.

From these results, we can see that the edge detection result is more effective than the conventional CNN. Also, diffusion image is influenced to the edge detection image and obtain interesting result like Fig.1(e).

4. Conclusions

In this study, we proposed an improvement of two-layer CNN for edge detection. We investigated output characteristics of our two-layer CNN and obtain interesting result by computer simulation.