18-12

# Investigation of Convergence Process in D-CNN

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## 1. Introduction

Cellular Neural Networks (CNN) were introduced by Chua and Yang in 1988 [1]. The CNN can be used for image processing applications. Wiring weights of the cells in the CNN are established by parameters called the template. In the previous study, we proposed CNN with dynamic template (D-CNN) [2]. In D-CNN, template is dynamically updated by learning. Then, we obtained new output characteristics which divided to two colors. Also, we confirmed that convergence of D-CNN is much more rapid than the conventional CNN. However, in the previous study, our investigation about output characteristic of D-CNN was not enough. Therefore, in this study, we investigate the convergence process of D-CNN in detail. We expect to understand how output images are obtained for some input images.

## 2. D-CNN

In D-CNN, the template of cell is changed at each update by learning. Calculate the comparison of the output value of each cell with the one-step-past outputs of the cell and its neighbor cells. The comparison equation is described as follows.

*Comparison Equation*:

$$Dif(i,j;k,l) = |v^{now}_{y,(i,j)} - v^{past}_{y,(k,l)}|. \quad (1)$$

In the previous study, among the 9 calculated values of $Dif(i,j;k,l)$, the cells with the smallest and the second smallest values are defined as "winner" and "second", respectively (Type 1). In this study, we also investigate when the largest and the second largest values defined as "winner" and "second", respectively (Type 2).

In update algorithm, we change the learning rate of the "winner" and the "second" as follows.

*Update Equation*:

$$a^{updated}_{winner} = a^{now}_{winner} + R_1(t)(v^{now}_{y,(i,j)} - v^{past}_{y,(i,j)}). \quad (2)$$

$$a^{updated}_{second} = a^{now}_{second} + R_2(t)(v^{now}_{y,(i,j)} - v^{past}_{y,(i,j)}). \quad (3)$$

$R_1(t)$ and $R_2(t)$ decrease at each calculation. The initial learning rates are described as follows.

*Initial Learning rate*:

$$Winner: \quad R_{10} \quad (-0.1 \le R_{10} \le 0.1). \quad (4)$$

$$Second: \quad R_{20} = R_{10}/4. \quad (5)$$

## 3. Examination Method

In this study, we use "Diffusion" template.

*Diffusion Template*:

$$A = \begin{bmatrix} 0.1 & 0.15 & 0.1 \\ 0.15 & 0 & 0.15 \\ 0.1 & 0.15 & 0.1 \end{bmatrix}, B = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, I = 0. \quad (6)$$

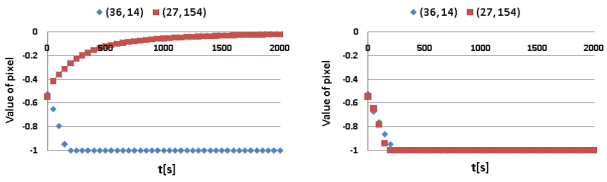
Figures 1(b) and (c) are output images in Type 1 and Type 2, respectively. Usually, an output image converges to one value by using "Diffusion" template. However, in these results, the output images converge to two values.

We investigate convergence process and relationship between the converged values and the values of neighbor cells in D-CNN. Firstly, we choose two similar pixels in the input image. Next, we investigate the convergence process of the two pixels with "Diffusion" template.

(a) (b) (c)

Figure 1: Simulation results. (a) Input image. (b) Output image using D-CNN (Type 1). (c) Output image using D-CNN (Type 2).

## 4. Simulation Results




(a) (b)

Figure 2: Convergence process for Fig. 1(a). (a) Type 1 ($R_{10}$=0.1). (b) Type 2 ($R_{10}$=0.1).

Figure 2 shows the convergence process in D-CNN. In Fig. 2(a), we can say that the gray points converge to 0 or −1. From this result, we can say that the convergence process depends on the values of surrounding cells. In this case, if surrounding cells have similar values, relatively bright area converges to −1. However, if surrounding cells have the values near 1, relatively bright area converges to around 0. Since edges of the output image in Fig. 1(c) are more diffused than those of Fig. 1(b), the convergence process has difference between Type 1 and Type 2.

## 5. Conclusions

In this study, we have investigated relationship between neighbor cells and convergence process in the cellular neural network with dynamic template (D-CNN). Also, we have investigated convergence process of some different definition types as "winner" and "second" in D-CNN. From simulation results, we confirmed the difference of convergence process in some color's pixels in D-CNN. And we feel that the prediction of output image using D-CNN can be performed.

**References**

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

[2] M. Kawahara, T. Inoue and Y. Nishio "Cellular Neural Network with Dynamic Template and its Output Characteristics" Proc. of IJCNN'09, pp. 1552-1558, Jun. 2009