2010 IEEE Workshop on
Nonlinear Circuit Networks, Tokushima, Dec 3-4, 2010

Image Processing Using Two-Template CNN With Conventional Cloning Templates

Riichiro Yaname
Dept. Information Business,
Shikoku University
Email: s1937090@edu.shikoku-u.ac.jp

Yasuteru Hosokawa
Dept. Media and Information System,
Shikoku University
Email: hosokawa@keiei.shikoku-u.ac.jp

Yoshifumi Nishio
Dept. Electrical and Electronic Eng.,
Tokushima University
Email: nishio@ee.tokushima-u.ac.jp

***Abstract*— In this study, two kinds of cloning templates of a discrete-time two-template CNN are proposed. Some conventional cloning templates are applied to these cloning templates. Therefore, it is not difficult to design a new cloning template for two-template CNN. Additionally, it is shown that the image processing capability is higher than a conventional CNN.**

I. Introduction

Cellular Neural Network (CNN) [1]-[3] is one of mutual coupling neural networks. There are many studies. One of advantage points is that cells are coupled only neighborhood cells. Namely, IC implementation is easily.

Some kinds of modified CNNs are proposed by individual researchers. One of modified CNNs is two-template CNN [4]. Two kinds of cloning templates of the two-template CNN can be set up at once. Some interesting oscillatory phenomena are observed in this system. Furthermore, the architecture of two-template CNN is almost same as a conventional CNN. Therefore, the advantage of IC implementation is not lost.

In past studies, although image processing is suitable for introducing the capability of the two-template CNN, there is not an investigation of image processing using the two-template CNN. Additionally, though some cloning templates for discrete-time CNN which have the same functions as continuous-time CNN are shown [5], there is not an investigation of discrete-time two-template CNN.

In this study, we propose two kinds of cloning templates for discrete-time two-template CNN. These templates are based on some conventional cloning templates. Additionally, the output function is set as a step function. It means that binary outputs are obtained in each iteration. Therefore, it is not difficult to design these cloning templates.

By some computer simulations, it is shown that the image processing capability is higher than a conventional CNN.

II. Two-Template CNN

Figure 1 shows an architecture of the two-template CNN. Cells α and β are arranged as a checkered pattern. Basically, the architecture is same as a conventional CNN. A difference between cell α and β is only values of cloning templates. The number of cells is set as M $\times$ N. The cell which is arranged at ith row and the jth column is called as $C(i,j)$. We investigate 1-neighborhood only in this study.

State equations of the discrete-time two-template CNN are given as follows.

1: Cell α

$$\begin{aligned} x_{ij}(t+1) = & \sum_{C(k,l)\in N_r(i,j)} A_\alpha(i,j;k,l)y_{kl}(t) \\ & \sum_{C(k,l)\in N_r(i,j)} B_\alpha(i,j;k,l)u_{kl} + I_\alpha \end{aligned} \tag{1}$$

2: Cell β

$$\begin{aligned} x_{ij}(t+1) = & \sum_{C(k,l)\in N_r(i,j)} A_\beta(i,j;k,l)y_{kl}(t) \\ & \sum_{C(k,l)\in N_r(i,j)} B_\beta(i,j;k,l)u_{kl} + I_\beta \end{aligned} \tag{2}$$

$A_{\{\alpha\beta\}}(i,j;k,l)y_{kl}$, $B_{\{\alpha\beta\}}(i,j;k,l)u_{kl}$, $I_{\{\alpha\beta\}}$ are called as the feedback coefficient, the control coefficient and bias current, respectively.

The output equation is given as follows.

$$y_{ij}(t) = \begin{cases} 1 & (x_{ij}(t) \geq 0) \\ -1 & (x_{ij}(t) < 0) \end{cases} \tag{3}$$

By this function, output values are binarized.

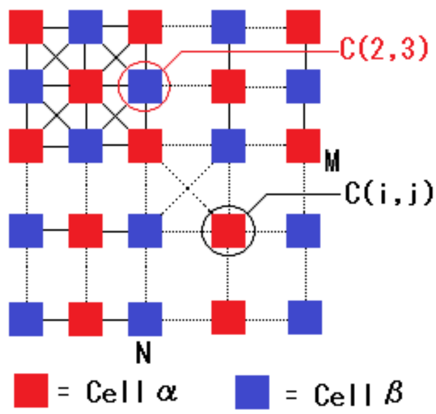


Fig. 1. Architecture of two-template CNN.

III. Simulations

A. System Set-up

In this section, computer simulations are carried out. All input images are gray scale images whose gradation is a 256 gradation shown in Fig. 2. The size is 256×256. Boundary conditions are set as 1.

Fig. 2. 256 gradation using in this study.

B. Dither

Figure 3 shows simulation results of the conventional CNN and the two-template CNN with following cloning templates.

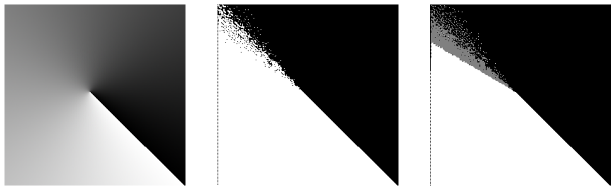
Conventional CNN:

$$\boldsymbol{A} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad \boldsymbol{B} = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix}, \quad I = 0, \tag{4}$$

Two-template CNN:

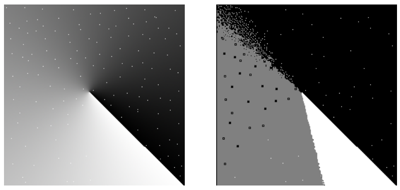
$$\begin{aligned} \boldsymbol{A}_\alpha &= \begin{pmatrix} 0 & 0.1 & 0 \\ 0.1 & 0 & 0.1 \\ 0 & 0.1 & 0 \end{pmatrix}, \quad \boldsymbol{B}_\alpha = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad I_\alpha = -3.7, \\ \boldsymbol{A}_\beta &= \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad \boldsymbol{B}_\beta = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix}, \quad I_\beta = -0. \end{aligned} \tag{5}$$

where input state values are set as random numbers. Figure 3 (a) shows an input image. Figures 3 (b) and (c) show simulation results of the conventional CNN and the two-template CNN, respectively. The cloning template of the conventional CNN and cell β of the two-template CNN means a dither. The cloning template of cell α of the two-template CNN means a noise rejection. In the case of the two-template CNN, we designed the cloning template by only coupling two cloning templates for a conventional CNN. Therefore, the designing method is a very simple. Additionally, the capability is higher than a conventional CNN. In Fig. 3 (c), a area which looks like gray is confirmed. This area is a checkered pattern. This area size can be changed by changing I_α. Thus we consider that a better output image can be obtained. This template has an another capability. Figure 4 shows a simulation result of the two-template CNN. Figures 4 (a) and (b) show an input image and a simulation result of the two-template CNN, respectively. In this case, some white dots are removed. Namely, a noise reduction is carried out. In order to realize these processing on a conventional CNN, two cloning templates which are a dither and a noise reduction are needed.



(a) (b) (c)

Fig. 3. Simulation results (Dither). (a) Input image. (b) Output image of the conventional CNN. (c) Output image of the two-template CNN.



(a) (b)

Fig. 4. Simulation results (Dither and noise reduction). (a) Input image. (b) Output image of the two-template CNN.

Now, the other results are shown. Figure 5 shows an input image. Figure 6 shows a simulation result of the two-template CNN with the cloning template (5). Figure 7 shows a simulation result of the conventional CNN with the cloning template (4) and cell α part of the cloning template (5) in sequence. In Fig. 6, we can observe some gray-scaled area. For instance, a camera, buildings, cameraman's pants and so on looks like gray. These area are checkered patterns. On the other hand, in the case of the conventional CNN which two kinds of cloning templates is applied, these area are blacked out. We consider that these results show the advantage of two-template CNN.

Fig. 5. Input image with noise.

Fig. 6. Simulation result of the two-template CNN. (Dither and noise reduction)

(a) Dithered image of the input image.

(b) Noise rejected image of (a).

Fig. 7. Simulation result of the conventional CNN.

C. Hole filling

Figure 8 shows simulation results of the conventional CNN and the two-template CNN on following cloning templates.

Conventional CNN:

$$\boldsymbol{A} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{pmatrix}, \quad \boldsymbol{B} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad I = -0.5, \tag{6}$$

Two-template CNN:

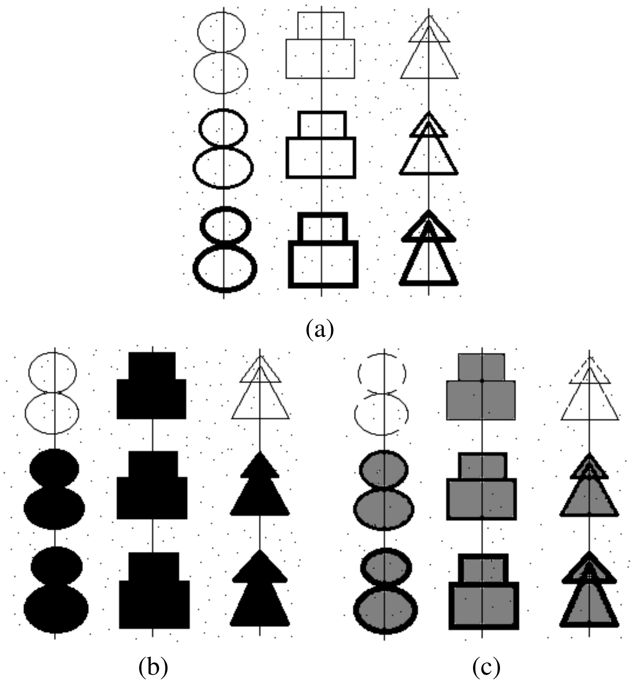


Fig. 8. Simulation results (Hole filling). (a) Input image. (b) Output image of the conventional CNN. (c) Output image of the two-template CNN.

$$\boldsymbol{A}_\alpha = \begin{pmatrix} 0 & 0.1 & 0 \\ 0.1 & 0 & 0.1 \\ 0 & 0.1 & 0 \end{pmatrix}, \quad \boldsymbol{B}_\alpha = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad I_\alpha = -3.7,$$
$$\boldsymbol{A}_\beta = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 2 & 0 \\ 1 & 0 & 1 \end{pmatrix}, \quad \boldsymbol{B}_\beta = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad I_\beta = -0.5 \tag{7}$$

Figure 8 (a) shows an input image. Figures 8 (b) and (c) show simulation results of a conventional CNN and two-template CNN, respectively. The cloning template of the conventional CNN means a hole filling. The cloning template of cell α of the two-template CNN means a noise rejection. The cloning template of cell β of the two-template CNN is based on a hole filling for a conventional CNN. The original matrix A of the cloning template is shown as follows.

$$\boldsymbol{A} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{pmatrix} \tag{8}$$

By rotating 45 degree, matrix A_β are obtained. This modifying means that coupling of cell β is kept. Matrix B_β and bias I_β are same as the original cloning template. In this case, we designed the cloning template by coupling and modifying two cloning templates for a conventional CNN.

Advantages of two-template CNN are the transparency of a hole filling and a noise reduction. In Fig. 8 (b), we can not see lines which pass though objects and all black dots are held. In Fig. 8 (c), a hole filling is carried out as a checkered pattern which looks like gray. Therefore, we can see the lines.

Additionally, some black dots are removed. On the other hand, there is a disadvantage. This cloning template can not work as hole filling in the case that the border line width is one dot. In particular, upper right side and upper left side objects of Fig. 8 are not filled. The reason is that cell β is arranged at checkered pattern. Though there are some advantage and a disadvantage, we consider that a two-template CNN is better than a conventional CNN in total.

Here, the other results are shown. Figure 9 shows a simulation result of the two-template CNN with the cloning template (7). Figure 10 shows a simulation result of the conventional CNN with the cloning template (6) and cell α part of the cloning template (7) in sequence. The input image of these two results is Fig. 5. In Fig. 9, we can observe some checkered pattern areas. Especially, the shade of cameraman's pants is processed effectively. On the other hand, in the case of the conventional CNN which is applied two kinds of cloning templates, These area is blacked out. In this case, we could not say that there is the advantage of the two-template CNN. However, we consider that the capability of the two-template CNN can be introduced.

Fig. 9. Simulation results of two-template CNN (Hole filling and noise reduction).

D. Discussion

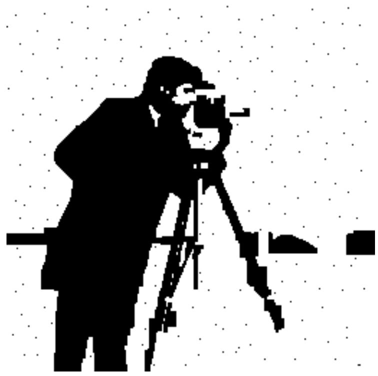
In above two subsections, we proposed two kinds of cloning templates for two-template CNN. We consider that the common points are follows:

- Initial state values are random numbers
- The template of cell α is noise rejection
- The template A of cell β is not connected with cell $alpha$ Initial state values are random numbers

It is expected that cloning templates which satisfy these points can be applied to two-template CNN. On the other hand, the investigation of cloning templates which do not satisfy these points is needed.

IV. Conclusions

In this study, we proposed two kinds of cloning templates for two-template CNN. The capabilities of these cloning templates have were shown. Furthermore, that these cloning templates could be designed easily.



(a)

(b)

Fig. 10. Simulation results of the conventional CNN (Hole filling and noise rejection). (a) Input image. (b) Output image of conventional Hole filling template. (c) Output image of Hole filling and noise reduction.

In our future works, applying these cloning templates to some famous images for image processing studies, template values optimization, designing another cloning templates and so on are considered.

References

[1] L. O. Chua and L. Yang, "Cellular Neural Networks: Theory," *IEEE Trans. Circuits Syst.*, vol. 35, no. 10, pp. 1257–1272, 1988.

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

[3] L. O. Chua, M. Hasler, G. S. Moschytz and J. Neirynck, "Autonomous Cellular Neural Networks: a unified paradigm for pattern formation and active wave propagation," *IEEE Trans. Circuits Syst. I*, vol. 42, no. 10, pp. 559577, 1995.

[4] J. Fujii, Y. Hosokawa and Y. Nishio, "Wave Phenomena in Cellular Neural Networks Using Two Kinds of Template Sets," *Proc. of NOLTA' 07*, pp. 23–26, 2007.

[5] H. Saito, K. Jin'no and M. Tanaka, "Universality of DT-CNN," *IEICE Technical Report*, no. NLP96-72, pp. 65–72, 1996.