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Application Using Checkered Arrangement of Cells in Two-Template CNN

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Abstract

In this study, three kinds of cloning templates of a discrete-time Two-Template CNN are proposed. These cloning templates are designed by using some conventional 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.

1. Introduction

Cellular Neural Network (CNN) [1]-[3] is one of mutual coupling neural networks. There are many studies. One of advantages is that cells are coupled only neighborhood cells. Therefore, 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 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 our previous studies, there is not an investigation of image processing using Two-Template CNN in spite that Two-Template CNN is suitable for image processing. Additionally, there is not an investigation of discrete-time Two-Template CNN in spite that some cloning templates which have the same functions as continuous-time CNN are shown [5].

In this study, two kinds of cloning templates for discrete-time Two-Template CNN are proposed. 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.

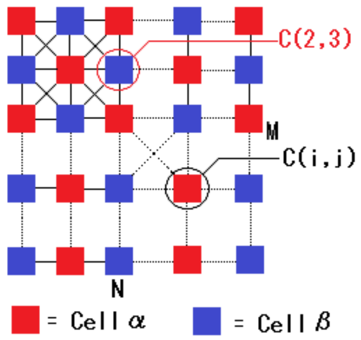


Figure 1: Architecture of Two-Template CNN.

2. Two-Template CNN

Figure 1 shows an architecture of 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.

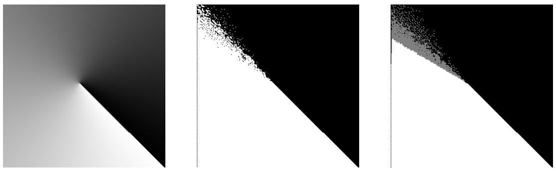
State equations of the discrete-time Two-Template CNN are given as follows.

Cell α:

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

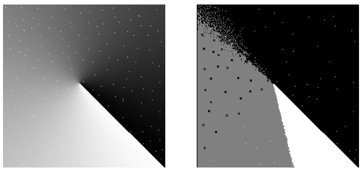
where i and j are odd numbers, or i and j are even numbers.
Cell β:

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



(a) (b) (c)

Figure 2: Simulation results (Dither). (a) Input image. (b) Simulation result of a conventional CNN. (c) Simulation result of Two-Template CNN.



(a) (b)

Figure 3: Simulation results (Dither and noise reduction). (a) Input image. (b) Simulation result of Two-Template CNN.

where i is an odd number and j is an even number, or i is an even number and j is an odd number.

$A_{\{\alpha\beta\}}(i,j;k,l)y_{kl}$, $B_{\{\alpha\beta\}}(i,j;k,l)u_{kl}$, $I_{\{\alpha\beta\}}$ 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.

3. Simulations

3.1. System Set-up

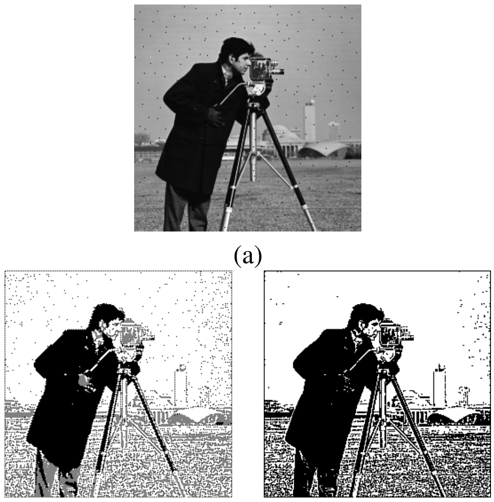
In this section, computer simulations are carried out. All input images are gray scale images whose gradation is a 256 gradation. The size is 256 × 256. Boundary conditions are set as 1.

3.2. Dither

Figure 2 shows simulation results of a conventional CNN and Two-Template CNN with following cloning templates.

Conventional CNN:

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



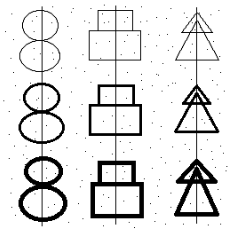
(b) (c)

Figure 4: Simulation results (Dither and noise reduction). (a) Input image with noise. (b) Simulation result of Two-Template CNN. (c) Simulation result of a conventional CNN.

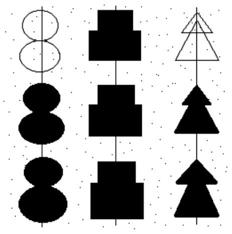
Two-template CNN:

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

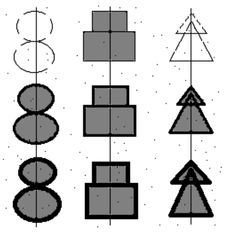
where input state values are set as random numbers. Figure 2(a) shows an input image. Figures 2(b) and (c) show simulation results of the conventional CNN and Two-Template CNN, respectively. The cloning template of the conventional CNN and cell β of Two-Template CNN means a dither. The cloning template of cell α of Two-Template CNN means a noise rejection. In the case of 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. 2(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 another capability. Figure 3 shows a simulation result of Two-Template CNN. Figures 3(a) and (b) show an input image and a simulation result of 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



(a)



(b)



(c)

Figure 5: Simulation results (Hole filling). (a) Input image. (b) Simulation result of a conventional CNN. (c) Simulation result of Two-Template CNN.

(a)

(b)

Figure 6: Simulation results (Hole filling and noise reduction). (a) Simulation result of Two-Template CNN. (b) Simulation result of hole filling and noise reduction.

dither and a noise reduction are needed.

Here, the other results are shown. Figure 4(a) shows an input image. Figure 4(b) shows a simulation result of Two-Template CNN with the cloning template (5). Figure 4(c) shows a simulation result of a conventional CNN. The cloning template (4) and cell α of the cloning template (5) are continuously applied. In Fig. 4(b), some gray-scaled area are observed. 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, these area are blacked out. We consider that these results show the advantage of Two-Template CNN.

3.3. Hole filling

Figure 5 shows simulation results of the conventional CNN and Two-Template CNN on following cloning templates.

Conventional CNN:

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

Two-template CNN:

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

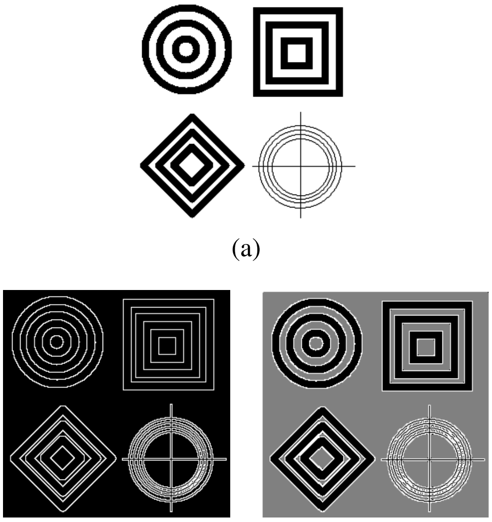
Figure 5(a) shows an input image. Figures 5(b) and (c) show simulation results of a conventional CNN and Two-Template CNN, respectively. The cloning template of the conventional CNN means hole filling. The cloning template of cell α of Two-Template CNN means noise rejection. The cloning template of cell β of Two-Template CNN is based on 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 hole filling and noise reduction. In Fig. 5(b), we can not obeserve lines which pass though objects and all black dots are kept. In Fig. 5(c), 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. Therefore, we consider that a Two-Template CNN is better than a conventional CNN.

Here, the other results are shown. Figure 6(a) shows a simulation result of Two-Template CNN with the cloning template (7). Figure 6(b) shows a simulation result of the conventional CNN. The cloning template (6) and cell α of the cloning template (7) are continuously applied. The input image of these two results is Fig. 4(a). In Fig. 6(b), some checkered pattern areas are observed. Especially, the shade of cameraman's pants is processed effectively. On the other hand, in the case of the conventional CNN, these area is blacked out. In this case, we could not say that there is the advantage of Two-Template CNN.



(a) (b) (c)

Figure 7: Simulation results (Edge detection). (a) Input image. (b) Simulation result of conventional edge detection template. (c) Simulation result of edge detection and dither.

3.4. Edge detection

Figure 7 shows simulation results of a conventional CNN and Two-Template CNN on following cloning templates.
Conventional CNN:

$$\boldsymbol{A} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \ \boldsymbol{B} = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix}, \ I = 2. \tag{9}$$

Two-template CNN:

$$\boldsymbol{A}_\alpha = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \ \boldsymbol{B}_\alpha = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix}, \ I_\alpha = 0,$$
$$\boldsymbol{A}_\beta = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \ \boldsymbol{B}_\beta = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix}, \ I_\beta = 2. \tag{10}$$

where input state values are set as random numbers. Figure 7(a) shows an input image. Figures 7(b) and (c) show simulation results of a conventional CNN and Two-Template CNN, respectively. The cloning template of the conventional CNN means edge detection. The cloning template of cell α of Two-Template CNN means dither. The cloning template of cell β of Two-Template CNN means edge detection. Both of them, edge detection can be applied. However, in Fig. 7(b), we can not see white parts which is included in graphics of the input image. By contrast, in Fig. 7(c), white parts can be confirmed as checkered patterns. Thus, we consider that a better result can be obtained.

3.5. Discussion

We consider that common points of these results are follows three points. Initial state values are random numbers. The cloning template A of cell α is noise rejection. The cloning template A of cell β is not connected with cell α. From these points, it is expected that cloning templates which satisfy these points can be applied to Two-Template CNN. On the other hand, investigating cloning templates which do not satisfy these points is needed.

4. Conclusions

In this study, we proposed three kinds of cloning templates for Two-Template CNN. As a result, some common points were shown.

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

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