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A Design Method of 5×5 Templates for Cellular Neural Networks

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***Abstract*—In this study, we propose a simple template design method of cellular neural networks by combining two existing templates. In this article, we investigate the output characteristics of simple image processings using the proposed template design method and show its effectiveness with simulation results.**

I. Introduction

Cellular Neural Networks (CNN) [1] 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. Unlike the conventional neural networks, the CNN has local connectivity property. Since the structure of the CNN resembles the structure of animals' retina, the CNN can be used for various image processing application.

Wiring weights of the cells are established by parameters called the template. The performance of the CNN is decided by the template. There are some major template design methods such as template learning [2]. However, the template leaning takes a long time to find desired template.

In this study, we propose a simple template design method of cellular neural networks by combining two existing templates. We investigate the output characteristics of image processing using the proposed template design method and show its effectiveness with simulation results.

II. Template Design Method

In this section, we propose a template design method of the CNN. In our template design method, we simply prepare two kinds of 3×3 different templates;

$Template\ 1:$

$$A_1 = \begin{bmatrix} a^1_{11} & a^1_{12} & a^1_{13} \\ a^1_{21} & a^1_{22} & a^1_{23} \\ a^1_{31} & a^1_{32} & a^1_{33} \end{bmatrix}, \quad B_1 = \begin{bmatrix} b^1_{11} & b^1_{12} & b^1_{13} \\ b^1_{21} & b^1_{22} & b^1_{23} \\ b^1_{31} & b^1_{32} & b^1_{33} \end{bmatrix}, \quad I_1. \tag{1}$$

$Template\ 2:$

$$A_2 = \begin{bmatrix} a^2_{11} & a^2_{12} & a^2_{13} \\ a^2_{21} & a^2_{22} & a^2_{23} \\ a^2_{31} & a^2_{32} & a^2_{33} \end{bmatrix}, \quad B_2 = \begin{bmatrix} b^2_{11} & b^2_{12} & b^2_{13} \\ b^2_{21} & b^2_{22} & b^2_{23} \\ b^2_{31} & b^2_{32} & b^2_{33} \end{bmatrix}, \quad I_2. \tag{2}$$

Next, we choose the mixing rate;
$Mixing\ Rate:$

$$p \qquad (0 \le p \le 1.0) \tag{3}$$

Finally, we create a new 5×5 combination template from the two 3×3 templates with the mixing rate; $Combination\ Template:$

$$A = \begin{bmatrix} pa^1_{11} & 0 & pa^1_{12} & 0 & pa^1_{13} \\ 0 & (1-p)a^2_{11} & (1-p)a^2_{12} & (1-p)a^2_{13} & 0 \\ pa^1_{21} & (1-p)a^2_{21} & pa^1_{22}+(1-p)a^2_{22} & (1-p)a^2_{23} & pa^1_{23} \\ 0 & (1-p)a^2_{31} & (1-p)a^2_{32} & (1-p)a^2_{33} & 0 \\ pa^1_{31} & 0 & pa^1_{32} & 0 & pa^1_{33} \end{bmatrix},$$

$$B = \begin{bmatrix} pb^1_{11} & 0 & pb^1_{12} & 0 & pb^1_{13} \\ 0 & (1-p)b^2_{11} & (1-p)b^2_{12} & (1-p)b^2_{13} & 0 \\ pb^1_{21} & (1-p)b^2_{21} & pb^1_{22}+(1-p)b^2_{22} & (1-p)b^2_{23} & pb^1_{23} \\ 0 & (1-p)b^2_{31} & (1-p)b^2_{32} & (1-p)b^2_{33} & 0 \\ pb^1_{32} & 0 & pb^1_{32} & 0 & pb^1_{33} \end{bmatrix},$$

$$I = pI_1 + (1-p)I_2. \tag{4}$$

The schematic picture of the procedure is shown in Fig. 1. In Fig. 1(c), the white elements are 0.

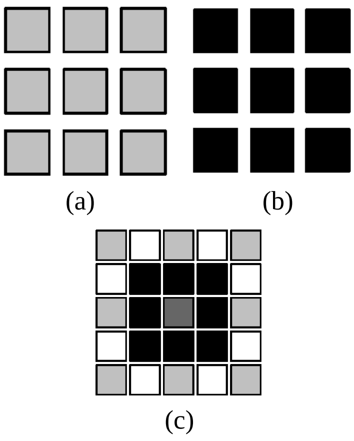


Fig. 1. Combining two templates. (a) Template 1 (3×3). (b) Template 2 (3×3). (c) Combination template (5×5).

The following is an example of the procedure.
$Template\ 1:$

$$A_1 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \quad B_1 = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 0 & 2 \\ 1 & 2 & 1 \end{bmatrix}, \quad I_1 = 0. \tag{5}$$

$Template\ 2$:

$$A_2 = \begin{bmatrix} 0 & 0.5 & 0 \\ 0.5 & 4 & 0.5 \\ 0 & 0.5 & 0 \end{bmatrix}, \quad B_2 = \begin{bmatrix} 0.2 & 0 & 0.2 \\ 0 & 1 & 0 \\ 0.2 & 0 & 0.2 \end{bmatrix},$$

$$I_2 = 4.5. \qquad (6)$$

$Mixing\ Rate$:

$$p = 0.8. \qquad (7)$$

$Combination\ Template$:

$$A = \begin{bmatrix} 0.8 & 0 & 0.8 & 0 & 0.8 \\ 0 & 0 & 0.1 & 0 & 0 \\ 0.8 & 0.1 & 2.4 & 0.1 & 0.8 \\ 0 & 0 & 0.1 & 0 & 0 \\ 0.8 & 0 & 0.8 & 0 & 0.8 \end{bmatrix},$$

$$B = \begin{bmatrix} 0.8 & 0 & 1.6 & 0 & 0.8 \\ 0 & 0.04 & 0 & 0.04 & 0 \\ 1.6 & 0 & 0.2 & 0 & 1.6 \\ 0 & 0.04 & 0 & 0.04 & 0 \\ 0.8 & 0 & 1.6 & 0 & 0.8 \end{bmatrix},$$

$$I = 0.9. \qquad (8)$$

III. Simulation Results for Noise Reduction

In this section, we show the simulation results for noise reduction. All the original templates in this section are found in [3]. We set the "Small Object Remover" template as Template 1 and the "Patch Maker" template as Template 2.

$Small\ Object\ Remover\ (Template\ 1)$:

$$A_1 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \quad B_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad I_1 = -1. \qquad (9)$$

By using this template, large objects remain and small objects are removed from input binary images.

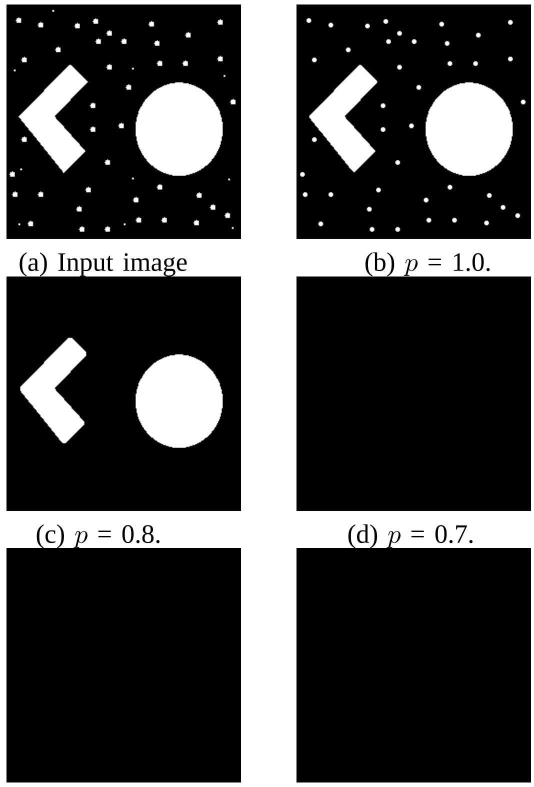
$Patch\ Maker\ (Template\ 2)$:

$$A_2 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix}, \quad B_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad I_2 = 4.5. \qquad (10)$$

By using this template, black objects are expanded without limit.

Figure 2 shows the simulation results using combination template. Figure 2(b) shows the simulation results using only "Small Object Remover" template for an input image with various size of spot noises. We can see that the "Small Object Remover" template cannot remove relatively large spot noises at all. Figures 2(c), (d), (e) and (f) show simulation results using combination template with different mixing rates. In Fig. 2(c), all noises removed and the two large objects are little distorted. However, when the ratio of the "Patch Maker" template is larger than 30%, the output image becomes completely black.

Remark: In this simulation, the mixing rate p=1.0 gives almost similar identical output image to the case that the standard CNN with the "Small Object Remover" template is used. However, the output is not always the same even if we choose p=1.0. Because the template 1 is expanded to 5x5 size and this can cause a different effect to the image. This means that the choice of template 1 or 2 is important in our template design method. In this noise reduction, we consider that the large noises can be removed by setting the "Small Object Remover" template outside of the combination template.



(a) Input image (b) p = 1.0. (c) p = 0.8. (d) p = 0.7. (e) p = 0.6. (f) p = 0.5.

Fig. 2. Simulation results using combination template of Small Object Remover Template (Template 1) and Patch Maker Template (Template 2) with different mixing rates.

IV. Conclusions

In this study, we have proposed the template design method of the CNN by combining existing templates. By computer simulations of simple image processing for binary images, we investigated the basic output characteristics of the proposed systems. As we expected, we could confirm the effects of both templates by combining them. At the moment, we do not say that the proposed method exhibited a superior performance than the original CNN. However, we feel that we obtained some results to broaden the research on the CNN design.

References

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

[2] Á. Zarándy, "The Art of CNN Template Design," Int. J. Circ. Theor. Appl., vol. 27, no. 1, pp. 5-23, Jan.-Feb. 1999.

[3] Cellular Sensory Wave Computers Laboratory Computer and Automation Research Institute Hungarian Academy of Sciences, "Cellular wave Computing Library (Template, Algorithms, and Programs) Version 2.1"