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Image Processing of Cellular Neural Networks with Mixtured Template

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***Abstract*— In this study, we propose mixtured template system as a space-varying system for image processing. This system has the structure that we assign one template to each cell from multiple templates which are chosen optionally. If the proposed system can realize to make multiple kind processings at once, then the generalization processing time is reduced. In this research, we show some interesting combination template by a simulation.**

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. Wiring weights of the cells are established by parameters called the template. If the templates of the cells in the CNN are identical, the system is called space-invariant system, or if the templates of the cells in the CNN are not identical, the system is called space-varying system. The space-varying system is not mainly used in the studies of CNN, and it is difficult to predict the results to use multiple templates. In the space-invariant system, the pattern extraction etc. can be processed by repeating two or more processing. However, it takes time for this processing. If multiple processing are made at once by the proposed system, processing time can be reduced. Also by mixing multiple templates, we hold up a hope that new performance that characteristic of each template are fused is discovered. In this research, we propose a mixtured template system of the CNN to rise performance of the CNN. We test the combinations of various templates to discover effective results using computer simulation. As a result, we obtain some interesting performance of two types of mixtured template system.

II. Cellular Neural Networks

In this section, we describe basic structure of the CNN. The CNN has M by N processing unit circuits called cells as Fig. 1. Cells are arranged in a reticular pattern to M line N row. We represent a cell $C(i,j)$ using a variable i which denotes vertical position and a variable j which denotes horizontal position. Cell contains linear and nonlinear circuit elements. The CNN is an array of cells. Each cells are connected to neighboring cells according to a template. The template is the same for all cells expect for boundary cells.

The state equation and the output equation of the cell are shown as follows.

State equation:

$$\frac{dv_{xij}}{dt} = -v_{xij} + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} A_{(i,j;k,l)}v_{ykl}(t) + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} B_{(i,j;k,l)}v_{ukl}(t) + I \quad (1)$$

Output equation:

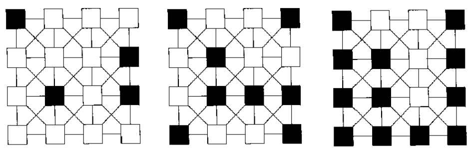
$$v_{yij}(t) = \frac{1}{2}(|v_{xij}(t)+1| - |v_{xij}(t)-1|) \quad (2)$$

v_x, v_y and v_u represent a state, an output and an input of cell, respectively. In the equation (1), A is the feedback template and B is the control template. These and bias I are collectively called general template.

III. Mixtured template system

In this study, we propose two types of Mixtured Template System (MTS). These systems are the CNN which have informations of multiple templates. In type 1 of MTS (MTS-1), one kind of template is selected randomly per each cell from multiple templates which are chosen optionally.

Figure 1 shows structure examples of MTS-1 using two kinds of templates.



(a) (b) (c)

Fig. 1. Examples of mixtured template using two types of templates (Black cells and white cells have different templates). (a) $white : black = 75 : 25$. (b) $white : black = 50 : 50$. (c) $white : black = 25 : 75$.

In this figure, black cells and white cells have different templates. In the system, mixture method is completely random. The ratio between black cells and white cells is decided optionally.

On the other hand, in type 2 of MTS (MTS-2), we consider that the template is resolved into the elements. Namely, in type 2 of MTS (MTS-2) each element of template is selected randomly each element from multiple templates which were chosen optionally. Templates (5), (6) show the examples that two kind templates (3), (4) is mixed at ratio of 5:5 by MTS-2.

Template 3:

$$A=\begin{bmatrix} a_1 & a_2 & a_3 \\ a_4 & a_5 & a_6 \\ a_7 & a_8 & a_9 \end{bmatrix}, B=\begin{bmatrix} b_1 & b_2 & b_3 \\ b_4 & b_5 & b_6 \\ b_7 & b_8 & b_9 \end{bmatrix}, \quad I=I_1. \tag{3}$$

Template 4:

$$A=\begin{bmatrix} \alpha_1 & \alpha_2 & \alpha_3 \\ \alpha_4 & \alpha_5 & \alpha_6 \\ \alpha_7 & \alpha_8 & \alpha_9 \end{bmatrix}, B=\begin{bmatrix} \beta_1 & \beta_2 & \beta_3 \\ \beta_4 & \beta_5 & \beta_6 \\ \beta_7 & \beta_8 & \beta_9 \end{bmatrix}, \quad I=I_2. \tag{4}$$

Template 5:

$$A=\begin{bmatrix} \alpha_1 & \alpha_2 & a_3 \\ \alpha_4 & a_5 & \alpha_6 \\ \alpha_7 & a_8 & a_9 \end{bmatrix}, B=\begin{bmatrix} \beta_1 & b_2 & \beta_3 \\ \beta_4 & \beta_5 & b_6 \\ b_7 & b_8 & \beta_9 \end{bmatrix}, \quad I=I_2. \tag{5}$$

Template 6:

$$A=\begin{bmatrix} a_1 & \alpha_2 & \alpha_3 \\ a_4 & \alpha_5 & a_6 \\ \alpha_7 & a_8 & \alpha_9 \end{bmatrix}, B=\begin{bmatrix} b_1 & \beta_2 & b_3 \\ \beta_4 & \beta_5 & \beta_6 \\ b_7 & \beta_8 & b_9 \end{bmatrix}, \quad I=I_2. \tag{6}$$

IV. Simulation

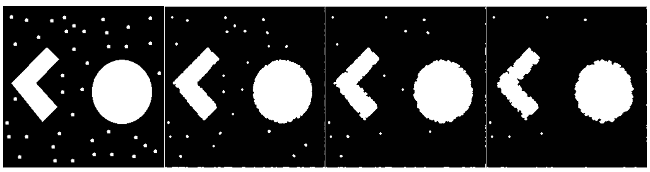
In this section, we show the simulation results of MTS-1 and MTS-2 for image processing using below two kind of templates.

$Small\ Object\ Remover$:

$$A=\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix}, B=\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \qquad I=-1. \tag{7}$$

$Patch\ Maker$:

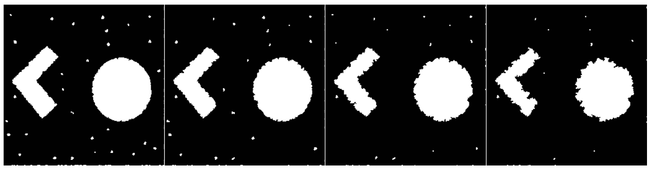
$$A=\begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix}, B=\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \qquad I=4.5. \tag{8}$$



(a) (b) (c) (d)

Fig. 2. Simulation Results of MTS-1 using Small Object Remover and Patch Maker. (a) Input image. (b) small object remover : patch maker= 80:20. (c) small object remover : patch maker= 70:30. (d) small object remover : patch maker= 60:40.

Figure 2 shows the simulation results of MTS-1. As a result, the performance is risen with mixing Patch Maker to Small Object Remover. However, when the ratio of Patch Maker to Small Object Remover is increasing, the strain of large objects grew.



(a) (b) (c) (d)

Fig. 3. Simulation results using MTS-2. (a) small object remover : patch maker= 70:30. (b) small object remover : patch maker= 60:40. (c) small object remover : patch maker= 50:50. (d) small object remover : patch maker= 40:60.

Figure 3 shows simulation results using MTS-2 which mixed Small Object Remover and Patch Maker. As a result, the noise decreased with increasing the ratio of Patch Maker. However, when the ratio of Patch Maker was got over 60%, the output image becomes completely black. A large object in the input image warps with increasing the ratio.

We examine about two kind results like denoising level of small object and distortion level of large object. The results are as follows.

TABLE I

PERFORMANCE OF NOISE REDUCTION

	Mixtured system 1		Mixtured system 2	
template (4):(5)=80:20	number of denoising	15	number of denoising	4
	distortion level	783	distortion level	663
template (4):(5)=70:30	number of denoising	l26	number of denoising	10
	distortion level	1015	distortion level	808
template (4):(5)=60:40	number of denoising	33	number of denoising	20
	distortion level	1438	distortion level	1033
template (4):(5)=50:50	number of denoising	—-	number of denoising	26
	distortion level	—-	distortion level	1394
template (4):(5)=40:60	number of denoising	—-	number of denoising	30
	distortion level	—-	distortion level	2116

The distortion level denotes difference of the original image and output image. By Table 1, MTS-1 decreased the noise well as against MTS-2 when ratio of Patch Maker was small. However, the distortion level is large. The MTS-2 did not decrease the noise if there are not big mixing ratio of Patch Maker. However, distortion level is small.

V. Simulation results for grayscale image

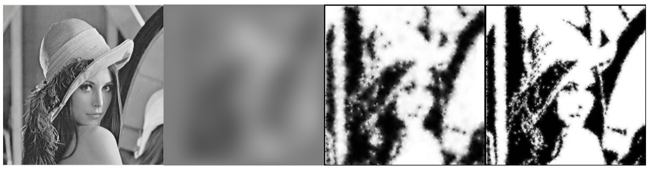
In this section, we use the grayscale image (Fig. 9) as input image. In this simulation. we use MTS-1 with Smoothing Operation and Diffusion.

Smoothing Operation:

$$A=\begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix}, B=\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \qquad I=0. \tag{9}$$

Diffusion:

$$A=\begin{bmatrix}0.1 & 0.15 & 0.1\\ 0.15 & 0 & 0.15\\ 0.1 & 0.15 & 0.1\end{bmatrix}, B=\begin{bmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{bmatrix}, \quad I=0. \tag{10}$$



(a) (b) (c) (d)

Fig. 4. Convergent output images with changing the ratio of (9) and (10). (a) Input image. (b) (9) : (10) = $0 : 100$. (c) $5 : 95$. (d) $20 : 80$.

Figure 4(a) is an input image. Figures 4(b)(c)(d) are the convergent output images with changing the ratio of (9) and (10). As a result, if we can discover suitable combination of multiple templates then the processing with both characteristics would be realized.

VI. Conclusions

In this study, we proposed the mixtured templates systems 1 and 2 as the space-varying templates systems. We investigated characteristics of the proposed system by simulation. As a result, we clarified that characteristic of CNN can be improved by the proposed system.

Acknowledgments

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References

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