Design of Two Template Cellular Neural Networks for Color Image Processing

Yasuteru Hosokawa
Dept. of Media and Information Systems,
Shikoku University
Furukawa, Ohjin, Tokushima, Japan
hosokawa@keiei.shikoku-u.ac.jp

Yoko Uwate and Yoshifumi Nishio
Dept. Electrical and Electronic Engineering,
Tokushima University
2-1 Minami-Josanjima, Tokushima, Japan
{uwate, nishio}@ee.tokushima-u.ac.jp

Abstract— **In this study, TTCNNs for color image processing were designed. In this design, Bayer arrangement is applied to TTCNNs. Some simulation results were shown for a possibility of one-layer color image processing using TTCNNs.**

Keywords; Cellular Neural Networks; Color Image Processing; Bayer Filter

I. INTRODUCTION

One of important advantages of Cellular Neural Networks (CNNs) [1][2] is a simple and uniform structure. The simple and uniform structure makes an IC implementation of CNNs easily. However, almost all modified CNNs proposed by many researchers became complicated systems by the modify.

Two Template CNNs (TTCNN) [3], which are one kind of Modified CNNs, keeps the simple and uniform structure of a conventional CNN. The difference from a conventional CNN is the number of signal lines for cloning template values only. The structure of one Cell is the same. Therefore, the simple and uniform structure is kept.

In this study, TTCNNs for color image processing are designed. In order to process a color image, Bayer arrangement, which is a well-known arrangement of a color filter array of an image sensor, is applied to TTCNNs. By this design, TTCNNs can process color image by one layer. Thus, this design has a possibility of hardware coupling an image sensor and TTTCNN.

II. TWO TEMPLATE CELLULAR NEURAL NETWORKS

Figure 1 shows a system model of Two Template CNN (TTCNN). Different cloning template values can be set between Cell alpha and Cell beta. Arrangement of two kinds of cells is a checkered pattern. In case of applied same cloning template values, this system becomes same as a conventional CNN. The difference from a conventional CNN is only this point. Therefore, TTCNN has an almost same structure as a conventional CNN. This feature means that the simple and uniform structure of a conventional CNN is kept. State equations are described as follows.

State equation of Cell alpha:

$$\frac{dx_{ij}}{dt} = -x_{ij} + I_{\alpha} + \sum_{c(k,l)} \boldsymbol{A}_{\boldsymbol{\alpha}}(i,j;k,l)y_{kl} + \sum_{c(k,l)} \boldsymbol{B}_{\boldsymbol{\alpha}}(i,j;k,l)u_{kl} \quad (1)$$

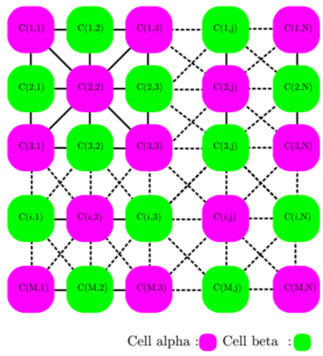


Figure 1. System Model of TTCNN.

State equation of Cell beta:

$$\frac{dx_{ij}}{dt} = -x_{ij} + I_{\beta} + \sum_{c(k,l)} \boldsymbol{A}_{\boldsymbol{\beta}}(i,j;k,l)y_{kl} + \sum_{c(k,l)} \boldsymbol{B}_{\boldsymbol{\beta}}(i,j;k,l)u_{kl} \quad (2)$$

Output function:

$$y_{ij} = 0.5(|x_{ij}+1| - |x_{ij}-1|). \quad (3)$$

Only some subscripts of state equations are different from a conventional CNN. Thus, the characteristic and structure of cells is same as a conventional CNN. Some template sets for this system were proposed in [6].

III. COLOR IMAGE PROCESSING BY TTCNN

In this section, Bayer arrangement and its application to TTCNN are described. Bayer arrangement is very simple as one-layer color image processing. This arrangement is used in almost all image sensors of one-layer. By applying this arrangement to TTCNN, one-layer color image processing of TTCNN can be realized.

A. Bayer Arrangement

Bayer arrangement patented by Bryce E. Bayer in 1975 is a kind of color image filter. Photo diodes used in an image sensor can obtain strength of light only. Therefore, in order to processing a color image, processing three primary colors is needed. Bayer arrangement can process three primary colors on one photo diodes array. This arrangement is used in almost all one-layer color image sensors because it is very simple and it can be realized with low costs.

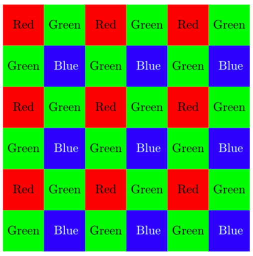


Figure 2. Bayer arrangement.

Processing of Bayer filter is as follows. First, an input image is filtered by Bayer arrangement as shown in Fig. 2. Next, each color pixel data is generated using four filtered pixels data which are a red, a blue, and two green. This process is known as demosaicing. The number of obtained color image data is equal to the number of photo diodes minus boundary pixels because filtered pixels data excepted boundary pixels is used four times. We can obtain color image data from two steps processing only.

B. Applying Bayer arrangement to TTCNN

Bayer arrangement is similar to cell arrangement of TTCNN. Cell alpha of TTCNN is corresponding to Red or Blue of Bayer arrangement. Cell beta is corresponding to Green. Hence, Bayer arrangement is applied to TTCNN for color image processing. Some of simulation results are shown in Figs. 3 and 4.

Figures 3 show some simulation result of applying CIE 1931 xy color space diagram [5] as an input image. Fig. 3 (a) is the input image. Figure 3 (b)-(d) are simulation results in case of applying following cloning template values, respectively.

$$\mathbf{A}_\alpha = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}, \quad \mathbf{A}_\beta = \begin{pmatrix} -1 & 1 & -1 \\ 1 & 0.5 & 1 \\ -1 & 1 & -1 \end{pmatrix}, \quad \mathbf{B}_\alpha = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad \mathbf{B}_\beta = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 1 \end{pmatrix}, \quad I_\alpha = 0, \quad I_\beta = -1 \tag{4}$$

$$\mathbf{A}_\alpha = \begin{pmatrix} 0 & 1 & 0 \\ 1 & -2 & 1 \\ 0 & 1 & 0 \end{pmatrix}, \quad \mathbf{A}_\beta = \begin{pmatrix} 2 & 1 & 2 \\ 1 & 1 & 1 \\ 2 & 1 & 2 \end{pmatrix}, \quad \mathbf{B}_\alpha = \begin{pmatrix} -1 & 0 & -1 \\ 0 & 4 & 0 \\ -1 & 0 & -1 \end{pmatrix}, \quad \mathbf{B}_\beta = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 1 \end{pmatrix}, \quad I_\alpha = -2, \quad I_\beta = 1 \tag{5}$$

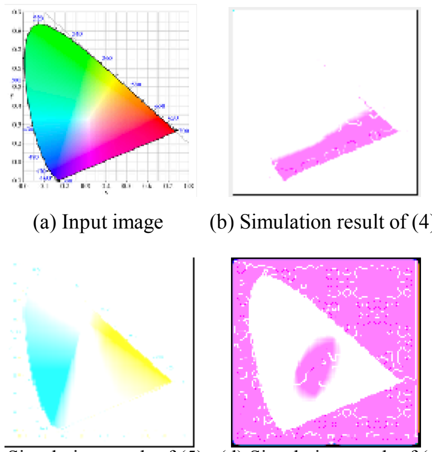
$$\mathbf{A}_\alpha = \begin{pmatrix} 1.6 & 1.4 & 1.6 \\ 1.4 & 0.8 & 1.4 \\ 1.6 & 1.4 & 1.6 \end{pmatrix}, \quad \mathbf{A}_\beta = \begin{pmatrix} -1 & 1.8 & -1 \\ 1.8 & 0.4 & 1.8 \\ -1 & 1.8 & -1 \end{pmatrix}, \quad \mathbf{B}_\alpha = \begin{pmatrix} 0 & 0.6 & 0 \\ 0.6 & -2 & 0.6 \\ 0 & 0.6 & 0 \end{pmatrix}, \quad \mathbf{B}_\beta = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 1.6 & -1 \\ -1 & -1 & -1 \end{pmatrix}, \quad I_\alpha = 0.6, \quad I_\beta = 0.1 \tag{6}$$

In Fig. 3 (b), purple is extracted. In Fig. 3 (c), cyan and yellow are extracted. In Fig. 3 (d), white is extracted as purple.

Another case is shown in Figs. 4. Figure 4 (a) shows an input image which shows a sky, a forest, and a river. Figure 4 (b) is a simulation result in case of applying following cloning template values.

$$\mathbf{A}_\alpha = \begin{pmatrix} -3 & 1 & 2 \\ -3 & -5 & -3 \\ -2 & 4 & -5 \end{pmatrix}, \quad \mathbf{A}_\beta = \begin{pmatrix} 3 & 2 & -2 \\ 3 & -4 & -3 \\ 3 & 2 & 0 \end{pmatrix}, \quad \mathbf{B}_\alpha = \begin{pmatrix} 2 & 1 & -1 \\ 3 & 4 & 3 \\ 3 & 4 & -5 \end{pmatrix}, \quad \mathbf{B}_\beta = \begin{pmatrix} -2 & 3 & 2 \\ -3 & -4 & 2 \\ -5 & 4 & 3 \end{pmatrix}, \quad I_\alpha = 3, \quad I_\beta = -1 \tag{7}$$

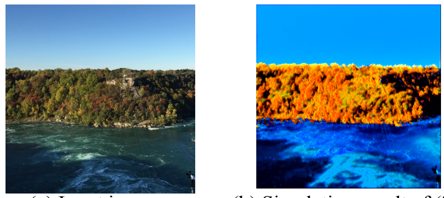
The forest part is recognized clearly as orange color. Thus, processing some simple color image can be confirmed.



(a) Input image (b) Simulation result of (4)

(c) Simulation result of (5) (d) Simulation result of (6)

Figure 3. Simulation results of applying CIE 1931 xy color space diagram [5].



(a) Input image (b) Simulation result of (7)

Figure 4. Simulation results of a picture of a sky, a forest, and a river.

IV. CONCLUSION

In this study, TTCNNs for color image processing are designed. In order to process a color image, Bayer arrangement, is applied to TTCNNs. By this design, it was confirmed that TTCNNs can process color image by one layer. This result shows a possibility of hardware coupling an image sensor and TTTCNN.

ACKNOWLEDGMENT

This work was partly supported by JSPS Grant-in-Aid for Scientific Research 16K06357.

REFERENCES

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

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

[3] J. Fujii, Y. Hosokawa and Y. Nishio, "Wave Phenomena in Cellular Neural Networks Using Two Kinds of Template Sets," *Proc. of International Symposium on Nonlinear Theory and its Applications*, pp. 23-26, 2007.

[4] Bryce E. Bayer, "Color Imaging Array, " *U.S. Patent 3971065*, Mar. 5, 1975.

[5] BenRG, File:CIE1931xy_blank.svg, Wikipedia Commons, https://comm ons.wikimedia.org/wiki/File:CIE1931xy_blank.svg

[6] R. Yamane, Y. Hosokawa and Y. Nishio, "Image Processing Using Two-Template CNN with Conventional Cloning Templates" *Proceedings of IEEE Workshop on Nonlinear Circuit Networks (NCN'10)*, pp. 5-8, Dec. 2010.