Two-Layer DT-CNN with Switching Template

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Abstract— **In this paper, we propose a new system of two-layer Discrete-Time Cellular Neural Network (DT-CNN) and investigate the output characteristics. The proposed system has different structure of conventional DT-CNN. In particular, the structure of proposed system is two-layer. Also two templates are switched by outputs value of each layer. From simulation results, we confirm that the proposed system is more effective than the conventional CNN for some image processings.**

I. Introduction

Our society has a fair amount of information. At present, a personal computer has a higher processing ability than a human to the extent of computational speed. Though, the personal computer is lower than processing speed of human for image and sound recognitions. Therefore, a neural network is the focus of attention as new model of information processing. The neural network bases on the concept of the processing of the cerebral nerve system. The key features of neural network are asynchronous parallel processing, continuous-time dynamics and global interaction of network elements.

Continuous Time Cellular Neural Network (CT-CNN) were introduced by Chua and Yang [1]. CT-CNN is used the concept of cellular automata and neural networks. The structure of CT-CNN is grating coupling of simple analog circuit. The CT-CNN makes it possible to high-speed parallel processing. Therefore, the CT-CNN can be used for various image processing applications [2]-[6]. The pattern of coupling is called template that make a decision about behavior of CNN. The CT-CNN has characteristics of local connection that provide an advantage to implementation of VLSI. Though, the CT-CNN has difficulty mounting at integrated circuit by the analog circuit. However, the CT-CNN has difficulty implementing by analog circuit. Therefore, the discrete-time CNN (DT-CNN) is developed in order to process with discrete-time [7]. The output of DT-CNN is expressed step function. In addition, output of DT-CNN can extend in multiple values because of outputs function are shifted discrete value levels of multiple-value. Also, the calculation of DT-CNN is easier than CT-CNN because calculation of DT-CNN is described by difference equation.

In this study, we consider DT-CNN with involvement of the effective structure at the CT-CNN. Two-layer CNN is constructed two conventional single-layer CNNs by two-coupling template. In processing of each layer, outputs of both layer exert an effect on processing of each other. Also, CNN cannot be process complex processing by space invariant template. In CNN with switching template, template is switched by pixel values of processing image. And, the CNN with switching template is switched makes it possibility to be not spatially homogeneous processing. In some image processings, the two-layer CNN and CNN with switching template are more effective than the conventional CNN [8]-[9]. Therefore, we proposed two-layer DT-CNN with switching template. From some image processings, we confirm that the proposed system can be effective than the conventional DT-CNN.

II. Cellular Neural Network

In this section, we explain about the conventional DT-CNN, two-layer CNN and CNN with switching template.

A. DT-CNN

In this subsection, we explain about the conventional DT-CNN. A block diagram of the DT-CNN is shown in Fig.1. The processing of DT-CNN uses three types value that are input, output and threshold values. Also, outputs characteristic of DT-CNN are shown in Fig.2. Output characteristic of DT-CNN is expressed the multiple-valued quantized function.

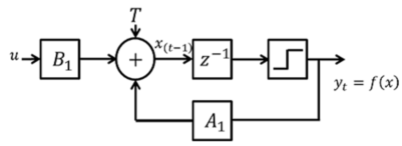

Fig. 1. Block diagram of the DT-CNN.

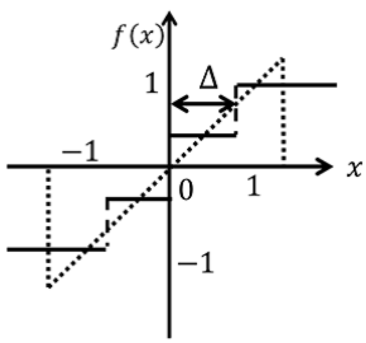

Fig. 2. The output characteristic of DT-CNN.

The state equation and output equation are described as follows.

State equation of the conventional DT-CNN :

$$
\begin{aligned}
x(t+1) &= \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} A(i,j;k,l) v_{ykl}(t) \\
&+ \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} B(i,j;k,l) v_{ukl}(t) + T \\
&(|i-k| \leq 1 \quad , \quad |j-l| \leq 1). \qquad (1)
\end{aligned}
$$

Output equation of the conventional DT-CNN :

$$
\begin{aligned}
v_{yij}(t) &= \begin{cases} 1 & (\epsilon \leq v_{xij}(t)) \\ g(v_{xij}(t)) & (-\epsilon < v_{xij}(t) < \epsilon) \\ -1 & (v_{xij}(t) \leq -\epsilon) \end{cases} \\
g(v_{xij}(t)) &= \begin{cases} \Delta[v_{xij}/\Delta + 1/2] & (L : odd) \\ \Delta([v_{xij}/\Delta] + 1/2) & (L : even) \end{cases} \\
\Delta &= 2\epsilon/(n-1). \qquad (2)
\end{aligned}
$$

B. Two-Layer CNN

In this subsection, we explain about the two-layer CNN. Figure 3 shows the block diagram of the conventional two-layer CNN. The conventional two-layer CNN is constructed by two conventional single-layer CNN. Two conventional single-layer CNN is coupled by two coupling templates C_1 and C_2. And the two coupling templates are used to transfer output values between both layers. Also, the conventional two-layer CNN has been confirmed to have more efficient structure for high performance image processing.

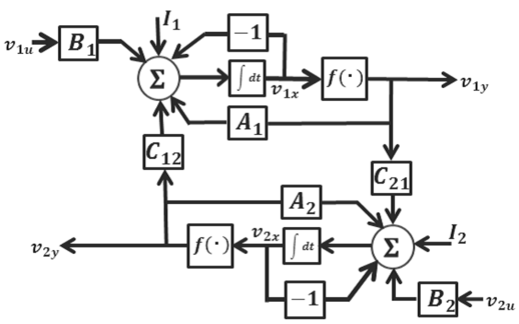

Fig. 3. Block diagram of the two-layer CNN.

C. CNN with Switching Template

In this subsection, we explain about the switching template. Dynamics of CNN is determined by template. Template of CNN is consisted from three types element that are feedback A, feedforward B and threshold T template. In generally, CNN can not process complex processing by space invariant template. Therefore, CNN with switching template is proposed. The CNN with switching template makes it possible to perform complex processing. The CNN with switching template is depend element as input values and output values. The CNN with switching template can process more effective image processing by using optimal switching condition.

III. Proposed System

In this section, we explain the system of the proposed two-layer DT-CNN. Figure 4 shows the block diagram of the proposed system. The structure of the proposed system based on conventional two-layer CNN. Also, the proposed system has two switching templates A_S and C_S that are switched by outputs value of each layer. In the two switching templates, A_S, C_S templates are switched two types by outputs value of each layer.

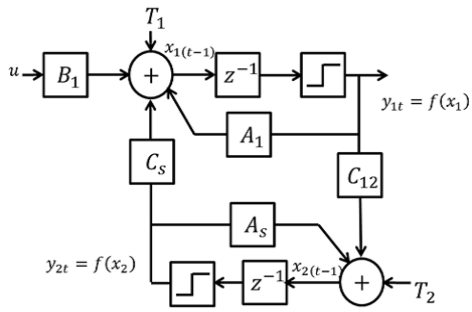

Fig. 4. Block diagram of the proposed system.

The switching condition expression and state, output equation are shown as follows.

Switching condition expression :

$$
\begin{aligned}
v_{y1ij}(t) &= v_{y2ij}(t) : A_{21} and C_{21} templates \qquad (3) \\
v_{y1ij}(t) &\neq v_{y2ij}(t) : A_{22} and C_{22} templates \qquad (4)
\end{aligned}
$$

State equation of the first-layer CNN :

$$
\begin{aligned}
x_1(t+1) &= \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} A_1(i,j;k,l) v_{y1kl}(t) \\
&+ \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} B_1(i,j;k,l) v_{ukl}(t) \\
&+ \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} C_s(i,j;k,l) v_{y2kl}(t) + T_1, \\
&(|i-k| \leq 1 \quad , \quad |j-l| \leq 1). \qquad (5)
\end{aligned}
$$

Output equation of the first-layer CNN :

$$
\begin{aligned}
v_{y1ij}(t) &= \begin{cases} 1 & (\epsilon \leq v_{x1ij}(t)) \\ g(v_{x1ij}(t)) & (-\epsilon < v_{x1ij}(t) < \epsilon) \\ -1 & (v_{x1ij}(t) \leq -\epsilon) \end{cases} \\
g(v_{x1ij}(t)) &= \begin{cases} \Delta[v_{x1ij}/\Delta + 1/2] & (L : odd) \\ \Delta([v_{x1ij}/\Delta] + 1/2) & (L : even) \end{cases} \\
\Delta &= 2\epsilon/(n-1). \qquad (6)
\end{aligned}
$$

State equation of the second-layer CNN :

$$\begin{aligned} x_2(t+1) &= \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} A_s(i,j;k,l)v_{y2kl}(t) \\ &\quad + \sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r} C_{12}(i,j;k,l)v_{y1kl}(t) + T_2, \\ &\quad (|i-k| \leq 1 \;\; , \;\; |j-l| \leq 1). \end{aligned} \tag{7}$$

Output equation of the second-layer CNN :

$$\begin{aligned} v_{y2ij}(t) &= \begin{cases} 1 & (\epsilon \leq v_{x2ij}(t)) \\ g(v_{x2ij}(t)) & (-\epsilon < v_{x2ij}(t) < \epsilon) \\ -1 & (v_{x2ij}(t) \leq -\epsilon) \end{cases} \\ g(v_{x2ij}(t)) &= \begin{cases} \Delta[v_{x2ij}/\Delta + 1/2] & (L: odd) \\ \Delta([v_{x2ij}/\Delta] + 1/2) & (L: even) \end{cases} \\ \Delta &= 2\epsilon/(n-1). \end{aligned} \tag{8}$$

IV. Simulation result

In this section, we show simulation results by using proposed system. In this simulation, we simulated edge detection and binarization. Used templates are found in [10]. Templates and thresholds of each layer are assigned as follows.
Template of binary:

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix}, \; B = T_1 = 0. \tag{9}$$

Template of edge detection:

$$\begin{aligned} A &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; B = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}, \\ T_1 &= -1. \end{aligned} \tag{10}$$

Template of first-layer, coupling template, thresholds:

$$\begin{aligned} A_1 &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; B = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}, \\ C_{12} &= \begin{bmatrix} 1 & 1 & 1 \\ 1 & 8 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \; T_1 = T_2 = 0. \end{aligned} \tag{11}$$

Switching template:

$$\begin{aligned} A_{21} &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; A_{22} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \\ C_{21} &= \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; C_{22} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}. \end{aligned} \tag{12}$$

(a) (b)

Fig. 5. Input and initial state images 1. (a) Lenna, (b) Cameraman,

(c) (d)

Fig. 6. Simulation results of binarization 1. (a) Simulation result of binarization by using conventional DT-CNN, (b) Simulation result of edge detection by using conventional DT-CNN, (c) Simulation result for first-layer of proposed system. (d) Simulation result for first-layer of proposed system.

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

Fig. 7. Closeup of simulation results. (a) Simulation result of binarization by using conventional DT-CNN, (b) Simulation result of edge detection by using conventional DT-CNN, (c) Simulation result for first-layer of proposed system. (d) Simulation result for first-layer of proposed system.

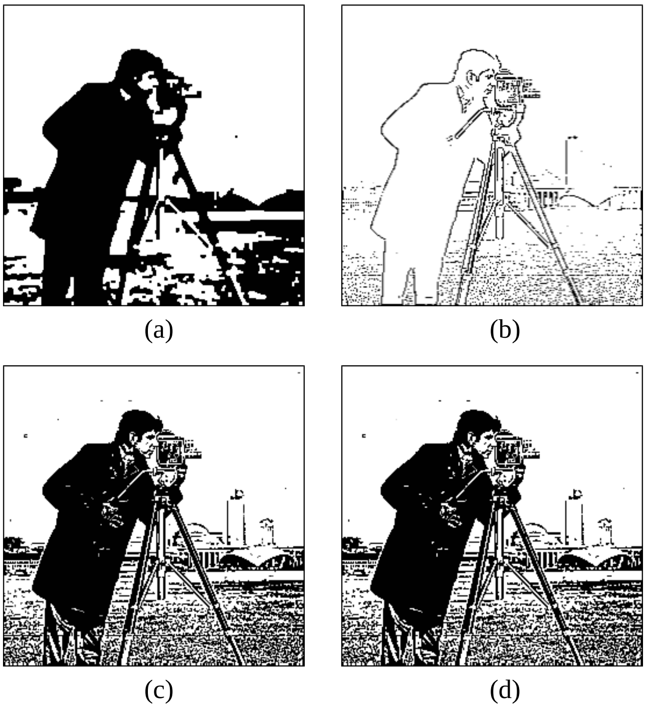

Fig. 8. Simulation results of binarization 2. (a) Simulation result of binarization by using conventional DT-CNN, (b) Simulation result of edge detection by using conventional DT-CNN, (c) Simulation result for first-layer of proposed system. (d) Simulation result for first-layer of proposed system.

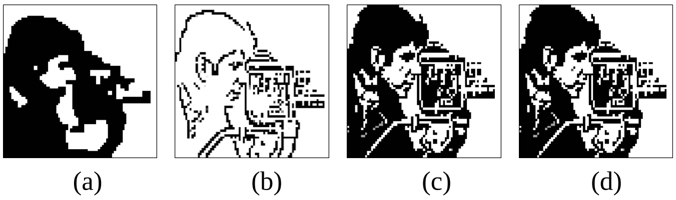

Fig. 9. Closeup of simulation results. (a) Simulation result of binarization by using conventional DT-CNN, (b) Simulation result of edge detection by using conventional DT-CNN, (c) Simulation result for first-layer of proposed system. (d) Simulation result for first-layer of proposed system.

Figure 5 shows the input images. In the Fig. 5(a), the past of background and a hat in the mirror are indistinct portions. Also, in the Fig. 5(b), the buildings of the background are indistinct portions. The simulation results are shown in Figs. 6 and 8. Closeup of simulation results are shown in Figs. 7 and 9.

Figures 6(a) and (b) show the simulation result by using conventional DT-CNN. On the other hand, Figs. 6(c) and (d) shows the simulation result by using proposed system. In the Fig. 6(a), the indistinct portions can not be detected. Therefore, in the Fig. 7(a), a detail that the decor of hat and the aspect of face can not be shown. Also, in the Fig. 6(b), the indistinct portions can not be detected. In contrast, in the Figs 6(c) and (d), indistinct portions can be detected. In addition, in the Figs. 7(c) and (d), the detail that the decor of hat and the aspect of face can be shown.

Figures 8(a) and (b) show the simulation result by using conventional DT-CNN. One the other hand, Figs 8(c) and (d) shows the simulation result by using proposed system. In the Fig. 8(a), the indistinct portions can not be detected. In addition, in the Fig. 9(a), a detail that the camera and the aspect of face can not be shown. Also, in the Fig. 8(b), the indistinct portions can be partially detected. In contrast, in the Figs. 8(c) and (d), indistinct portions can be detected. In addition, in the Figs. 9(c) and (d), the detail that the camera and the aspect of face can be shown.

From simulation results, we can say that the proposed system is more effective than the conventional DT-CNN.

V. Conclusions

In this paper, we have proposed two-layer DT-CNN with two switching templates. The proposed system has that two types of templates (A_S, C_S) are switched by outputs value of each layer. From simulation results, the proposed system could be detected about the indistinct and the detail portions. Therefore, we could say that the proposed system is more effective than the conventional DT-CNN.

In the future works, we would like to compare outputs characteristic by quantitative investigation. In addition, we would like to investigate about other image processings.

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