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Cellular Neural Network with Preference Theory for Image Processing

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Abstract

In this study, we propose Cellular Neural Network with the Preference Theory (PT-CNN). The proposed model includes human behavior system in the structure of cellular neural network. We apply human behavior system to the template of cellular neural network. We observe that the proposed model obtains intriguing results for the edge detection.

1. Introduction

Recent years, the amount of information which should be processed at once is increasing by the information society. General digital processing is a sequential operation. The information processing time is longer, moreover it is not possible to real-time signal processing. Therefore information process using a neural network that is designed based on the human nervous system has been investigated. Cellular Neural Networks (CNN) were introduced by inspired from the cellular automata and the neural networks [1]. CNN has local connectivity property and it makes the CNN tailor made for VLSI implementation. Then, CNN has the features of time continuity, spatial discreteness, nonlinearity and parallel processing capability. Furthermore, the structure of CNN resembles that of animals' retina. Therefore, CNN can be used for various image processing applications[2]-[4].

Coupling strength between cells of CNN is established by a parameter called the template. There is a limit to the amount of information which a cell obtain from the neighborhood. My research group focused on sociality or actual circle of friends, and have obtained intriguing results[5][6]. Therefore, we focus on behavior system of human.

We would like to explain about preference theory. Preference theory is psychology to build a successful relationship. In conventional psychology, human behavior is considered theory that is decided by the stimulus from the outside. However, human choose a best action for purpose in each case. We personally choose own action. For example, relationship is broken only by order when people get angry. Therefore, we can build a successful relationship by presenting an option and negotiation. In fact, preference theory is controlled by inside. In this study, we propose Cellular Neural Network with preference theory (PT-CNN) incorporating psychological behavior system to the structure of the CNN.

2. Cellular Neural Network

CNN is the circuit having the units called cells of $M \times N$ matrix. A circuit model of cell is shown Fig. 1. One cell is one pixel in image processing. It is composed of circuit elements of the linear and nonlinear. We show below the output equation and the equation of state of each cell.

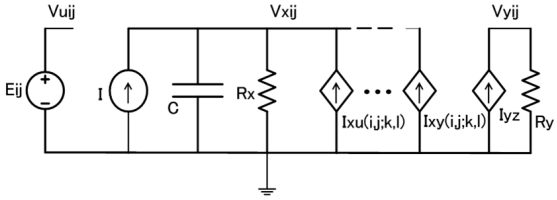


Figure 1: The circuit model of cell.

State equation:

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

v_x represents the state value of a cell, v_y represents the output value of a cell, and v_u represents the input value of a cell. In addition, *A* is feedback template, *B* is control template, *I* is a bias. Dynamics of CNN is determined by these values.

Output equation:

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

For the output equation, output characteristic are expressed with a piecewise linear function, moreover output value of CNN assume continuous value from -1 to 1 in Fig. 2. Therefore, the output image is expressed as binary.
Then, we show below the block diagram in Fig. 3.

When the distance between each cell that is directly connected is k, cells is called k-neighborhood. Such composition

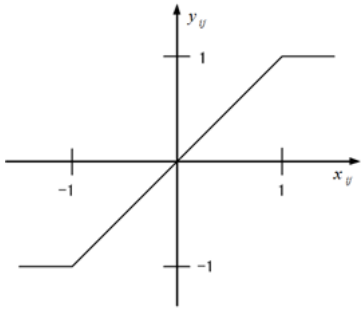


Figure 2: Output characteristic of CNN.

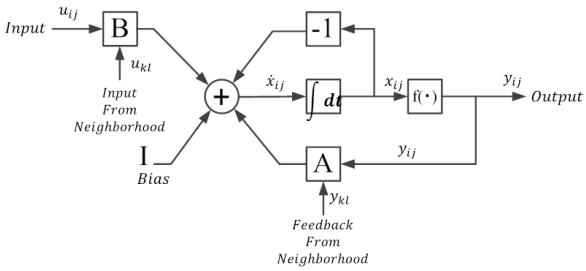


Figure 3: The block diagram of cell.

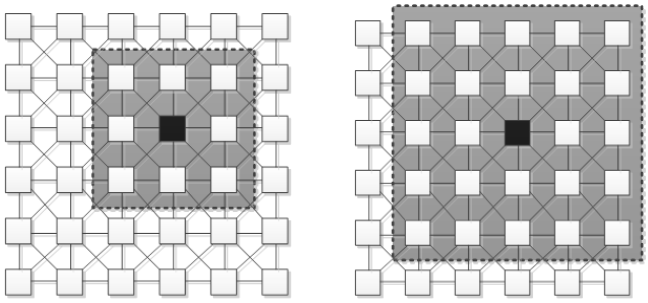
is called k-th joint composition. Examples of the first coupling configuration is shown in Fig. 4(a), and examples of the secondary coupling configuration is shown in Fig. 4(b). The area surrounded by the dotted line is neighborhood of black cell. In other words, Fig. 4(a) shows that center cell is directly coupled to the eight nearby cells, moreover Fig. 4(b) shows that center cell is directly coupled to the 24 nearby cells. r-neighborhood of cell is defined as:

$$N_r(i,j) = \{C(k,l)|max\{|k-i|,|l-j|\} \leq r, \\ 1 \leq k \leq M; 1 \leq l \leq N\}. \quad (3)$$

3. Cellular Neural Network with the Preference Theory

CNN is processed by the information of neighboring cells. There is a limit to the amount of information that a cell is obtained from neighboring cells. Therefore, a method to extend a template is proposed. However, the processing is not always sensitive. For example, a noise is detected in edge detection. Additionally, it is necessary to set up a new template. There are not many kinds of bigger template than 3×3. Thus, we propose the model of the CNN using a combination of preference theory.

The flow of outside control psychology is Fig. 5(a). Conventional CNN is spatially uniform. Cells influenced by value

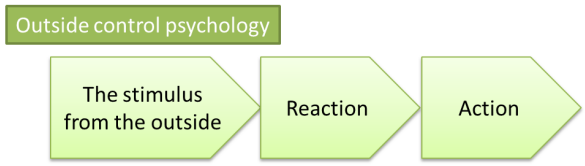


(a) First coupling configuration.

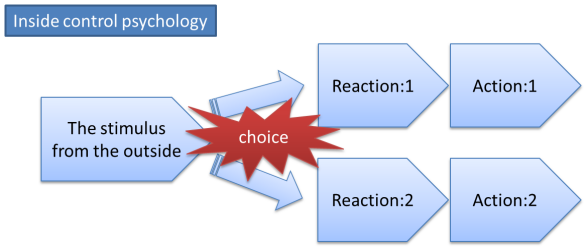
(b) Secondary coupling configuration.

Figure 4: Configuration of CNN.

of template are spatially. When we assume stimulus from the outside as template, conventional CNN is similar inside control psychology. The flow of preference theory is Fig. 5(b). In the proposed model, we feed choice to the cell that is applied values of the template. Therefore, the proposed model resembles preference theory.



(a) The flow of outside control psychology.



(b) The flow of preference theory.

Figure 5: The flow of human behavior.

In this structure, central cell chooses automatically eight cells which propagate information from cell to cell. Even if neighborhood is expanded, information is propagated from only optimal eight cells. Therefore, the 3×3 template can be used like Fig. 6. The proposed model choose eight cells by

most different values from a central cell. Since boundaries or contours drastically change, we applied the proposed model to edge detection. In fact, this structure composes automatically an asymmetrical template. Since values differ for every cell, template is updated.

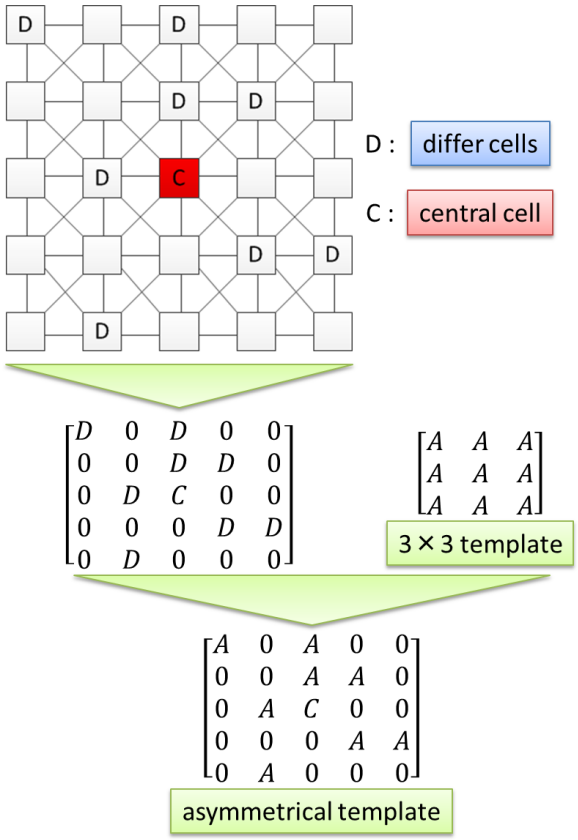


Figure 6: The flow of using 3×3 template on the proposed model.

3.1 Edge Detection

In this section, we show the simulation results of edge detection by the proposed model and conventional CNN. The proposed model choose eight cells by most different values from a central cell. We use three type of the image in edge detection. In Fig. 7(a), the image of LENNA contains the person area that is brought to a focus, and the background area that is not brought to a focus. The pillar of the background is indistinct. Moreover, since the shuttlecock of a hat is fine, it needs high-precision processing. In Fig. 8(a), many objects are stacked up. The shadow of front pepper is changing brightness gradually. In Fig. 9(a), there is little light-and-darkness difference of the whole image. The portion of hair and eyes are fine. The region of the right annular finger is complex.

3×3 *Edge detection template* :

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad B = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}, \quad I = -1. \tag{4}$$

5×5 *Edge detection template* :

$$A = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 24 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix},$$

$$I = -1. \tag{5}$$

Figures 7 to 9 show the simulation results of edge detection. The pillar on the left side in the background is an indistinct portion in Fig. 7(a). The indistinct portion is not detected by using the 3×3 template CNN in Fig. 7(b). In the same way, detection is deficient in Figs. 8(b) and 9(b). The edge of the indistinct portion is detected in Fig. 7(c) and 7(d), however excessive information is detected in Fig. 7(c). The same is equally true of Figs. 8 and 9. We can obtain the result equivalent to to using 5×5 template by only information from eight cells.

4. Conclusions

In this study, we have proposed a new model of CNN. The model is Cellular Neural Network with the Preference Theory (PT-CNN) which included psychological behavior system in the structure of cellular neural network. From the simulation results of edge detection, the proposed model is better than the conventional CNN.

As future works, we would like to simulate a image with a high pixel count since the proposed model can consider case of a expanded neighborhood.

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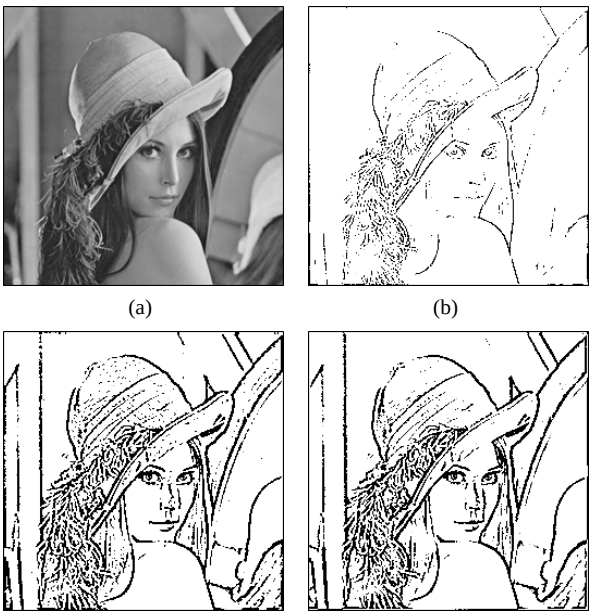
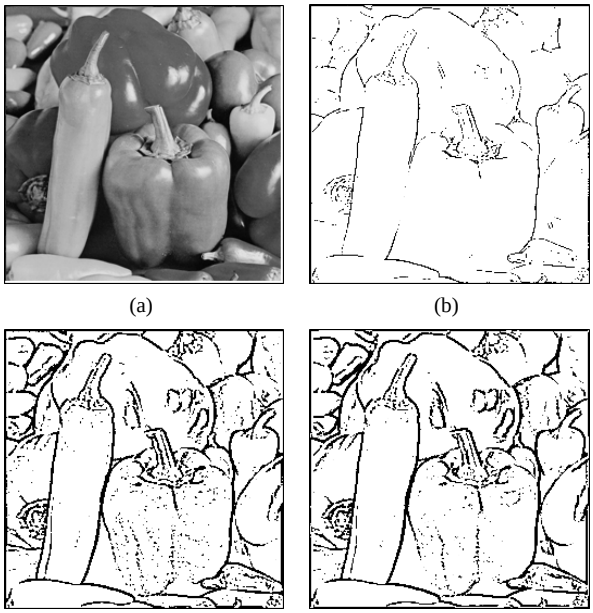


(a) (b) (c) (d)

Figure 7: Simulation result 1. (a) Input image (LENNA). (b) Result of 3×3 template . (c) Result of 5×5template. (d) Result of proposed model.



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

Figure 8: Simulation result 2. (a) Input image (Pepper). (b) Result of 3×3 template . (c) Result of 5×5template. (d) Result of proposed model.

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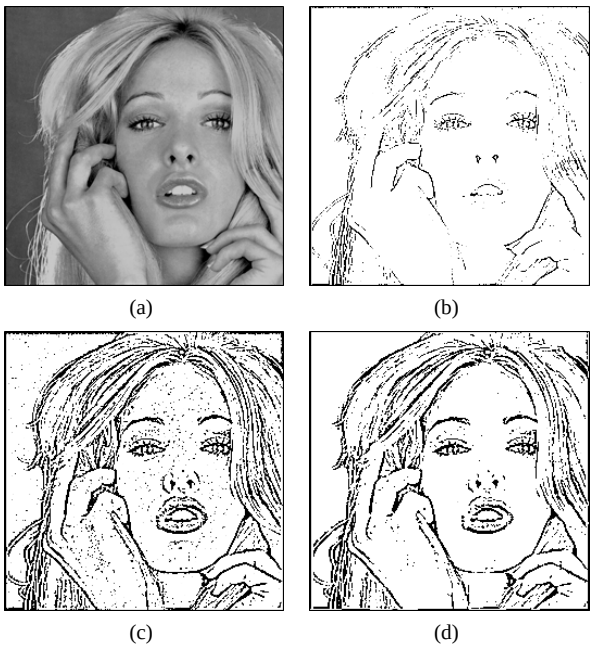

(a) (b) (c) (d)

Figure 9: Simulation result 3. (a) Input image (Woman). (b) Result of 3×3 template . (c) Result of 5×5template. (d) Result of proposed model.