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Advanced Edge Detection Using Small World Cellular Neural Network

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1. Introduction

A few years ago, Tsuruta et al. have proposed Small World Cellular Neural Networks (SWCNN). SWCNN is the system that shortcut connections are introduced into the original CNN and can be applied to some image processing tasks. We have investigated the performance of the SWCNN by changing the structure of the network keeping the number of all branches same and have clarified that the SWCNN can realize edge detection of gray scale images. In this study, we propose a new SWCNN system for better edge detection of gray scale images.

2. Proposed SWCNN Model

The CNN has nonlinear processing units called cells. Cells are arranged in a reticular pattern to M lines and N rows. We represent a cell $C(i,j)$ using i which denotes vertical position and j which denotes horizontal position. The state equation of the cell and parameters for edge detection in the proposed SWCNN system are as follows.

State Equation:

$$\dot{x}_{ij}(t) = -x_{ij}(t) + I + \sum_{C(k,l)\in N'r(i,j)} A(i,j;k,l)y_{kl}(t) - \sum_{C(k,l)\in N'r(i,j)} B(i,j;k,l)u_{kl} - C_0 \times \left| \sum_{C(k,l)\in N'r(i,j)} C(i,j;k,l)u_{kl}(t) \right|. \quad (1)$$

Parameters for edge detection:

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, C = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}, I = -1.$$

$$B = \begin{bmatrix} -4 & 0 & 4 \\ -4 & 0 & 4 \\ -4 & 0 & 4 \end{bmatrix}, \begin{bmatrix} -4 & -4 & 0 \\ -4 & 0 & 4 \\ 0 & 4 & 4 \end{bmatrix}, \begin{bmatrix} -4 & -4 & -4 \\ 0 & 0 & 0 \\ 4 & 4 & 4 \end{bmatrix}, \begin{bmatrix} 0 & -4 & -4 \\ 4 & 0 & -4 \\ 4 & 4 & 0 \end{bmatrix},$$
$$\begin{bmatrix} 4 & 0 & -4 \\ 4 & 0 & -4 \\ 4 & 0 & -4 \end{bmatrix}, \begin{bmatrix} 4 & 4 & 0 \\ 4 & 0 & -4 \\ 0 & -4 & -4 \end{bmatrix}, \begin{bmatrix} 4 & 4 & 4 \\ 0 & 0 & 0 \\ -4 & -4 & -4 \end{bmatrix}, \begin{bmatrix} 0 & 4 & 4 \\ -4 & 0 & 4 \\ -4 & -4 & 0 \end{bmatrix}$$

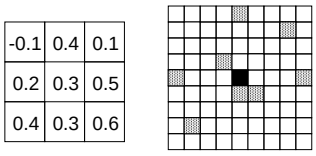
In the state equation (1), $N'_r(i,j)$ describes the set of neighboring cells which $C(i,j)$ has. $N_r(i,j)$ denote neighboring cells in the conventional CNN and is described by the following equation.

$$N_r(i,j) = \{C(k,l) | \max|k-l|, |l-j| < r, \quad 1 < k < M; 1 < l < N\} \quad (2)$$

In the proposed SWCNN system, $N_r(i,j)$ are changed according to the following condition (4).

$$u_{min} \leq |u_{ij} - u_{kl}| \leq u_{max} \quad (3)$$

If the input u_{kl} of neighboring cells $C(k,l)$ satisfies the above condition, the connections must be reconnected to shortcuts that have the same directions with the old connections with the distance Lm. Figure 1(b) shows an example of $N'_r(i,j)$ when the neighboring input of Fig. 1(a) is given to $C(i,j)$. Since the template B for the proposed method has 8 diffrent sets, the final output image is obtained by combining 8 output images. In the state equation (1), the 5th term decreases the unfavorable ingredient in output image. C_0 is the parameter controling the effect of this operation.



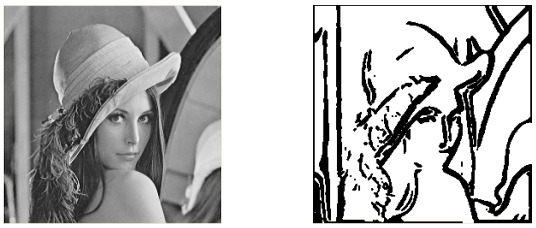
(a) (b)

Figure 1: An example of $N'_r(i,j)$ of $C(i,j)$ with neighboring inputs (a). (a) Neighboring inputs. (b) $N'_r(i,j)$.

4. Simulation results

In this section, we explain the flow of proposed method. First, we perform the 8 difference processing with the SWCNN system and we get the first 8 output images. Next, we perform noise reduction from the first output images and we get the second output images. Next, we perform or operation for 8 second output images and we get final output image (Fig. 2 (b)).

Figure 2 shows the simulation result. Input image is Fig. 2(a). We set the parameters as follows for this simulation. $u_{\min} = 0.001$, $u_{\max} = 0.2$, $Lm = 4$, $C_0 = 0.8$. From the result, the complex hair edge lines can be detected by the proposed system.



(a) (b)

Figure 2: Simulation results of edge detection using the proposed SWCNN system. (a) Input image. (b) Output image using the proposed SWCNN system.

4. Conclusions

In this article, we have proposed a new SWCNN system and investigated the features and the usefulness. We have applied the proposed SWCNN to edge detection of gray scale images and we clarified that the proposed SWCNN system realized to detect the complex hair edge lines.

Reference

[1] L.O. Chua and L. Yang, *"Cellular Neural Networks: Theory And Applications,"* IEEE Trans. Circuits & Syst., vol. 35, pp. 1257-1290, Oct. 1988.