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Noise Removal and Edge Detection by Three-Layer Cellular Neural Networks with A New Layer Arrangement

Muhammad IZZAT bin Mohd Idrus Yoshihiro KATO
Yoko UWATE Yoshifumi NISHIO
(Tokushima University)

1. Introduction

Cellular Neural Networks (CNN) were introduced by L. O. Chua and Lin Yang [1]. The idea of the CNN was inspired from the architecture of the cellular automata and the neural networks. Compare to the conventional neural networks, the CNN has local connectivity property. The CNN has been researched in various ways such as image processing and pattern recognition.

The two-layer CNN showed better performance than single layer CNN in some image processing [2]. Recently, three-layer CNN has been proposed to get better performance in color image processing [3].

In this study, we propose a new layer arrangement of three-layer CNN. We investigate the output characteristics between the single layer CNN, two-layer CNN and the proposed structure by apply to the binary and gray-scale images for edge detection and noise removal simultaneously.

2. Proposed Structure

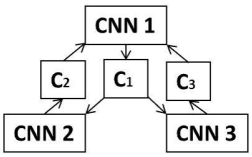


Figure 1: Block Diagram of the proposed structure.

Figure 1 shows the arrangement of the proposed structure. The output of the first layer CNN (CNN1) is delivered into the second layer CNN (CNN2) and third layer CNN (CNN3) by through coupling template (C_1). In other way, the outputs of the CNN2 and the CNN3 are delivered into the CNN1 by through coupling templates (C_2) and (C_3) respectively. This arrangement is the different point between the proposed structure and the previous structure of three-layer CNN.

3. Simulation Results

In this section, we show simulation results by using the proposed structure. In this simulation, we use three types of templates which are "*Small object remover*", "*Edge detection*" and "*Smoothing*". This idea is inspired from previous study which was two templates "*Edge detection*" and "*Smoothing*" have been used in the two-layer CNN [2]. In our designed template, we simply add one more template which is "*Small object remover*" to remove some small noises in the image. The templates of the proposed method are designed as follows.

*Template of CNN*1 :

$$A_1 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix},\ B_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix},\ I_1 = 0. \quad (1)$$

*Template of CNN*2 :

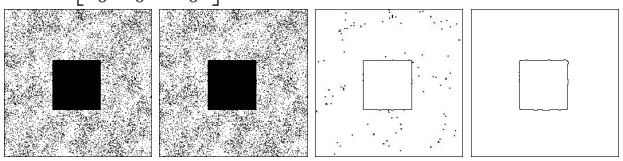
$$A_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix},\ B_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix},\ I_2 = -1. \quad (2)$$

*Template of CNN*3 :

$$A_3 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix},\ B_3 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix},\ I_3 = -0.5. \quad (3)$$

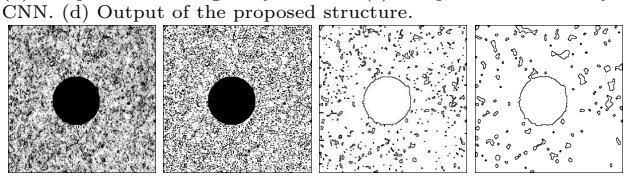
Coupling Templates :

$$C_1 = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix},\ C_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix},$$
$$C_3 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & 0 \end{bmatrix}. \quad (4)$$



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

Figure 2: Simulation results of binary image. (a) Input image. (b) Output of the single layer CNN. (c) Output of the two-layer CNN. (d) Output of the proposed structure.



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

Figure 3: Simulation results of gray-scale image. (a) Input image. (b) Output of the single layer CNN. (c) Output of the two-layer CNN. (d) Output of the proposed structure.

Figure 2(a) and Fig. 3(a) show noisy images of binary and gray-scale respectively. We compare the results between the single layer CNN, the two-layer CNN and the proposed structure. For the binary image, the output of the single layer CNN does not show almost anything difference between input image. In Fig. 2(c), the output of the two-layer CNN shows that edge of square can be detected. However, the noises cannot be removed completely. In Fig. 2(d), the output of proposed structure shows that noises can be removed in binary image and also edge of square can be detected. For the gray-scale image, the output of the single layer CNN does not show almost anything difference between input image. In Fig. 3(c) and Fig. 3(d), the output of the two-layer CNN and the proposed structure are almost same in detection of edge of circle. However, in noise removal's performance, the output of the proposed structure shows slightly better than the output of the two-layer CNN.

From these results, we can say that the proposed structure is the most effective structure for this study of image processing.

4. Conclusions

In this study, we have proposed a new layer arrangement of three-layer CNN. In the proposed structure, we only use one single layer CNN to connect with the other two single layer CNNs. From the simulation results of the proposed structure, we can say that the proposed structure have potential in image processing.

References

[1] L. O. Chua and L. Yang, "Cellular Neural Networks: Theory," IEEE Trans. Circuits Syst., vol. 32, pp. 1257-1272, Oct. 1988.
[2] Z. Yang, Y. Nishio and A. Ushida, "Image Processing of Two-Layer CNNs:Applications and Their Stability," IEICE Trans. Fundamentals, vol. E85-A, No. 9, pp. 2052-2060, Sept. 2012.
[3] T. Inoue and Y. Nishio, "Research of Three-Layer Cellular Neural Networks Processing Color Images," IEICE Technical Report, NLP2008-25, pp. 33-36, Jul. 2008.