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Analysis of Small World CNN with Limited Connection Length

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1. Introduction

The Cellular Neural Network (CNN) has been successfully used for various high speed parallel signals processing applications such as image processing and pattern recognition. A few years ago, Tsuruta et al. have proposed Small-World Cellular Neural Network (SWCNN) model, which is constructed by introducing some random couplings between separated cells (hereafter we call this connection SW connection) [1]. Direction-Preserving SWCNN (DP-SWCNN) is obtained by rewiring some original connections by SW connections with keeping the direction [2].

Although SWCNN has some potential applications including watermarking, circuit implementation is complicated because of SW connections with random structure. In this study, we consider the case that the length of SW connection is limited to simplify the structure of SWCNN and investigate the performance of the network.

2 Proposed DP-SWCNN Model

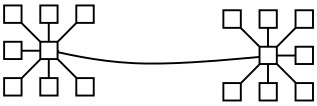


Figure 1: SW connection between two cells of the proposed DP-SWCNN.

The proposed DP-SWCNN is obtained by rewiring some original connections of the regular CNN by SW connections with random length less than a given maximum length Lm. Further, we modify the connection method of the DP-SWCNN in [2]. Namely, the original connections from the two cells connected a SW connection are removed if the connections are toward the same direction as the SW connections as shown in Fig. 1.

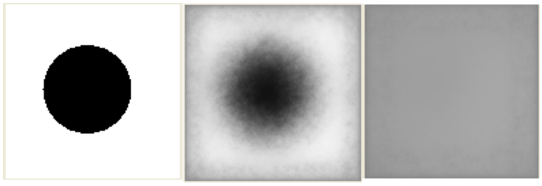
The state equation of each cell $C(i,j)$ of the proposed DP-SWCNN is formulated by Eq. (1). In Eq. (1), y_{pq} is the output of the two cells connected by the SW connections. The parameters a and b denote the position numbers of the eliminated neighbor cells. In this study, we fix the rewiring rate p_c is equal to 1.

$$\dot{x}_{ij}(t) = -x_{ij}(t) + I + \sum_{\substack{kl\in N_r(i,j)\\ kl\notin ab}} A_{ij;kl}\, y_{kl}(t) + \sum_{kl\in N_r(i,j)} B_{ij;kl}\, u_{kl}(t) + A_{ij;ab}\, y_{pq}(t) \qquad (1)$$

3. Simulation Results of Diffusion Analysis

We apply the proposed DP-SWCNN to diffusion analysis. The size of the network is 128×128. Figure 2 shows an example of the simulated results of diffusion with the maximum length of the SW connection Lm =10.

Figure 3 shows the relation between Lm and the convergence time. Figure 4 shows the relation between Lm and the characteristic path length of the small-world network.



(a) (b) (c)

Figure 2: Simulation result of diffusion (Lm =10). (a) Initial image. (b) Output image at t =1000. (c) Steady state output image.

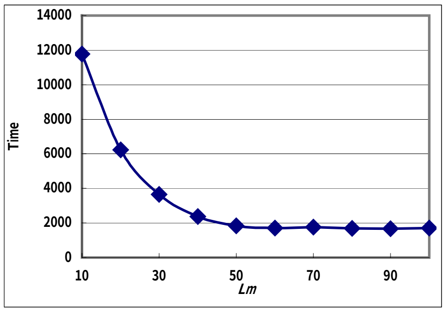


Figure. 3: Convergence time.

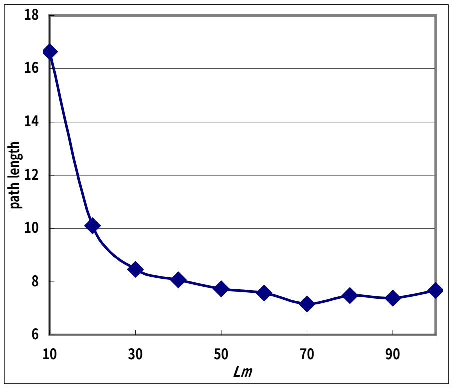


Figure 4: Characteristic path length.

4. Conclusion

In this study, we have proposed a new type of DP-SWCNN and have investigated its basic characteristics. Development of new applications using the proposed DP-SWCNN is an important future work.

Reference

[1] K. Tsuruta, Z. Yang, Y. Nishio, A. Ushida, "Small-World Cellular Neural Networks for Image Processing Applications," Proceedings of European Conference on Circuit Theory and Design (ECCTD'03), vol. 1, pp. 225-228, Sep. 2003.

[2] K. Tsuruta, Z. Yang, Y. Nishio, A. Ushida, "Diffusion Analysis of Direction-Preserving Small-World CNN," Proceedings of IEEE International Workshop on Cellular Neural Networks and their Applications (CNNA'04), pp. 352-357, Jul. 2004.