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Relationship between a Number of Cells and Phenomena in Cellular Neural Networks Using Three Kinds of Cloning Templates

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Abstract

Cellular Neural Networks (CNNs) have been investigated by many researchers. Additionally, many kinds of modified CNNs have been proposed. In this study, CNN using three kinds of cloning templates which is one of modified CNNs is investigated. The cells are coupled as triangle lattices. Three kinds of cloning templates are placed uniformly. The system was proposed as one of coupled oscillatory systems. Some oscillatory phenomena including chaos are observed.

1. Introduction

There are many studies of coupled oscillatory systems. In these systems, observed phenomena are influenced by the network structures which are ladder, ring, full-coupled and so on. On the other hand, some interesting phenomena can be observed in Cellular Neural Networks (CNN)[1][2] using two kinds of cloning templates in [3]. Oscillatory phenomena are observed in the system. It mean that the system is one of novel coupled oscillatory systems. However, remarkable phenomena are not observed.

Cellular neural networks using three kinds of cloning templates are reported in [4]. This system consists of three kinds of cells which have different cloning templates. Chaotic phenomena in CNN using three cells which have different cloning templates are reported in [5]. Therefore, the proposed system is one of chaotic coupled oscillatory systems and a novel coupled system. The element of the system is coupled as triangle lattice. By applying symmetric cloning template, the system becomes homogeneous coupled system.

In this study, a relationship between a number of cells and phenomena in cellular neural networks using three kinds of cloning templates is investigated.

2. Cellular neural networks using three kinds of cloning templates

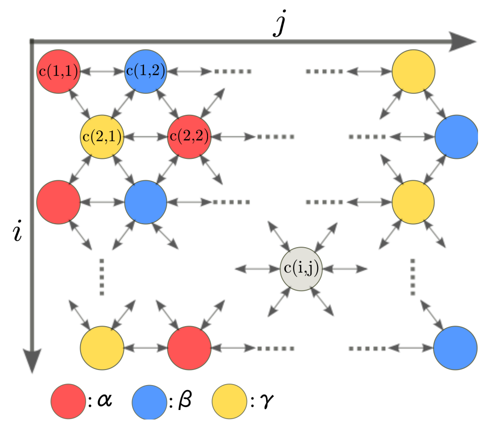

Figure 1: Structure of cellular neural networks using three kind of cloning templates.

Figure 1 shows a structure of cellular neural networks using three kinds of cloning templates. Cells are coupled as triangle lattice. The system consists of three kinds of cells which name is Cell α, Cell β or Cell γ. The difference of three kinds of cells is only values of cloning templates. By setting the boundary condition as a periodic condition, three kinds of cells are placed uniformly as shown in Fig. 1.

The state equations are shown as follows.

Cell α:

$$\frac{dx_{ij}}{dt} = -x_{ij} + I_\alpha + \sum_{c(k,l)} A_\alpha(i,j;k,l)y_{kl} + \sum_{c(k,l)} B_\alpha(i,j;k,l)u_{kl} \quad (1)$$

Cell β:

$$\begin{aligned}\frac{dx_{ij}}{dt} =& -x_{ij} + I_\beta \\ &+ \sum_{c(k,l)} A_\beta(i,j;k,l) y_{kl} \\ &+ \sum_{c(k,l)} B_\beta(i,j;k,l) u_{kl}\end{aligned} \tag{2}$$

Cell γ:

$$\begin{aligned}\frac{dx_{ij}}{dt} =& -x_{ij} + I_\gamma \\ &+ \sum_{c(k,l)} A_\gamma(i,j;k,l) y_{kl} {}_{x_a x} \\ &+ \sum_{c(k,l)} B_\gamma(i,j;k,l) u_{kl}\end{aligned} \tag{3}$$

where $A_{\{\alpha\beta\gamma\}}(i,j;k,l)y_{kl}$, $B_{\{\alpha\beta\gamma\}}(i,j;k,l)u_{kl}$, $I_{\{\alpha\beta\gamma\}}$ show feedback value, input value, bias value, respectively.

The output function is shown as follows.

$$y_{ij} = f(x_{ij}). \tag{4}$$

where

$$f(x) = 0.5(|x+1| - |x-1|). \tag{5}$$

In this study, symmetric cloning template is set as follows for keeping a symmetric property.

$$\begin{aligned}\boldsymbol{A}_\alpha &= \begin{pmatrix} & k & & l & \\ l & & 1.24 & & k \\ & k & & l & \end{pmatrix}, \\ \boldsymbol{A}_\beta &= \begin{pmatrix} & -m & & k & \\ k & & 1.1 & & -m \\ & -m & & k & \end{pmatrix}, \\ \boldsymbol{A}_\gamma &= \begin{pmatrix} & l & & m & \\ m & & 1.0 & & l \\ & l & & m & \end{pmatrix}, \\ \boldsymbol{B}_\alpha &= \boldsymbol{B}_\beta = \boldsymbol{B}_\gamma = 0 \text{ and} \\ I_\alpha &= I_\beta = I_\gamma = 0.\end{aligned} \tag{6}$$

where k, l, m show the coupling strengths between Cell α and Cell β, Cell α and Cell γ, Cell β and Cell γ, respectively. $\boldsymbol{B}_{\alpha,\beta,\gamma}$ and $\boldsymbol{I}_{\alpha,\beta,\gamma}$ are set as 0 because the purpose of this system is the investigation as a coupled system. Using system equations Eq. (1) - (6), computer simulations are carried out.

3. Computer simulations

We define an unit which consists of two Cell α, two Cell β and two Cell γ as shown in Fig. 2. In this study, one, two and four cases are investigated.

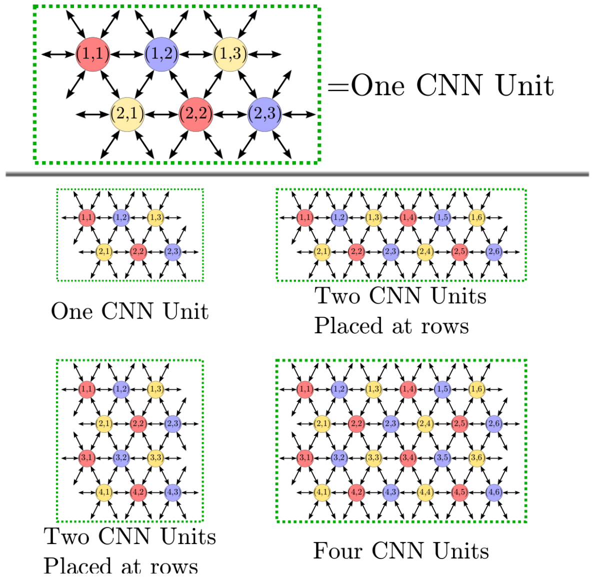

Figure 2: Definition of CNN units in this study.

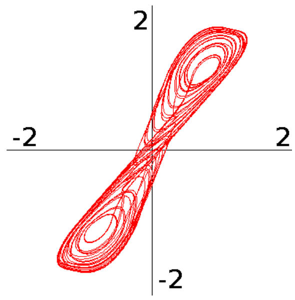

Figure 3: Chaotic phenomena in the case of three cells.

3.1 Three cells case

As a reference, the case of three cells are shown in Fig. 3. This case was reported in [5]. Figure 3 shows the simulation result. A double-scroll type attractor is observed. By changing parameter k, some periodic orbits, bifurcation phenomena and chaos are observed.

3.2 One CNN unit case (six cells)

Figure 4- 6 shows the case of six cells. Clustering phenomena are observed. Six cells are divided into two groups. $c(1,1)$ and $c(1,2)$ have very similar waveforms and inverse waveform of $c(1,3)$ is also similar to $c(1,1)$. Similarly, $c(2,1)$, $c(2,2)$ and $c(2,3)$ have also similar waveforms. Namely, each group consists of same row cells in Fig. 2. Note that these are not synchronized. By changing a parameter k or l, sojourn time of high or low waveforms is changed. Figure 5 shows a case of increasing a parameter k. Sojourn time

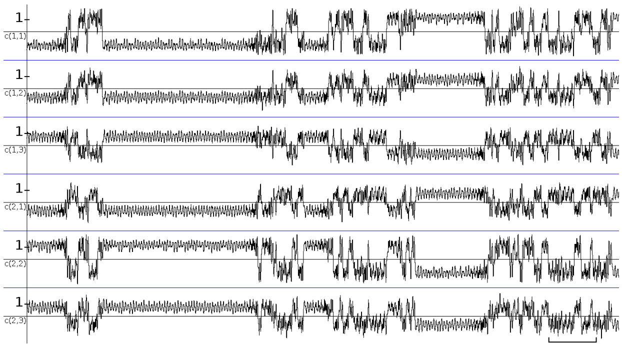

Figure 4: Waveforms in the case of six cells. $k = -1.06$, $l = -1.07$ and $m = 1.47$.

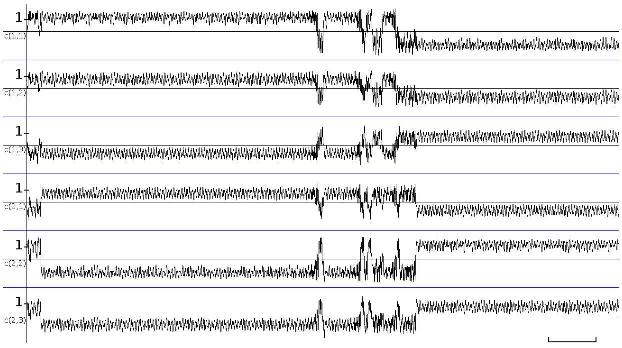

Figure 5: Waveforms in the case of six cells. $k = -1.05$, $l = -1.07$ and $m = 1.47$.

of high or low waveforms is increased. On the other hand, decreasing a parameter k decreases sojourn time as shown in Fig. 6.

3.3 Two CNN units placed at rows case (Twelve cells)

Figure 7 shows a simulation result in the case of two CNN units placed in two rows. Four groups which consists of same row cells are observed. By changing a parameter k or l, sojourn time of high or low waveforms is changed.

3.4 Two CNN units placed at columns case (Twelve cells)

Figure 8 shows a simulation result in the case of two CNN units placed in two columns. However, a synchronization of switching phenomena are observed as shown in the center of Fig. 8. Additionally, the relationship between parameters k or l and sojourn time of waveforms is disappeared.

3.5 Four CNN units case

Figure 9 shows a simulation result in the case of four CNN units case. Clustering phenomena as shown in the left side

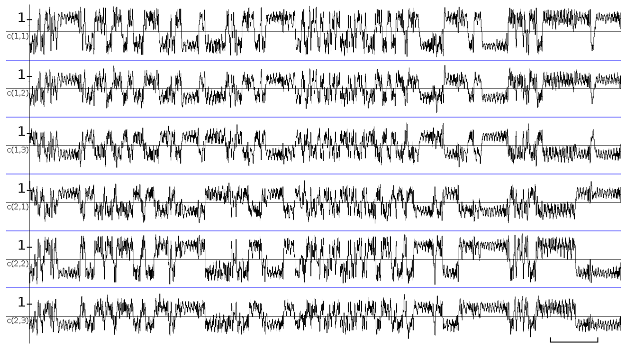

Figure 6: Waveforms in the case of six cells. $k = -1.095$, $l = -1.07$ and $m = 1.47$.

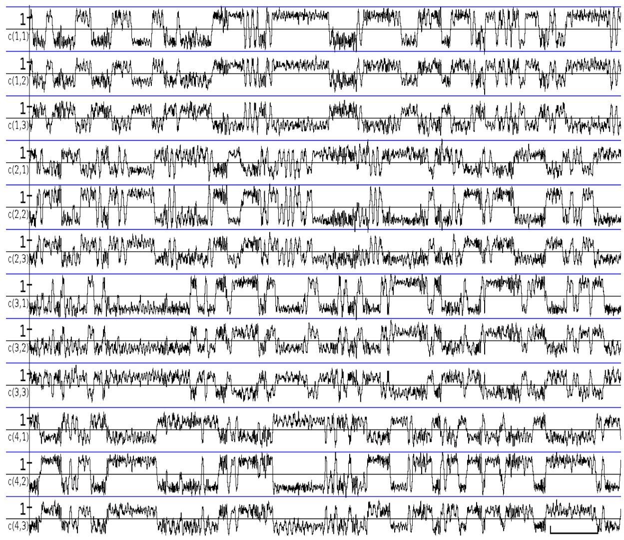

Figure 7: Waveforms in the case of two rows. $k = -1.06$, $l = -1.07$ and $m = 1.47$.

of Fig. 9 are observed. These clusters are depend on initial states. Two kinds of oscillatory phenomena (left side and right side of Fig. 9) are observed alternately. These switching is almost same timing. Note that these waveforms are not synchronized. By changing a parameter k or l, sojourn time of high or low waveforms is changed.

4. Considerations

In one CNN unit case and two CNN units placed at rows case, same row cells become one cluster. The reason is considered as follows. Cell α, Cell β and Cell γ are placed at one row in turn. Therefore, one row becomes one loop which consists of Cell α, Cell β and Cell γ.

In the other case, any cells can not become the loop. Therefore, a cluster which consists of same cells can not observed.

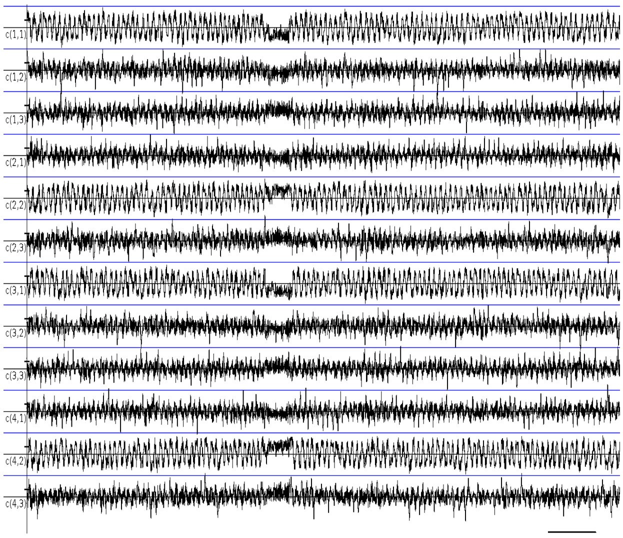

Figure 8: Waveforms in the case of two columns. $k = -1.20$, $l = -1.30$ and $m = 2.50$.

In two CNN units placed at columns case, each cell connects to the other one by twice. For instance, $c(1,1)$ in Fig. 2 is connected to $c(2,1)$ by upper right and lower right. This is the reason of why this case differ from other results.

5. Conclusions

In this study, cellular neural networks using three kinds of cloning templates have been proposed. Some computer simulations were carried out. In cases of one CNN unit case and two units case, clustering phenomena are observed. The clusters do not depend on initial values. Additionally, switching phenomena are observed in all cases.

Difference of results means that clustering phenomena are influenced by the number of cells and the structure. In the future work, symmetrical case which consists of nine cells will be investigated.

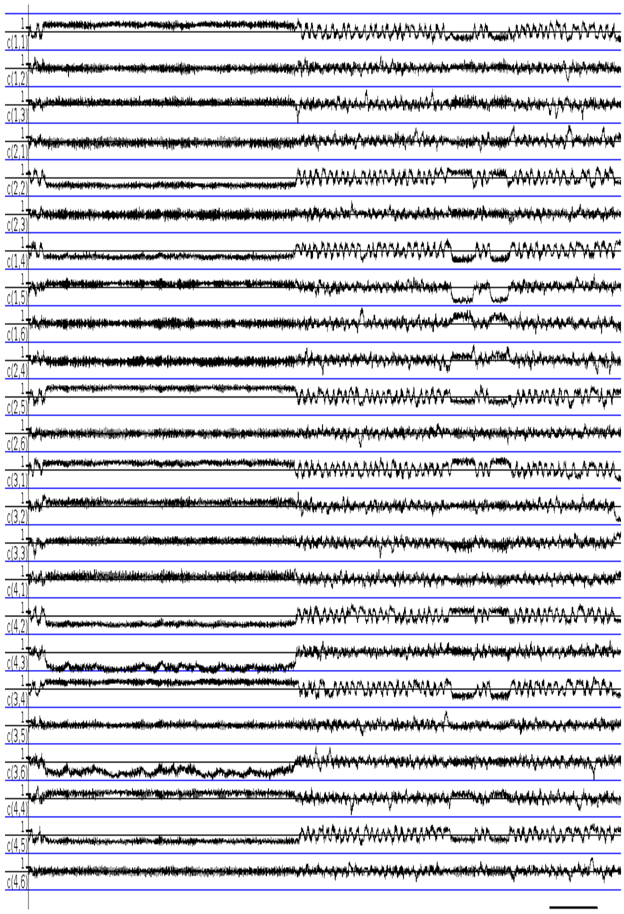

Figure 9: Waveforms in the case of twenty four cells. $k = -1.26$, $l = -1.20$ and $m = 2.50$.

References

[1] L. O. Chua and L. Yang, "Cellular Neural Networks: Theory," *IEEE Trans. Circuits Syst.*, vol. 35, no. 10, pp. 1257–1272, 1988.

[2] L. O. Chua and L. Yang, " Cellular Neural Networks: Applications," *IEEE Trans. Circuits Syst.*, vol. 35, no. 10, pp. 1273–1290, 1988.

[3] J. Fujii, Y. Hosokawa and Y. Nishio, "Wave Phenomena in Cellular Neural Networks Using Two Kinds of Template Sets," *Proc. of NOTLA '07*, pp. 23–26, 2007.

[4] M. Tanaka, Y. Hosokawa and Y. Nishio, "Chaotic Phenomena in Cellular Neural Networks Using Three Kinds of Cloning Templates," *Proc. of NCN '13*, pp. 30–33, 2013.

[5] F. Zou, and J. A. Nossek, " Bifurcation and chaos in cellular neural networks," *IEEE Trans. Circuits Syst. I*, vol. 40, no. 3, pp. 166–173, 1993.