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Phase-Wave Propagation Phenomena in Two-Dimensional Cellular Neural Networks

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1. Introduction

Cellular Neural Networks (CNN) are constructed by many cells connected each other. The cell contains linear and nonlinear current sources controlled by voltage. Investigating the nonlinear phenomena is an important work for clarifying dynamics of CNNs.

One of the nonlinear phenomena observed in CNNs is phase-wave propagation phenomena [(1)]. The CNN constructed by 2 cells can oscillated by choosing appropriate parameters. Coupling oscillating CNNs, 1-dimensional 2-layer CNN can be construc ted. Putting initial phase difference to any cells in 1-dimensional 2-layer CNN, phase-wave propagation phenomena that the phase difference is propagate to other cells could be observed.

In this work, we report nonlinear phenomena could be observed in 2-dimensional CNNs.

2. 2-Dimensional CNN

In this study, we consider what kind of phenomena can be observed in the CNN oscillators coupled in 2-dimension.

We use 2-layer 2-Dimension modified CNN as shown in Fig. 1.

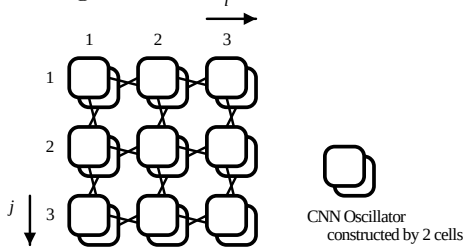

Fig.1: 2-Dimension Array constructed by CNN Oscillators (3×3)

The circuit equation governing the CNN in Fig. 1 are written as

$$\dot{x_{1,i,j}} = -x_{1,i,j} + a_1 y_{1,i,j} + c_1 x_{2,i,j} \quad (1)$$

$$\dot{x_{2,i,j}} = -x_{2,i,j} + a_2 y_{2,i,j} + c_2 x_{1,i,j} \quad (2)$$

$$+d_2 \left(y_{1,i,(j-1)} + y_{1,i,(j+1)} + y_{1,(i-1),j} + y_{1,(i+1),j} \right) \quad (3)$$

$$y_{\ell,i,j} = 0.5 \left(|x_{\ell,i,j} + 1| - |x_{\ell,i,j} - 1| \right) \quad (4)$$

$$(i = 1, 2, \cdots, M, \quad j = 1, 2, \cdots N, \quad \ell = 1, 2)$$

where $x_{\ell,i,j}$ is the state, $y_{\ell,i,j}$ is the output of $\mathrm{CELL}_{\ell,\mathrm{i,j}}$. This modified CNN is different from the original CNN in state feedback from the cell which is at the same position in the other layer. a_ℓ, c_ℓ and d_ℓ are the feedback parameters form the output its own cell, from *state* of the cell which is at the same position in the other layer, and from the output of the neighborhood cell in the other layer, respectively.

For numerical analysis we use this set of parameters which are same values at 1-Dimension CNN, as shown follows,

$$a_1 = 1, c_1 = 1, a_2 = 1.2, c_2 = -1.1, d_2 = 0.05$$

3. Simulation Result

For numerical simulation, we consider 2-dimensional CNN constructed by 9 cells, $M = 3$, $N = 3$. And the initial conditions are given as follows:

Table 1: Initial State $x_{h,i,j}(0)$

(a) $x_{1,i,j}(0)$

		i		
		1	2	3
j	1	1.0	-1.0	-1.0
	2	-1.0	1.0	1.0
	3	-1.0	1.0	1.0

(b) $x_{2,i,j}(0)$

		i		
		1	2	3
j	1	0.0	0.0	0.0
	2	0.0	0.0	0.0
	3	0.0	0.0	0.0

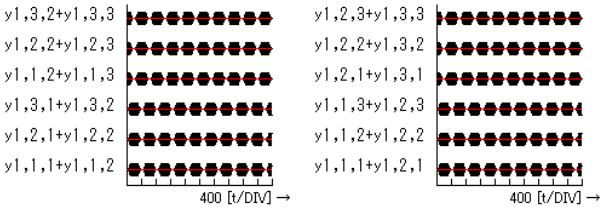

Fig.2: Simulation Result

4. Conclusions

In this works, we could be observed phase-wave propagation phenomena in 2-dimensional CNNs. We can observe phase-wave propagation phenomena to horizontal and vertical directions.

(1) Z. Yang, K. Tsuruta, Y. Nishio and A. Ushida, "Investigation of phase-wave propagation phenomena in second order CNN arrays", Proc. of ISCAS'04, vol. 3, pp. 49-52, 2004.