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Phasewave Propagation Phenomena in 2-Dimensional Cellular Neural Networks

Koji URABE
Dept. Electronic Control Eng.,
Niihama N.C.Tech.
coji@ect.niihama-nct.ac.jp

Yoshifumi Nishio
Dept. Electrical and Electronic Eng.,
Tokushima University
Email: nishio@ee.tokushima-u.ac.jp

***Abstract*— Investigating the nonlinear phenomena is an important work for clarifying dynamics of CNNs. One of the nonlinear phenomena observed in 1-Dimensional CNNs is phase-wave propagation phenomena. For applying to image processing by the phase-wave propagation phenomena, in this work, we report nonlinear phenomena could be observed in 2-dimensional CNNs.**

I. 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.

II. 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.

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

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

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

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

$$y_{\ell,i,j} = 0.5\left(|x_{\ell,i,j}+1| - |x_{\ell,i,j}-1|\right) \tag{3}$$

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

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.

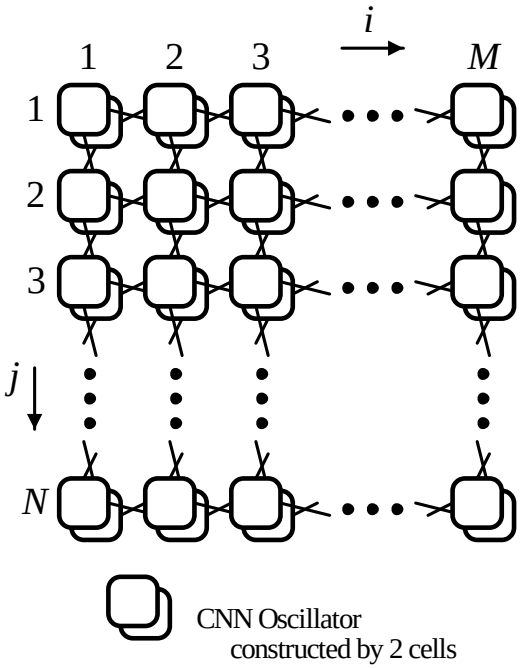

Fig.1: 2-Dimension Array constructed by CNN Oscillators ($N \times M$)

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

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

III. Simulation Results

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

(a) (b)

Fig.2: Simulation Result

Simulation Results are shown in Fig. 2, The horizontal axis is time, the vertical axis in Fig. 2 (a) is the sum of voltages of vertical adjacent outputs and the vertical axis in Fig. 2 (b) is the sum of voltages of horizontal adjacent outputs,

If the sum of voltages of adjacent outputs is zero, the phase difference between adjacent outputs is +180 [deg]. After transition, the phase difference +180[deg] is observed in cells shown as follows:

(A) Between the vertical positions 1 and 2
(B) Between the vertical positions 2 and 3
(C) Between the horizontal positions 1 and 2
(D) Between the horizontal positions 2 and 3

(A) and (B) are observed alternately and phase wave propagation phenomana is grenerated to vertical direction. (C) and (D) are observed alternately. and phase wave propagation phenomana is grenerated to horizontal direction, too.

From Fig. 2 (a) and (b), (A) and (C) are observed in the same time. (B) and (D) are observed in the same time, too.

IV. 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.

References

[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.

[2] K. Urabe and Y. Nishio, “Comparing Two-Layer CNN with van der Pol Oscillators Coupled by Inductors”, Proc. of NOLTA’06, pp. 723-726, Sep. 2006.