Associative Memory Function using Oscillators with Sparse Coupling

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1. Introduction

Associative memory is realized by using the synchronization phenomenon in the coupling system of van der Pol oscillators (VDP) [1]. However, this model has problems with wiring reduction and associative memory functionality during circuit implementation. In this study, sparse coupling is used to disconnect oscillators from each other and to evaluate associative memory.

2. System Model

The input pattern and the stored patterns are shown in Fig.1.

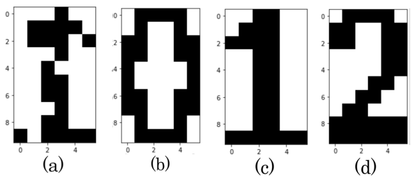

Figure 1: 6 × 10 patterns. ((a) is input pattern, (b), (c) and (d) are stored patterns).

A model of sixty mutually coupled VDPs used in this study. Figure 2 shows the circuit model of the VDP.

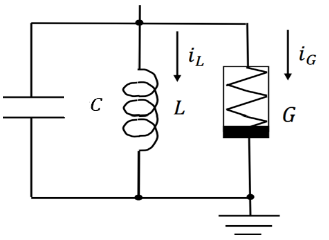

Figure 2: The circuit model of the VDP.

The normalized circuit equations are given as follows:

$$\begin{cases} \dfrac{dx_n}{d\tau} = \varepsilon x_n(1-x_n^2) - y_n + \alpha K \displaystyle\sum_{k=1}^{60}(x_n - x_k), \\ \dfrac{dy_n}{d\tau} = x_n \end{cases} \quad (1)$$

Where α is the connectivety matrix, it represents the state of coupling between oscillators, and it is possible to disconnect the coupling between the specified oscillators, different from the past studies.

3. Simulation Results

Simulations are performed with and without disconnection, and the phase differences are compared. Where the initial values of x and y are random between 0 and 0.1 ε=0.1, s=0.005, in Eq (1). Simulations are performed for τ=0 ∼ 2000. Associative memory is realized when Fig. 1 (c) is a correctly recalled pattern and it is the output pattern. Count is the number of times the reference oscillator passed through the Poincar section. Phase differences Fig. 2 (b) shows that the oscillators in the broken part of pattern Fig. 1 (a) are disconnected from 20 oscillators chosen at random.

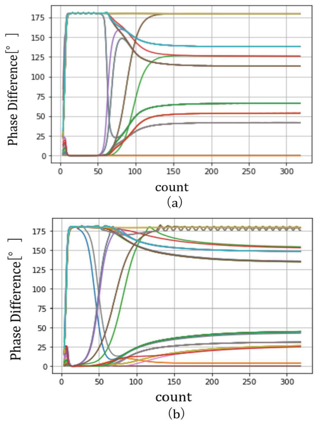

Figure 3: Phase differences.((a) Oscillator coupling is not disconnected,(b) Oscillator coupling is disconnected.)

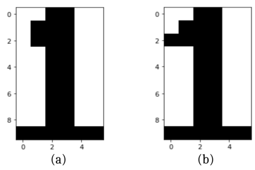

Figure 4: Recall paterns of simulation (a) and (b) (count=90).

From the simulation results, the phase difference is separated by 0 and 180 degrees for Fig. 3 (b). This means that the pattern of recall is fast and the black-and-white conservation pattern is clear.

4. Conclusion

In this study, we compared the performance of associative memory by partially disconnecting the coupling of oscillators using sparse coupling. As a result, black and white patterns were more clearly called out when the coupling was cut, because the phase difference was more obviously differentiated. In the future, we would like to be able to realize associative memory even when the number of stored patterns is increased.

References

[1] Kohei Yamamoto et al, "Analysis of Associative Memory Using Oscillator Synchronization, ", Proceedings of IEEE Workshop on Nonlinear Circuit Networks (NCN'21), 2021.