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Realization of Associative Memory using Synchronization of van der Pol Oscillators

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1. Introduction

In this study, associative memory is realized by using the synchronization phenomenon in the coupling system of van der Pol oscillators (VDP). The synchronization is controlled by setting the coupling strength of each VDP, and associative memory is realized based on the above.

2. Associative memory by the coupling VDPs

VDP used in this syudy is shown in Fig.1. All VDPs(W1∼W60) are mutually coupling via resistors. The circuit equation is normalized to Eq.(1).

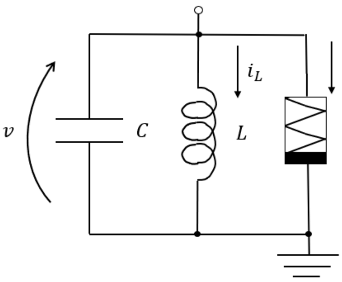

Figure 1: Circuit model of van der Pol Oscillator.

$$\begin{cases} \frac{dx_n}{d\tau} = \varepsilon x_n(1-x_n^2) - y_n + \sum_{k=1}^{60} K(x_k - x_n) \\ \frac{dy_n}{d\tau} = x_n \qquad n = 1, 2, ..., 60. \end{cases} \tag{1}$$

For Eq.(1), K is redefined as $K = \begin{cases} E_0 \times s \\ E \times s \end{cases}$,
s is the coupling strength, E_0 and E are the storage matrix determined based on the input pattern and stored patterns. The oscillators W1∼W60 are associated with the patterns from the top left, and f^0 and f^p create with black as -1 and white as 1. p is the number of patterns to be stored.

$$\begin{cases} f^0 = (f^0_{W1} \;\; f^0_{W2} \;\; f^0_{W3} \;\; \cdots \;\; f^0_{W60}) \\ f^p = (f^p_{W1} \;\; f^p_{W2} \;\; f^p_{W3} \;\; \cdots \;\; f^p_{W60}) \end{cases} \tag{2}$$

E_0 and E are defined as Eq.(3) using f^0 and f^p:

$$E_0 = f^{0T} f^0, \quad E = \sum_{k=1}^{p} f^{kT} f^k. \tag{3}$$

The recall is first synchronized with E_0, then changed to E for resynchronization. From the calculated phase, the pattern is output in the same color when it is synchronized with the reference oscillator W1, and in a different color when it is asynchronous.

3. Simulation of associative memory

Three patterns to be stored are shown in Fig.2(a)∼(c), and input the patterns shown in Fig.2(d).

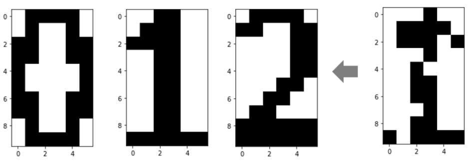

Figure 2: Stored and input patterns.

Calculate E_0 and E based on Fig.2. $0 \leq x, y \leq 0.1$ and $\varepsilon = 0.1$. $s = 0.01$, calculated with $\tau = 0 \sim 250$, and the storage matrix is replaced at $\tau = 50$. As a result, the pattern in Fig.3 was output and associative memory was realized.

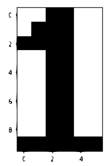

Figure 3: The recall pattern.

Figure 3 shows the result of inputting the broken 1 in Fig.2(d), but even when inputting the broken 0 and 2, it was possible to accurately recall 0 and 2.

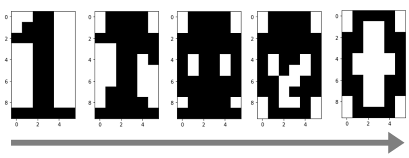

Figure 4: The recall pattern when $s = 0.1$.

Simulations were also performed when the coupling strength s was increased from 0.01. As an example, Fig.4 shows the simulation results for s = 0.1. As a result, associative memory could not be realized because of the phenomenon of recalling 0 or 1 depending on time. Therefore, it seems that associative memory cannot be realized with this method unless the binding strength is small.

4. Conclusion

In this study, associative memory of 6×10 patterns was realized with the coupling VDPs. However, in the coupling VDPs, it was also confirmed that if the coupling strength was too large, it would not be recalled properly.