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Statistical Analysis of Clustering in Chaotic Circuits Coupled by an Inductor

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1. Introduction

Spatiotemporal phenomena observed from large-scale coupled chaotic networks have attracted many researchers' attention and have been studied strenuously by many researchers [1].

In this study, we particularly focus on clustering phenomenon observed from continuous-time real physical systems. We statistically analyze clustering observed from six chaotic circuits coupled by an inductor in detail.

2. Circuit Model

Figure 1 shows a circuit model. In the circuit, N identical chaotic circuits are coupled by an inductor.

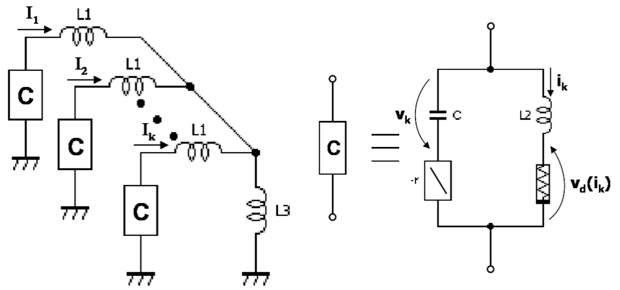

Figure 1: Circuit model.

First, we approximate the $i - v$ characteristics of the nonlinear resistor by the following function.

$$v_d(i_k) = \sqrt[9]{r_d\, i_k}. \qquad (1)$$

By using the following variables and parameters,

$$t = \sqrt{L_1 C}\,\tau, \quad a = \sqrt[8]{r_d \frac{C}{L_1}}, \quad \text{``}\cdot\text{''} = \frac{d}{d\tau},$$
$$I_k = a\sqrt{\frac{C}{L_1}}x_k, \quad i_k = a\sqrt{\frac{C}{L_1}}y_k, \quad v_k = az_k, \qquad (2)$$
$$\alpha = \frac{L_1}{L_2}, \quad \beta = r\sqrt{\frac{C}{L_1}}, \quad \gamma = \frac{L_3}{L_1 + L_3},$$

the circuit equations are normalized and described as

$$\begin{aligned} \dot{x}_k &= \beta(x_k + y_k) - z_k \\ &\quad - \frac{\gamma}{1+(N-1)\gamma}\sum_{j=1}^{N}\{\beta(x_j + y_j) - z_j\} \\ \dot{y}_k &= \alpha\{\beta(x_k + y_k) - z_k - f(y_k)\} \\ \dot{z}_k &= x_k + y_k \qquad (k = 1, 2, \cdots, N) \end{aligned} \qquad (3)$$

where

$$f(y_k) = \sqrt[9]{y_k}. \qquad (4)$$

3. Clustering Phenomenon

We carried out computer calculations for $N = 6$. Figure 2 shows a computer calculated result. From Fig. 2, we can confirm an occurrence of a clustering phenomenon and chaotic changes of the cluster size.

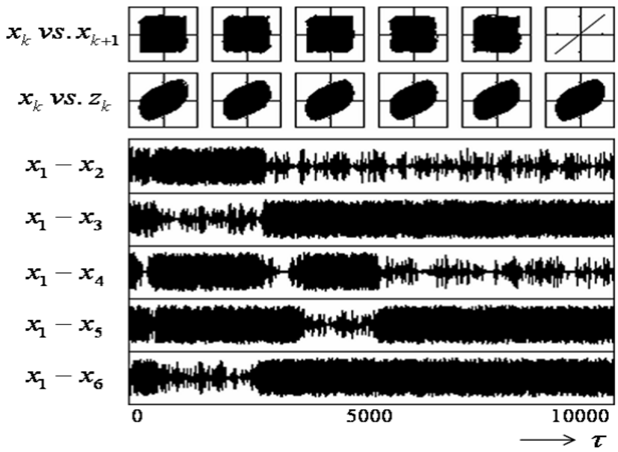

Figure 2: Computer calculated result for $N = 6$. $\alpha = 20.0$. $\beta = 0.265$. $\gamma = 0.3$. $(k = 1, 2, 3, 4, 5, 6.)$ $(x_7 = x_1.)$

4. Statistical Analysis

The probability distribution of cluster types is shown in Tab. 1. For example, the probability of the cluster type "2-1-1-1-1" is 3.006%. This cluster type means that any two subcircuits are synchronized and four others are asynchronous states and the number of clusters is 5.

Table 1: Probability distribution of cluster types.

Cluster type	Probability	Cluster type	Probability
1-1-1-1-1-1	0.00204	3-3	0.25662
2-1-1-1-1	0.03006	4-1-1	0.00033
2-2-1-1	0.10004	4-2	0.00048
2-2-2	0.00597	5-1	0.00000
3-1-1-1	0.08581	6	0.00000
3-2-1	0.51865		

5. Conclusions

In this study, we investigated clustering phenomenon observed from six chaotic circuits coupled by an inductor. We analyzed statistical information of the clustering, such as cluster types.

References

[1] Y. Nishio and A. Ushida, "Chaotic Wandering and its Analysis in Simple Coupled Chaotic Circuits" IEICE Transactions on Fundamentals, vol. E85-A, no. 1, pp. 248-255, Jan. 2002.