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Synchronization Phenomena of Coupled Chaotic Circuits with Different Network Topology

Katsuki NAKASHIMA Yoko UWATE Yoshifumi NISHIO
(Tokushima University)

1. Introduction

Nonlinear phenomena of coupled chaotic circuits are drawing attention from many researchers. In this study, we investigate the synchronization phenomena of coupled two symmetrical structures and the influence of the network topology. One network generates chaotic attractors and the other network generates three-periodic attractors. Moreover, we compare synchronization of symmetrical and asymmetrical structures.

2. System model

The chaotic circuit is shown in Fig. 1 and the system models are shown in Fig. 2. This chaotic circuit consists of two inductors L_1 and L_2, one capacitor C, negative resistor $-r$ and two diodes. We propose the system models that the two symmetrical structures are coupled by a resistor in Fig. 2(a). In addition, we propose the system models that the two asymmetric structures are coupled by a resistor in Fig. 2(a'). In Fig. 2(a) and (a'), we set CC1 to CC5 as chaotic solution and CC6 to CC10 as three periodic solutions.

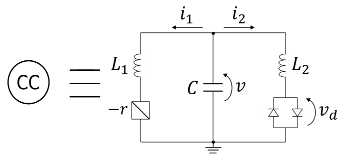


Figure 1: Chaotic circuit.

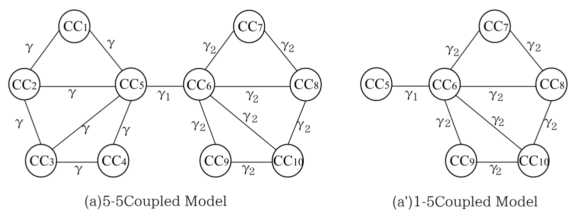


Figure 2: System models.

The normalized equations of chaotic circuits are given as follows:

$$\begin{cases} \dfrac{dx_i}{d\tau} = \alpha x_i + z_i \\ \dfrac{dy_i}{d\tau} = z_i - f(y_i) \\ \dfrac{dz_i}{d\tau} = -x_i - \beta y_i - \displaystyle\sum_{i,j=1}^{10} \gamma_{ij}(z_i - z_j) \\ \qquad (i, j = 1, 2, \cdots, 10). \end{cases} \quad (1)$$

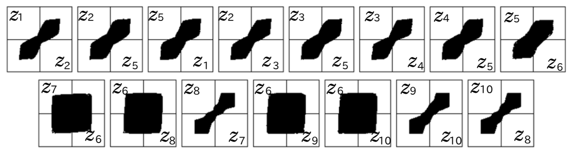
Where γ is the coupling strength. $f(y_i)$ is described as follows:

$$f(y_i) = \frac{1}{2}\left(\left|y_i + \frac{1}{\delta}\right| - \left|y_i - \frac{1}{\delta}\right|\right). \quad (2)$$

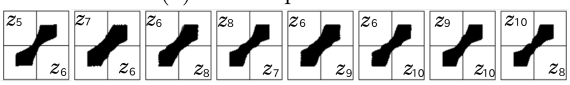
We define α_c to generate the chaotic attractor, and α_p is defined to generate the three-periodic attractors.

3. Simulation results

We set the parameters of the system as $\alpha_c = 0.460$, $\alpha_p = 0.412$, $\beta = 3.0$ and $\delta = 470.0$. In this study, we set the coupling strength γ as 0.2, the coupling strength γ_1 between the topologies as 0.1 and γ_2 as 0.01 in all models. Figure 3 shows the lissajous figure. Table 1 shows synchronization rate. From Fig. 3, between CC5 and CC6 are chaotic synchronization. In model(a), CC7-CC6, CC6-CC8, CC6-CC9 and CC6-CC10 are asynchronous. CC8-CC7, CC9-CC10 and CC10-CC8 are chaotic synchronization. Therefore, in CC8-CC7, CC9-CC10 and CC10-CC8, synchronous and asynchronous states changes irregularly in the simulation time.



(a) 5-5 Coupled model.



(a') 1-5 Coupled model.

Figure 3: Lissajous figures.

Table 1: Synchronization rate.

Circuit	5-5Coupled Model (%)	1-5Coupled Model (%)
1 − 2	53	
2 − 5	37	
5 − 1	34	
2 − 3	54	
3 − 5	38	
3 − 4	60	
4 − 5	34	
5 − 6	27	42
7 − 6	5	26
6 − 8	5	34
8 − 7	43	44
6 − 9	5	32
6 − 10	5	37
9 − 10	45	46
10 − 8	49	50

4. Conclusions

In this study, we have proposed system models using two symmetrical structures and asymmetrical structures that are coupled by a resistor. We have investigated the synchronization phenomena by changing the topology and the influence of topology. As a result, network with coupled symmetrical structures has a strong influence on one circuit that are coupled between the structures. However, network with coupled asymmetric structures has the influence on all of the circuits in topology.