1-11

Synchronization Phenomena in Coupled Chaotic Circuits with Coupling Strength Depending on Number of Links

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1. Introduction

In our living life, complex network can be seen in various fields. Synchronization phenomena observed in complex network have been investigated by many researchers. There are various investigations of synchronization using chaotic circuits.

In this study, we focus on indirect connection and coupling strength of coupled chaotic circuit network. Indirect coupling refers to a connection through multiple circuits. We set coupling strength depending the number of links. The network has scale free property.

2. System model

The chaotic circuit model is shown in Fig. 1. Figure 2 is network to used in this study. The point which constitute the network is called node and the lines connecting nodes are called links. Nodes having many links are called hubs.

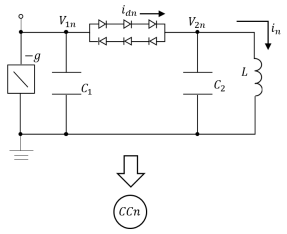

Figure 1: Circuit model.

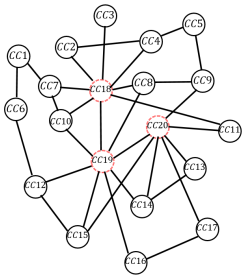

Figure 2: Network model.

Normalized circuit equations of the coupled chaotic circuits are as follows:

$$\begin{cases} \dfrac{dx}{d\tau} = z_n, \\ \dfrac{dy}{d\tau} = \alpha\gamma y_n - \alpha f(y_n - z_n) - \alpha\delta_{nm} \displaystyle\sum_{m\in S_n} (y_n - y_m), \\ \dfrac{dz}{d\tau} = f(y_n - z_n) - x_n. \end{cases} \tag{1}$$

In this equation, δ denotes the coupling strength. S_n is a set of nodes which are connected to CCn. We define synchronization as Eq. (2). Synchronization rate is ratio of number of synchronization to all calculate point.

$$|y_n - y_m| < 0.03 \qquad (n, m = 1, 2, \cdots, 20) \tag{2}$$

We decide coupling strength value based on the difference of links. The value of coupling strength is determined by degree of the node using Eq. (3).

$$\delta_{nm} = \frac{1.0}{1.0 + u} \tag{3}$$

We set that u is difference of degree between two nodes.

3. Simulation results

We investigate synchronization of CC18-CC19 when we change each coupling strength. Some link is multiplied magnification. We confirm synchronization when other links change synchronization of CC18-CC19. This link basically has about 80% synchronization rate. When synchronization rate reaches 50% to 70%, we judge that synchronization is changed. In Fig. 3, we represent some links. There are various types of these links. We choose indirect link, links with indirect and strong coupling strength, links far from CC18-CC19.

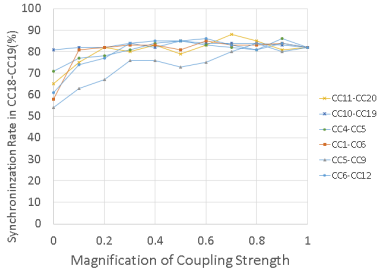

Figure 3: Synchronization rate of chosen links.

When some links of coupling strength are extremely weak, synchronization of CC18-CC19 is weakened. Next, we calculate magnification one by one for all links and investigate synchronization rate. Figure 4, we checked judged links.

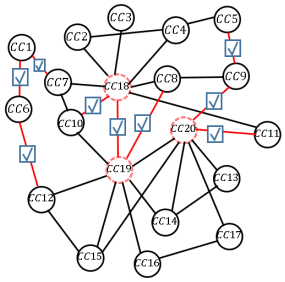

Figure 4: Judged links in network.

In this result, when some links open or extremely weaken the coupling strength, synchronization of far links is weaken.

4. Conclusion

In this study, we have investigated the influence of indirectry coupling by using a scale-free coupled chaotic network with changing the couplings strength. We compare some synchronization when the coupling strength was changed some values.

In this result, we found that the strength of synchronization is different even with the same coupling strength. We could not clarify the reason in this study. We must compare this result with other result. Next, we focus other links which have similar terms and simulate in the same way.