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Synchronization Phenomena of Coupled Chaotic Circuits Network with Distance-Dependent Coupling Strength

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1. Introduction

Modern phenomena and society can be expressed using the network. The occurrence of synchronization in the network has merit and demerit. When the synchronization rate is high in the network, the propagation of information and the likes is carried out quickly. However, there is a harmful effect that computer virus and infectious diseases and any other adverse effect.

In this study, we investigate how the synchronization changes when the coupling strength between the circuits is changed by distance, and how the synchronization changes depending on the position of the hub in the network.

2. System Model

The chaotic circuit model is shown in Fig. 1. Furthermore, the network model which we used in this study is shown in Fig. 2. The point that constitutes the network is called a node and the lines connecting them are called links. Nodes with many of these links are called hubs.

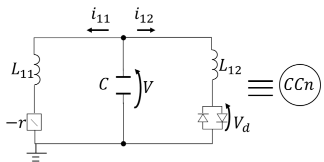

Figure 1: Circuit model.

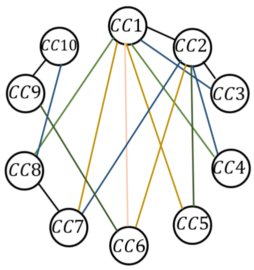

Figure 2: Network model.

Normalized circuit equations of coupled chaotic circuits are as follows:

$$\begin{cases} \dfrac{dx_i}{d\tau} = \alpha x_i + z_i, \\ \dfrac{dy_i}{d\tau} = z_i - \dfrac{1}{2}\left(\left|y_i + \dfrac{1}{\gamma}\right| - \left|y_i - \dfrac{1}{\gamma}\right|\right), \\ \dfrac{dz_i}{d\tau} = -x_i - \beta y_i - \displaystyle\sum_{k \in C_n}^{N} \delta_{ij}(z_i - z_j), \end{cases} \quad (1)$$

where C_n is set of nodes which are connected to CCn.

Figure 3 shows all length of the edge and name A to E. Table 1 shows the coupling strength when the shortest link's coupling strength is 1,000. "CStr" is the coupling strength. In this study, Method A is a state in which the arrangement of Fig. 2 is not changed. Method B is a state in which CC2 and CC6 are exchanged from the state of Fig. 2.

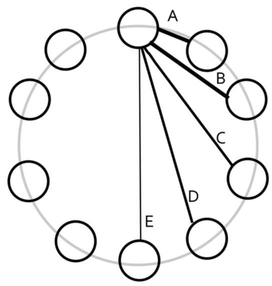

Figure 3: Definition of length.

Table 1: Coupling strength.

Link	A	B	C	D	E
CStr	1.000	0.145	0.055	0.032	0.029

3. Simulation results

In this study, we set the coupling strength A to E multiplied by 0.14. Tables 2 and 3 show the simulation results of the synchronization rate in method A and method B. "Link" means which link is to be referred. For example, "CC1-CC2" link is 1-2. "SRate" is the synchronization rate.

Table 2: Synchronization rate in method A.

Link	1-2	1-3	1-4	1-5	1-6	1-7	1-8	2-1
SRate[%]	44	37	15	6	8	26	25	41
Link	2-4	2-5	2-6	2-7	6-9	7-8	8-10	9-10
SRate[%]	14	6	7	26	11	41	26	41

Table 3: Synchronization rate in method B.

Link	1-2	1-3	1-4	1-5	1-6	1-7	1-8	2-1
SRate[%]	44	37	15	6	8	26	25	41
Link	2-4	2-5	2-6	2-7	6-9	7-8	8-10	9-10
SRate[%]	14	6	7	26	11	41	26	41

As shown in Table 2, when the coupling strength becomes weaker, the synchronization rate is small. However, the synchronization rate between hubs remain strong even if the coupling strength has weak value.

3. Conclusion

In this study, we investigated how the synchronization rate changes due to the distance. And, the synchronization rate changes due to the position of the hub in the network.

In this result, the synchronization rate becomes lower in the case of the far link where the coupling strength becomes weak. However, the synchronization rate is high between the hubs even if the coupling strength has weak value. So, we need to investigate the relationship between the coupling strength and number of links.