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Influences of a Kind of Coupled Elements on Synchronization Phenomena in an Asymmetrical Coupled Chaotic Circuit

Yasuteru Hosokawa† and Yoshifumi Nishio‡

†Shikoku University
Furukawa, Ohjin, Tokushima, Japan
Phone:+81-88-665-1300
FAX:+81-88-665-1318
Email: hosokawa@keiei.shikoku-u.ac.jp

‡Tokushima University
2-1 Minami-Josanjima, Tokushima, Japan
Phone:+81-88-656-7470
FAX:+81-88-656-7471
Email: nishio@ee.tokushima-u.ac.jp

Abstract

It is very interesting to study about large-scale chaotic coupled systems using two kinds of elements. However, there are not any study using two kinds of elements. In this study, relationship between synchronization phenomena and parameter mismatches in coupling chaotic systems using two kinds of elements are investigated.

1. Introduction

There are studies about coupled chaotic circuit systems. In these studies, chaos synchronization, spatio-temporal chaotic phenomena, many kind of bifurcation phenomena are observed. These phenomena are investigated for engineer applications, understanding many kinds of natural phenomena, relationship of signal processing of brain neurons. In recent years, large-scale chaotic coupled systems have been investigated because a computer performance is high performance. One of very famous study is Coupled Map Lattice (CML) which is proposed by Kaneko. CML consists of simple difference equations. However, many interesting phenomena can be observed and some of these phenomena are corresponding to natural phenomena. Therefore, the study of large-scale chaotic coupled systems becomes important.

On the other hands, there are many kinds of networks which consist of two kinds of elements in the real world. For instance, relationship between male and female in human society, information processing by servers and clients in computer networks, signal processing by pMOS and nMOS in VLSI, relationship among male and female clusters of animals, meteorological phenomena caused by the relationship between anticyclone and cyclone and so on. These phenomena can be caused by coupling two kinds of elements artificially or naturally. It cannot be observed in the case of one kinds of elements. Although it is very interesting to study about large-scale chaotic coupled systems using two kinds of elements, there are not any study using two kinds of elements.

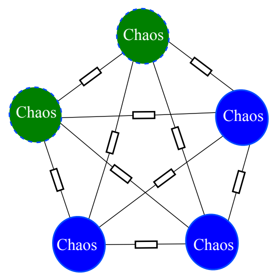

Figure 1: System model.

In this study, relationship between synchronization phenomena and parameter mismatches in coupling chaotic systems using two kinds of elements are investigated. Some models which include parameter mismatches are already proposed. The reason is that there are not identical things in the real world, there are some differences between two things which are considered as identical things. Positively, individual differences of elements are important factors for observed phenomena in the case of coupling system which consists of two kinds of elements.

2. System model

Figure 1 shows a system model in this study. The system consists of two kinds of elements. Each element is coupled with the others. Additionally, there are small parameter mismatches in one kind of elements. Normally, by increasing parameter mismatches, synchronization rates of a system is decrased. However, it is not always to observe the phenomena in this system model. In following section, computer simulation results are shown in the case that some kinds of chaotic circuits are applied as the elements. In order to carry out computer simulations, normalized system equations of each system are derived as follows.

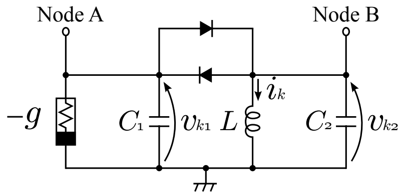

Figure 2: Chaotic circuit using System 1 and 2.

2.1. System 1

Figure 1 shows a chaotic circuit as used System 1. By selecting one of two coupling nodes (Node A and B), asymmetry of the system is realized. Normalized system equations are given as follows.
Subsystem A ($1 \leq k \leq m$):

$$\begin{cases} \dot{x}_k = & \alpha\beta x_k - \alpha\gamma f(x_k - y_k) \\ & +\alpha\delta\{\displaystyle\sum_{i=n+1}^{m+n} x_i + \sum_{j=1}^{n} y_j - (m+n)x_k\}, \\ \dot{y}_k = & \gamma f(x_k - y_k) - z_k, \\ \dot{z}_k = & (1+p_k)y_k. \end{cases} \quad (1)$$

Subsystem B ($m+1 \leq k \leq m+n$):

$$\begin{cases} \dot{x}_k &= \alpha\beta x_k - \alpha\gamma f(x_k - y_k), \\ \dot{y}_k &= \delta\{\displaystyle\sum_{i=n+1}^{m+n} x_i + \sum_{j=1}^{n} y_j \\ & -(m+n)y_k\} + \gamma f(x_k - y_k) - z_k, \\ \dot{z}_k &= (1+q_k)y_k, \end{cases} \quad (2)$$

where,

$$f(x) = x + \frac{(|x-1| - |x+1|)}{2}.$$

x_k, y_k and z_k are correspoinding to v_{k1}, v_{k2} and i_k respectively. Function $f(x)$ is correspondinig to a characteristic of diodes.

2.2. System 2

In this system, the circuit as shown in Fig. 2 is also applied. However, only Node A is used in this system. Normalized system equations are given as follows.

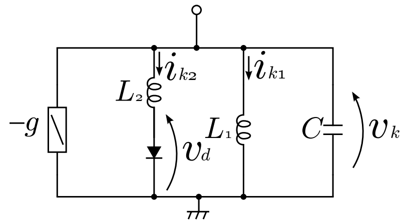

Figure 3: Chaotic circuit using System 3.

Subsystem A ($1 \leq k \leq m$):

$$\begin{cases} \dot{x}_k = & \alpha\beta x_k - \alpha\gamma f(x_k - y_k) \\ & +\alpha\delta\left\{\displaystyle\sum_{i=1}^{m+n} x_i - (m+n)x_k\right\}, \\ \dot{y}_k = & -z_k + \gamma f(x_k - y_k), \\ \dot{z}_k = & (1+p_k)y_k, \end{cases} \quad (3)$$

Subsystem B ($m+1 \leq k \leq m+n$):

$$\begin{cases} \dot{x}_k = & \varepsilon\beta x_k - \varepsilon\gamma f(x_k - y_k) \\ & +\varepsilon\delta\left\{\displaystyle\sum_{i=1}^{m+n} x_i - (m+n)x_k\right\}, \\ \dot{y}_k = & \zeta\left\{-z_k + \gamma f(x_k - y_k)\right\}, \\ \dot{z}_k = & \eta(1+q_k)y_k, \end{cases} \quad (4)$$

where,

$$f(x) = x + \frac{(|x-1| - |x+1|)}{2}.$$

x_k, y_k and z_k are corresponding to v_{k1}, v_{k2} and i_k, respectively. Function $f(x)$ is correspondinig to a characteristic of diodes.

2.3. System 3

Figure 3 shows a chaotic circuit which is as a element of System 3. Normalized system equations are given as follows.
Subsystem A ($1 \leq k \leq m$):

$$\begin{cases} \dot{x}_k = & (1+p_k)z_k \\ \dot{y}_k = & \alpha\left\{z_k - f(y_k)\right\}, \\ \dot{z}_k = & -x_k - y_k + \beta z_k \\ & +\delta\{\displaystyle\sum_{i=1}^{m+n} z_i - (m+n)z_k,\} \end{cases} \quad (5)$$

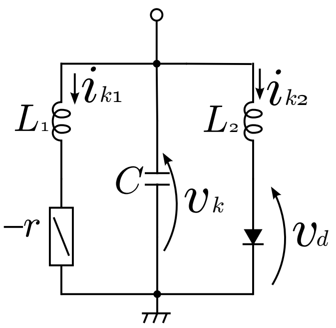

Figure 4: Chaotic circuit using System 4.

Subsystem B ($m+1 \leq k \leq m+n$):

$$\begin{cases} \dot{x}_k = & (1+q_k)z_k \\ \dot{y}_k = & \zeta\left\{z_k - f(y_k)\right\}, \\ \dot{z}_k = & \eta[-x_k - y_k + \beta\theta z_k \\ & +\delta\{\sum_{i=1}^{m+n} z_i - (m+n)z_k,\}] \end{cases} \quad (6)$$

where,

$$f(y_k) = \frac{\gamma y_k + 1 - |\gamma y_k - 1|}{2}.$$

x_k, y_k and z_k are corresponding to i_{k1}, i_{k2} and v_k. Function $f(x)$ is corresponding to a characteristic of diodes.

2.4. System 4

Figure 4 shows a chaotic circuit which is as a element of System 4. Normalized system equations are given as follows. Subsystem A ($1 \leq k \leq m$):

$$\begin{cases} \dot{x}_k = & \alpha_a x_k + z_k \\ \dot{y}_k = & (1+p_k)\beta\left(z_k - f(y_k)\right), \\ \dot{z}_k = & -x_k - y_k - \delta(m+n) + \delta\left\{\sum_{i=1}^{m+n} z_i,\right\} \end{cases} \quad (7)$$

Subsystem B ($m+1 \leq k \leq m+n$):

$$\begin{cases} \dot{x}_k = & \alpha_b x_k + z_k \\ \dot{y}_k = & (1+q_k)\beta\left(z_k - f(y_k)\right), \\ \dot{z}_k = & \varepsilon\left[-x_k - y_k - \delta(m+n) + \delta\left\{\sum_{i=1}^{m+n} z_i,\right\}\right] \end{cases} \quad (8)$$

where,

$$f(y_k) = \frac{|\gamma y_k + 1| - |\gamma y_k - 1|}{2}.$$

x_k, y_k and z_k are corresponding to i_{k1}, i_{k2} and v_k. Function $f(x)$ is corresponding to a characteristic of diodes.

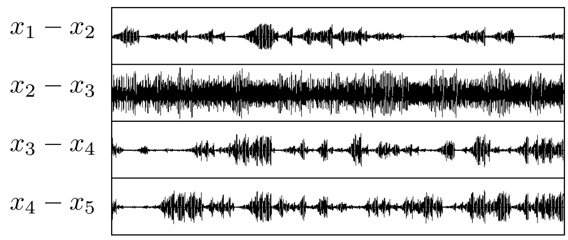

Figure 5: One of the simulation results of System 1.

3. Computer Simulations

3.1. Configuration of simulations

The number of elements is 5. The number of Subsystem A and B is 2 and 3, respectively. Figure 5 shows one of simulation results of system 1. This figure shows a difference between two elements like $x_1 - x_2$. The amplitude is zero means a synchronization state. Phenomena changing between synchronization state and asynchronization state are observed. Additionally, rates of synchronization state and asynchronization state is changed by changing the parameter mismatches. In order to investigate the rates, we define synchronization state as follows:

$$|x_k - x_{k-1}| < 0.01 \quad (9)$$

Furthermore, parameter mismatches q_k is set as follows:

$$q_k = Q(k-1). \quad (10)$$

where k is the element number and Q is corresponding to parameter mismatches of Subsystem B. Rates of synchronization states are calculated by computer simulations. Each simulation result is shown as following subsections.

3.2. System 1

Figure 6 shows a relationship of a rate of the synchronization time and small parameter mismatches in the case of System 1. By increasing Q, a rate of the synchronization time of Subsystem A is increased. The circuit as shown in Fig. **??** can generate double-scroll-type attractors. However, we could not observed the phenomena in the parameter range which double-scroll-type attractors are observed in.

3.3. System 2

Figure 7 shows a relationship of a rate of the synchronization time and small parameter mismatches in the case of System 2. This result is similar to Fig. 6. In this case, the phenomena is observed in the parameter range which double-scroll-type attractors are observed in.

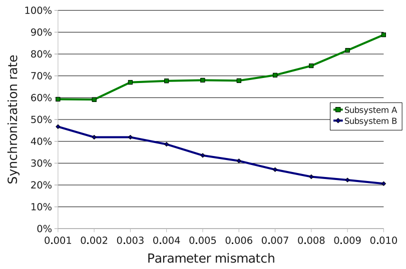

Figure 6: Relationship between synchronization rates and small parameter mismatches in the case of System 1. $m = 2$, $n = 3$, $p_k = 0.001(k-1)$, $\alpha = 0.400$, $\beta = 0.500$, $\gamma = 20.0$ and $\delta = 0.070$

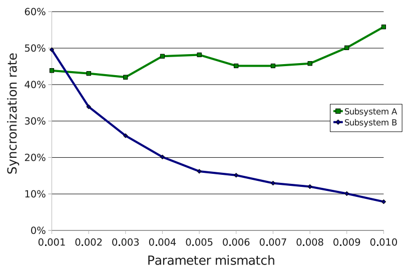

Figure 7: Relationship between synchronization rates and small parameter mismatches in the case of System 2. $m = 2$, $n = 3$, $p_k = 0.001(k-1)$, $\alpha = 0.600$, $\beta = 0.500$, $\gamma = 20.0$, $\delta = 0.070$, $\varepsilon = 0.6$, $\zeta = 1.5$ and $\eta = 0.5$.

3.4. System 3 and 4

Figure 8 and 9 shows a relationship of a rate of the synchronization time and small parameter mismatches in the case of System 3 and 4, respectively. These results are also similar to Fig. 6.

4. Conclusions

In this study, a relationship between synchronization phenomena and parameter mismatches in coupling chaotic systems using two kinds of elements have been investigated.

As a result, following common points are mentioned. Two subsystems are not synchronized each other. By increasing synchronization rate of Subsystem B, synchronization rate of Subsystem A is incrased. Additionally, the phenomena can be observed in the case of chaotic states only.

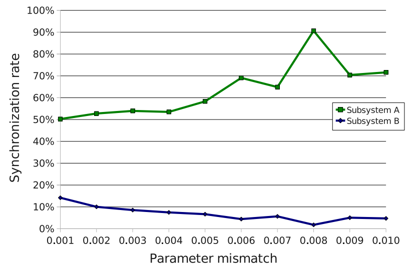

Figure 8: Relationship between synchronization rates and small parameter mismatches in the case of System 3. $m = 2$, $n = 3$, $p_k = 0.001(k-1)$, $\alpha = 6.00$, $\beta = 0.400$, $\gamma = 100.0$, $\delta = 0.060$, $\varepsilon = 1.4$, $\zeta = 7$, $\eta = 0.5$, and $\theta = 1.2$.

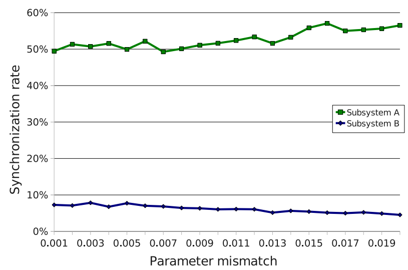

Figure 9: Relationship between synchronization rates and small parameter mismatches in the case of System 4. $m = 2$, $n = 3$, $p_k = 0.001(k-1)$, $\alpha_a = 0.41$, $\alpha_b = 0.43$, $\beta = 3.50$, $\gamma = 470$, $\delta = 0.130$ and $\varepsilon = 0.7$.

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