# Clusteling Methods Using Synchronization of Chaotic Circuit Networks

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*Abstract*— **In our previous studies, we have investigated clustering phenomena observed from several types of coupled chaotic networks. In this study, an approach for clustering on complex networks by using synchronization phenomena of coupled chaotic circuits is proposed. We introduce three major chaotic circuit networks and their clustering patterns depending on the chaotic circuits and the network structures.**

***Keywords; clustering, coupled chaotic circuits, synchronization***

## I. INTRODUCTION

Clustering phenomena is one of interesting nonlinear phenomena observed from coupled oscillatory systems. In our living life, clustering can be applied for many kinds of applications such as data mining, image processing and analysis of complex network structure. Therefore, there are many different clustering algorithms are developed in the different fields. Recently, studies of social network have attracted attention from many researchers for creating efficient organization. Therefore, it is important to analyze the social network structure to find out the characteristics such as clustering phenomena. In order to process big data in social network, development of fast clustering algorithms is required. On the other hand, coupled chaotic circuits can be realized by real electronic circuits and can observe various amusing phenomena. In recent years, many studies of coupled chaotic circuits have been reported by using different kinds of network topologies. We have investigated clustering phenomena in a simple network of coupled chaotic circuits. We believe that it is possible to apply the coupled oscillatory systems for clustering algorithms. In our previous studies, we have investigated clustering phenomena observed from several types of coupled chaotic networks [1]-[3].

In this study, we propose a novel clustering algorithm method by using synchronization states of the coupled chaotic circuits. For this investigation, the chaotic circuits are placed on 2-dimentional space. We observe the various clustering phenomena in a social network model using three types of coupled chaotic circuits when we change the scaling parameter of the coupling strength.

*The basic synchronization/clustering phenomena observed from the circuit network models in this paper are shown in Refs. [1]-[3].

## II. CHAOTIC CIRCUITS AND NETWORKS

### A. *Network model-1 [1]*

Here, we explain the first chaotic circuit network model. Figure 1 shows the chaotic circuit. Then the normalized circuit equation is expressed as the following equations.

$$\begin{aligned}\dot{x} &= \alpha x + z\\ \dot{y} &= z - f(y)\\ \dot{z} &= -x - \beta y\end{aligned} \qquad (1)$$

Where f(y) is described as:

$$f(y) = \frac{\delta}{2}\left(\left|y + \frac{1}{\delta}\right| - \left|y - \frac{1}{\delta}\right|\right) \qquad (2)$$

For the computer simulations, we set the parameters as $\alpha = 0.460, \beta = 3.0$ and $\delta = 470$. The characteristics of the function $f(y)$ can be described 3-segment piecewise-linear function. In this study, the value of $\gamma_{ij}$ reflects the distance between the chaotic circuits in an inverse way, described by the following equations:

$$\gamma_{ij} = \frac{g}{d_{ij}^2} \qquad (3)$$

$d_{ij}$ denotes the Euclidean distance between i-th circuit and j-th circuit. The parameter $g$ is a scaling parameter that determines the coupling strength.

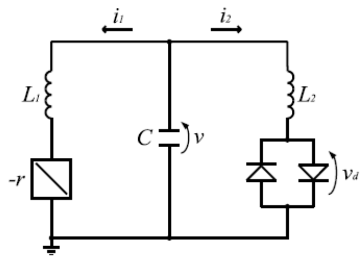


Fig. 1. Chaotic circuit.

We show the obtained clustering phenomena by using the computer simulations. We configure the social network of the chaotic circuits in 2-dimentional space when 16 chaotic circuits are coupled globally. The typical clustering patterns are shown in Fig. 2. We divide the network to 5 groups when the coupling strength is fixed with g=0.000080.

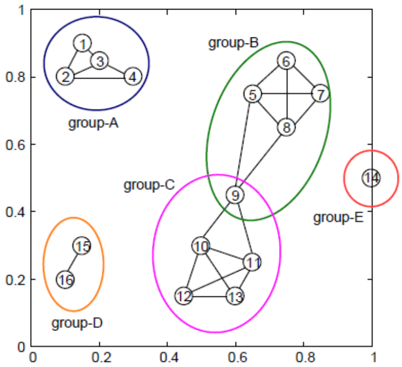


Fig. 2. Groups in coupled chaotic circuits network (N=16).

## B. *Network model-2 [2]*

Here, we focus on the influence of local bridge on a complex network of 25 coupled chaotic circuits. Figure 3 shows the chaotic circuit model called Mori-Shinriki chaotic circuit. From synchronization phenomena of coupled chaotic circuits, we show that synchronization of local bridge is easy to break down.

By means of computer simulations, the network switches to global synchronization and partial synchronization. The result of partial synchronization is shown in Fig. 4. Namely, local bridge almost be-haves asynchronously. These phenomena show that local bridge is the weak ties for promoting information propagation.

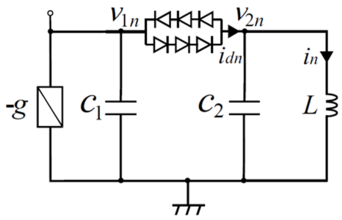


Fig. 3. Chaotic circuit.

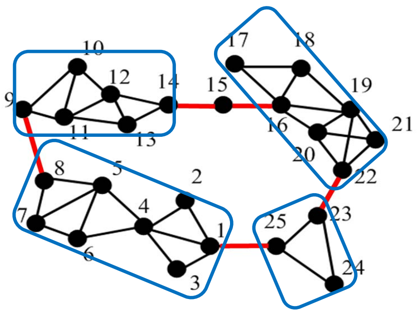


Fig. 4. Clustering phenomena.

## C. *Network model-3 [3]*

In this section, we focus on synchronization in complex network with hubs and dispersion by using parametrically ex-cited van der Pol oscillators as shown in Fig. 5. By using the computer simulations, we confirm various synchronous states and clustering phenomena and observe the effect of hubs in complex network. The typical example of the simulation result is shown in Fig. 6.

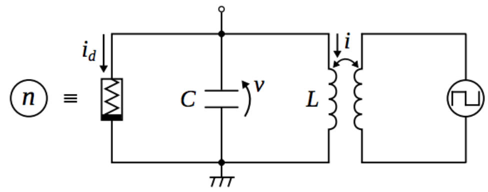


Fig. 5. van der Pol oscillator under parametrically excitation.

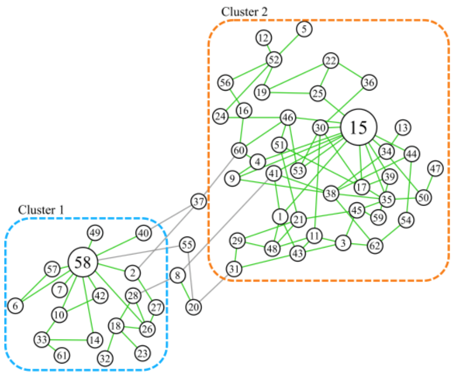


Fig. 6. Clustering phenomena.

# III. CONCLUSIONS

In this study, we have proposed the clustering method using the synchronization phenomena of coupled chaotic circuits. We observed the various kinds of clustering phenomena by changing the scaling parameter of the coupling strength.

In the future works, we would like to apply this approach for more large-scale social networks. Furthermore, we would like to focus on community structure in a social network.

# REFERENCES

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