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Chimera State in a Coupled Reduction Network of Kuramoto Model

Toru KUMAGAWA Yoshifumi NISHIO Yoko UWATE
(Tokushima University)

1. Introduction

This study presents about a chimera state in which an array of identical oscillators split into two dominants. Namely one coherent and phase locked, the other incoherent and asynchronized. In this study, a system with reduced coupling is proposed and synchronization state is investigated.

2. System Model

The Kuramoto model is used in this study. We consider a network of N coupled limit-cycle oscillators whose phase are $\theta_i, i = 1,2,...,N$. The equation of the Kuramoto model is shown in Eq. (1).

$$\frac{\partial \theta_i}{\partial t} = \omega_i + \frac{K}{N}\sum_{j=1}^{N}\sin(\theta_j - \theta_i). \quad (1)$$

At this time, the native frequencies ω_i of the oscillators are randomly distributed. Where K is the global coupling strength.

These oscillators are located around a cycle and rotate at their own frequencies to define a complex order parameter R.

$$Re^{i\varphi} = \frac{1}{N}\sum_{j=1}^{N} e^{i\theta_j}. \quad (2)$$

Where φ indicates the average phase of the coupled oscillators, and the order parameter R ($0 \leq R \leq 1$) indicates a measure of phase coherence. In the case of $R = 1$, it indicates that all oscillators come to a single tight clump. In the case of $R = 0$, it indicates that oscillators are scattered uniformly around the cycle. From Eq. (2), Eq. (3) is as follows.

$$\frac{\partial \theta_i}{\partial t} = \omega_i - KR\sin(\theta_j - \varphi). \quad (3)$$

Where ω_i follows the Cauchy distribution. In conventional studies, all-to-all oscillators are coupled. In this study, we propose that one oscillator is coupled to the most other oscillators, however they are not coupled to some other oscillators. At this time, each oscillator should be coupled uniformly.

In this simulation, the number of oscillators $N = 20$ and the coupling strength $K = 9.0$.

3. Simulation Results

Figure 1 shows time t evolution of R. The order parameter R is indicated synchronization rate. R is up and down with time. It is indicated oscillators close to fully synchronous and then some oscillators become asynchronous.

Figures 2 and 3 show the phase diagram indicating the position of the oscillator when $t = 5.0$. Figure 2 shows that most oscillators are synchronous, however, there are a few asynchronous oscillators. Figure 3 shows that the synchronized parts and asynchronized parts are separated. It looks like two synchronization, however, there are fewer oscillators asynchronous to each other. These state are the chimera state.

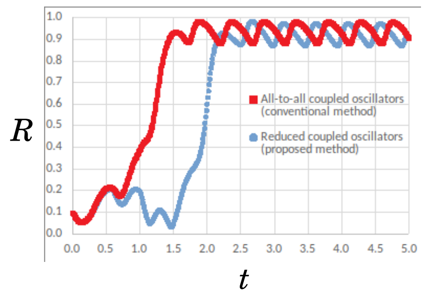

Figure 1: Time evolution of R.

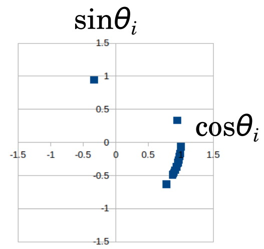

Figure 2: Phase diagram of all-to-all coupled oscillators.

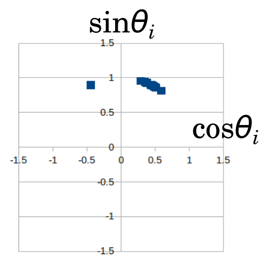

Figure 3: Phase diagram of reduced coupled oscillators.

4. Conclusion

This study have been observed the chimera state.

It was found that if the coupling method is uniform, the chimeric state can be observed even if the coupling of the oscillator is reduced.