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Investigation of Delay in Two Coupled Maps with Intermittency Chaos

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1. Introduction

In the realistic large-scale network, delay occurs between communication and information-processing rate necessarily. In this study, we focus on the influence of delay in two coupled cubic maps with intermittency chaos. Moreover, we investigate the average length of laminar part.

2. Two Coupled Cubic Maps

A cubic map is expressed as following equation:

$$f(x) = ax^3 + x(1 + a), \tag{1}$$

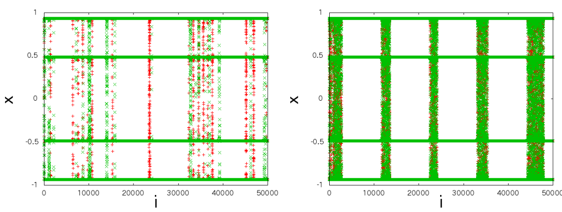
where a represents a bifurcation parameter. We consider two coupled maps with delays. The coupling method is expressed as following equation:

$$\begin{cases} x_{(1,i+1)} = (1-g)f(x_{(1,i)}) + gf(x_{(2,i-\tau)}) \\ x_{(2,i+1)} = (1-g)f(x_{(2,i)}) + gf(x_{(1,i-\tau)}), \end{cases} \tag{2}$$

where g represents the coupling strength, τ represents the delay between the maps and i represents the iteration time.

3. Simulation results

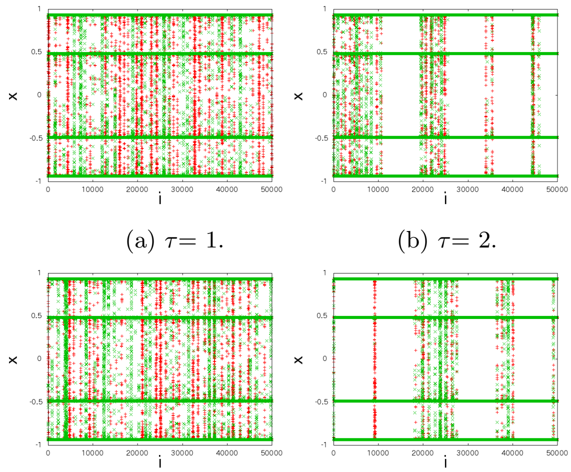
Figure 1 shows time series of intermittency chaos. Intermittency chaos is switching laminar and burst. Laminar represents four periodic solutions and burst represents the chaotic state. In this study, the initial conditions and parameter of each cubic map are fixed with $x_{(1,0)} = 0.1$, $x_{(2,0)}$ = -0.2 and a = -3.82842712. The iteration time is i = 50000. Figure 1 shows that the width of burst part becomes to long by increasing the value of g.



(a) g = 0.0000001. (b) g = 0.0001.

Figure 1: Swiching laminar and burst (a = -3.82842712 and $\tau = 0$).

From this point forword, the coupling strength g is fixed with g = 0.0001. Figure 2 shows the simulation results when we vary the delay τ and the difference in length of laminar between uneven numbers ($\tau = 1, 3$) and even numbers (τ = 2, 4). There is not much difference between Fig. 2(a) and (c). Laminar part of Fig. 2(d) is longer than laminar part of Fig. 2(b).



(a) τ= 1. (b) τ= 2.

(c) τ= 3. (d) τ= 4.

Figure 2: Simulation results (a = -3.82842712 and g = 0.0000001).

Furthermore, we investigate the length of laminar in coupled cubic maps with delay. Here, we define laminar part when $|x - \pm 0.483$ or $\pm 0.934| < 0.002$. Figure 3 shows the average length of laminar part when the delay is varied. It shows the short average length of laminar part in uneven numbers ($\tau = 1, 3, 5, \cdots, 15$). Conversely, it shows the long average length of laminar part in even numbers ($\tau = 2, 4, 6, \cdots, 16$). In that, the average length of laminar part with $\tau = 4$ is the longest in this study. The average length of laminar part with $\tau = 8$ is the shortest in delay of even numbers.

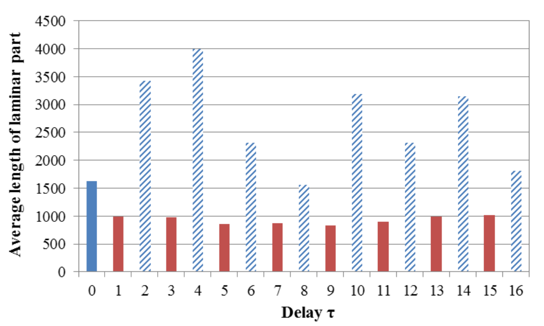


Figure 3: Average length of laminar part.

4. Conclusion

In this study, we have investigated the influence of delay in two coupled cubic maps. We confirmed that the long average length of laminar part in delay of even numbers. In our future works, we would like to investigate the influence of delay when increasing the number of maps.