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Chen model analysis

Chen, L., Liu, R., Liu, Z. P., Li, M., & Aihara, K. (2012). Detecting early-warning signals for sudden deterioration of complex diseases by dynamical network biomarkers. Scientific reports, 2(1), 1-8.

Model description

We have a system with five variables, Z_1, Z_2, Z_3, Z_4 and Z_5. It does not represent any biological system, but it's a good example to show how the DNB works. In the supplementary information, we can find the system of differential equations that describes its dynamics and this is the one I used to perform the analysis. In the paper, they found that the system undergoes a bifurcation detected by Z_1 and Z_2 near $P = 0$, where P is the bifurcation parameter.

Model analysis

I made the analysis using GrindR. Firstly, I transformed the deterministic model to an stochastic one adding additive noise. The functions `run` and the option `after` allow me to do this easily. The noise magnitude was $\sigma = 0.1$ in all cases.
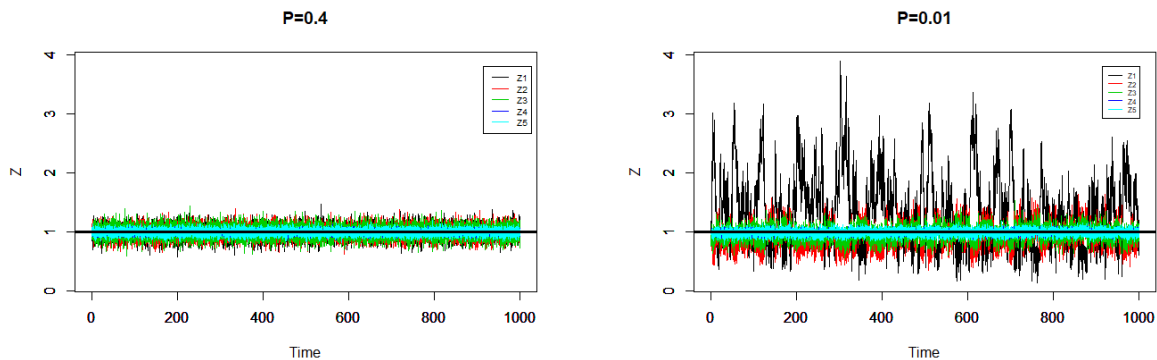
Figure 2-b and 2-c

Figure 1: The simulation time was set at $1,000$ and the time steps where 0.1. The vertical line is the normalized steady state in both cases.

As we can see in Firgure 1, near the tipping point ($P = 0.01$), the variance of Z_1 and Z_2 drastically increase as reported in the original publication.
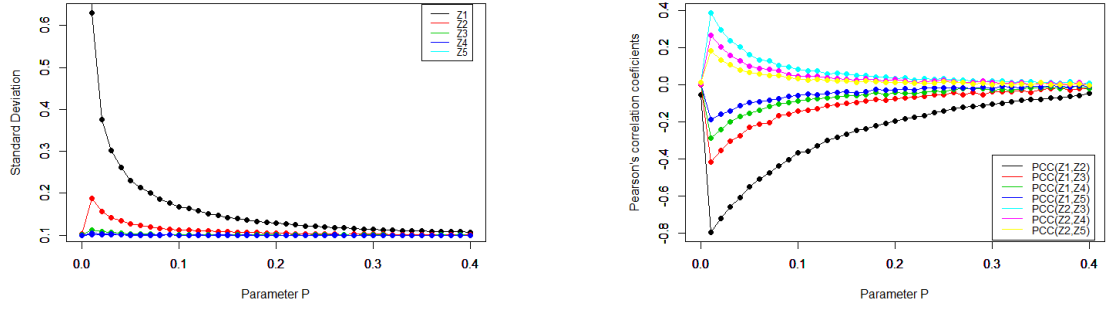
Figure 2-d and 2-e

Figure 2: The simulation time was set at $5,000$ and the time steps where 0.01. The right figure shows the Pearson's correlation coefficient of molecules of the dominant group and between the dominant group and the other variables.

As we can see in Figure 2, the standard deviation of molecules Z_1 and Z_2 increases near the tipping point $P = 0$. On the other hand, the Pearson's correlation coefficient (PCC) between Z_1 and Z_2 increases in absolute value.

Figure 2f

(a)

(b)

(c)

(d)
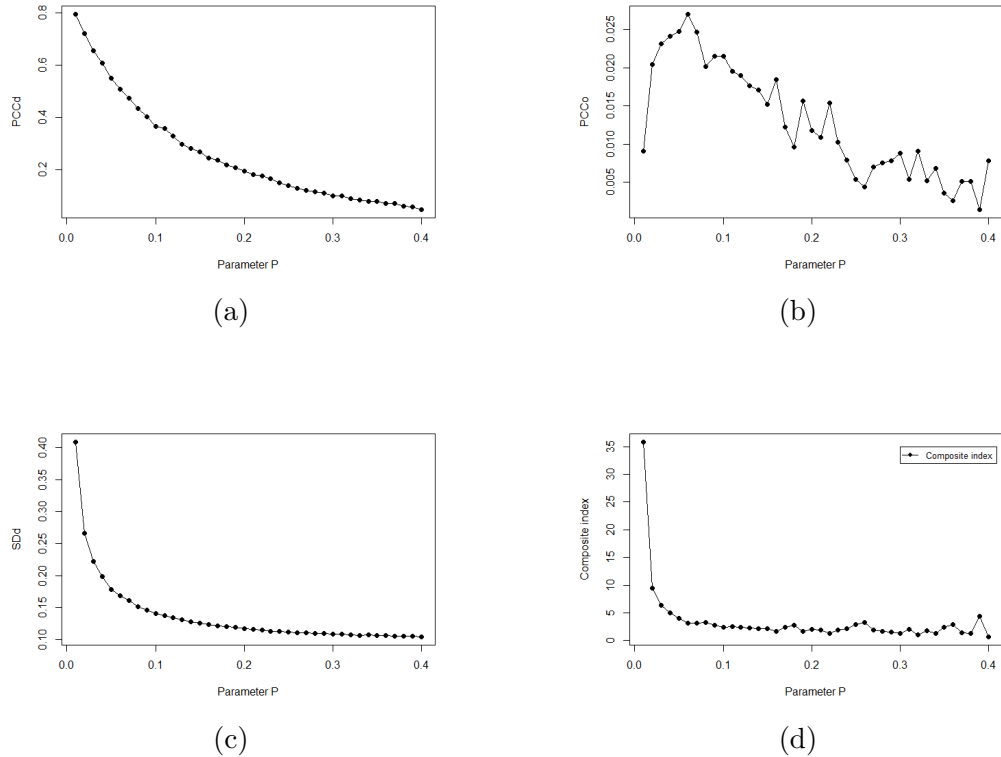
Here, first, it is shown the graph of the three conditions that molecules in the dominant group must satisfy simultaneously to be considered as such (see Figure a,

b and c). The average Pearson's correlation coefficients of Z_1 and Z_2 drastically increase in absolute value (Figure a). On the other hand, the average PCC between Z_1 and Z_2 and the other variables does not show a decrease in absolute value (Figure b). Finally, the average standard deviations of molecules Z_1 and Z_2 drastically increase as reported in the paper (Figure c).

Even though the PCC between Z_1 and Z_2 and the other variables does not show a decrease in absolute value, computing the composite index, it was found that this marker drastically increases near the bifurcation as it was stated in the original publication.