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Delayed feedback control of chaos by self-adapted delay time

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Abstract

We present a novel technique for stabilizing unstable periodic orbits of chaotic systems. It uses a continuous feedback loop in the form of the difference between an actual and a delayed output signal of the system with a variable delay time. This time is chosen to be equal to the interval between the last and the kth previous maximum of the output signal and is changed at every kth maximum. During the procedure, the delay time asymptotically tends to the period of the period-k unstable periodic orbits and the control signal vanishes. The method is illustrated with the help of the Rössler ordinary differential equations and the Mackey–Glass delay differential equations.

Chaotic systems are characterized by their extreme sensitivity to small perturbations in their initial conditions. That inherent feature, known as the "butterfly effect", often is troublesome or even unwanted in many cases of practical importance. An efficient scheme to control chaos has been proposed by Ott, Grebogi, and Yorke (OGY) [1]. The key precondition was that the typical chaotic attractor embeds an infinite number of unstable periodic orbits (UPOs) of distinct periods T_k. They can be stabilized by an only small, carefully chosen, feedback perturbation applied to some system parameter available for external adjustment. The OGY method is a very general one. It does not require any a priori analytical knowledge of the system dynamics and has been successfully applied to various physical experiments including a magnetic ribbon [2], a spin-wave system [3], a chemical system [4], an electric diode [5], laser systems [6], and cardiac systems [7].

Any experimental application of the OGY method necessitates permanent computer analysis of the state of the system. The changes of the parameter, however, are discrete in time, since the method deals with the Poincaré map of the system. This makes the method touchy to noise. Small noise gives rise to occasional bursts of the system directing to the region far away from the periodic orbit to be controlled. These bursts are more frequent for large noise [1]. Various modifications of the OGY method considered in Refs. [4–11] are also discrete in time (see also Ref. [12] for a survey).

An alternative approach based on a continuous-time control has been proposed by one of us [13–15]. The method deals with a chaotic system which can be presented by a set of ordinary differential equations

$$\frac{\mathrm{d}y}{\mathrm{d}t} = P(y, \boldsymbol{x}) + F(t), \quad \frac{\mathrm{d}\boldsymbol{x}}{\mathrm{d}t} = \boldsymbol{Q}(y, \boldsymbol{x}). \tag{1}$$

Imagine that Eqs. (1) are unknown, but some scalar variable $y(t)$ can be measured as a system output.

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