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Comparative analysis of chaos control methods: A mechanical system case study

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A B S T R A C T

Chaos may be exploited in order to design dynamical systems that may quickly react to some new situation, changing conditions and their response. In this regard, the idea that chaotic behavior may be controlled by small perturbations allows this kind of behavior to be desirable in different applications. This paper presents an overview of chaos control methods classified as follows: OGY methods – include discrete and semi-continuous approaches; multiparameter methods – also include discrete and semi-continuous approaches; and time-delayed feedback methods that are continuous approaches. These methods are employed in order to stabilize some desired UPOs establishing a comparative analysis of all methods. Essentially, a control rule is of concern and each controller needs to follow this rule. Noisy time series is treated establishing a robustness analysis of control methods. The main goal is to present a comparative analysis of the capability of each chaos control method to stabilize a desired UPO.

1. Introduction

Non-linearities are responsible for a great variety of possibilities in natural systems. Chaos is one of these possibilities being related to an intrinsic richness. A geometrical form to understand chaos is related to a transformation known as Smale horseshoe that establishes a sequence of contraction–expansion–folding which causes the existence of an infinity number of unstable periodic orbits (UPOs) embedded in a chaotic attractor. This set of UPOs constitutes the essential structure of chaos. Besides, chaotic behavior has other important aspects as sensitive dependence to initial conditions and ergodicity.

These aspects of chaos may be exploited in order to design dynamical systems that may quickly react to some new situation, changing conditions and their response. Under this condition, a dynamical system adopting chaotic regimes becomes interesting due to the wide range of potential behaviors being related to a flexible design. The idea that chaotic behavior may be controlled by small perturbations applied in some system parameters allows this kind of behavior to be desirable in different applications.

In brief, chaos control methods may be classified as discrete and continuous methods. Semi-continuous method is a class of discrete method that lies between discrete and continuous method. The pioneer work of Ott et al. [27] introduced the basic idea of chaos control proposing the discrete OGY method. Afterwards, Hübinger et al. [20] proposed a variation of the OGY technique considering semi-continuous actuations in order to improve the original method capacity to stabilize unstable orbits. Pyragas [29] proposed a continuous method that stabilizes UPOs by a feedback perturbation proportional to the difference between the present and a delayed state of the system.

This article deals with a comparative analysis of chaos control methods that are classified as follows: OGY methods – include discrete and semi-continuous approaches [27,20]; multiparameter methods – also include discrete and semi-continuous approaches [10,11]; and time-delayed feedback methods that are continuous approaches [29,34]. Fig. 1 presents an overview of chaos control methods analyzed in this work.

Many research efforts were presented in literature in order to improve the originals chaos control techniques and there are numerous review papers concerning these procedures. In this regard, Shinbrot et al. [33], Ditto et al. [14], Grebogi and Lai [18] and Dubé and Després [15] discussed concepts of chaos and its control presenting discrete chaos control techniques based on OGY method. Pyragas [30] presented an overview of continuous chaos control methods based on time-delayed feedback and mentioned several numerical and experimental applications. Ogorzalek [25], Arecchi et al. [3] and Fradkov and Evans [16] presented review articles that furnish a general overview of chaos control methods, including discrete and continuous techniques. Besides these methods, Boccaletti et al. [6] also treated tracking and synchronization

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