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"Stabilizing Periodic Solutions of the Lorenz System using a MIMO Delayed Feedback Controller"

Chaos is the behavior of any complex system for which the time evolution depends sensitively on its initial condition. An accurate prediction of long-term behavior of such systems is impossible because any uncertainty in the beginning will produce rapidly growing errors in the prediction of the system's behavior. Controlling chaos consists in perturbing a chaotic system in order to stabilize a given unstable periodic orbit (UPO) embedded in the chaotic attractor. Nowadays, different techniques have been proposed to achieve this goal. Time delayed feedback controller (DFC) is an efficient tool for stabilizing UPOs of chaotic systems. This method is based on the online measurement of the current state of the system x(t), and uses the time-delayed difference x(t)-x(t-T) multiplied by a factor K as a control signal. If the delay time is equal to the period T of an unstable periodic orbit of the system, the orbit may become stable and the control signal K[x(t)-x(t-T)] vanishes. This controller has been used successfully for various chaotic systems because it doesn't require any prior knowledge of the system, except the period of the desired orbit. However, this controller is not able to stabilize some chaotic systems. Researchers had thought that DFC is not able to stabilize systems with odd number of real positive Floquet exponents. One of these systems is the Lorenz system for which previous efforts were able to stabilize it using DFC only by adding an unstable dynamic term to the system to overcome the "Odd-Number limitation". Even after scientists found out that this limitation for DFC doesn't exist, stabilizing the Lorenz system with a DFC without an unstable external term was not successful.

In this presentation, the idea of using the harmonic balance method in a new framework to obtain the analytical equations of predicted periodic solutions of the Lorenz system will be explored. Using these analytical equations, a multi-input multi-output (MIMO) DFC is designed and implemented for stabilizing a desired unstable periodic solution of the Lorenz system. In DFC implementation, choosing an appropriate signal to use in the delayed feedback loop and an appropriate point for introducing the control signal are very important tasks. Considering these facts, we overcome the mentioned problem by our controller structure without adding an unstable term to the system. The proposed controller is also able to stabilize the equilibrium points of the system.