Seminar

Institute for Plasma Research

Title : Study and Determination of Dynamical Systems

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Date : 14th November, 2019 (Thursday)

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Venue : Committee 3, New Building, IPR

Abstract:

A dynamical system is any system (physical, biological or social) that changes over time. Such systems can often be modeled by a set of differential equations involving time derivatives. If we know the governing equations describing their dynamics, we can extract a lot of interesting information about their behavior such as their future state and the different collective states exhibited by them in different parametric domains.

Our first study [1] considers such a dynamical system consisting of a coupled set of complex Ginzburg-Landau oscillators. This model exhibits a great variety of collective behavior ranging from synchrony to chaos and many intermediate states between them. Therefore, it has been widely used as a paradigm for the mathematical study of a large variety of nonlinear phenomena in physical, chemical and biological systems. The present study is devoted to an investigation of the effect of time-delayed coupling on the collective dynamics of this popular paradigmatic model. Since time delay arising from finite propagation speed of signals or latency time of chemical reactions or biological processes is inevitable in most real-life systems, our motivation is to determine the existence and stability domains of the various collective states in the presence of such delays. Detailed numerical investigations show that time delay has indeed a significant impact on the characteristic properties of the collective modes that include synchronous states, clustered states, chaos, amplitude mediated chimeras and incoherent splay states. In general, time delay is found to lower the threshold value of the coupling strength for the occurrence of such states and to shift the existence domain towards more negative values of the linear dispersion parameter. The stability properties of these modes are determined using a combination of numerical and analytical methods.

Our second study is on the prediction of system dynamics from data. For many physical systems, exact governing equations are not known. If we have access to the measurement data for such systems, the governing equations can be determined using machine learning methods such as symbolic regression. As an application, we have taken the experimental measurements of anode glow oscillations in a glow discharge plasma device [2]. In the past, these oscillations are found to display a behavior that is qualitatively similar to a van der Pol-like equation, but the exact form of the equations governing their dynamics is not known. Our goal is to determine these equations from the experimental data and extract further information about the dynamics of anode glow oscillations in the glow discharge plasmas from them. We investigate two algorithms for the determination of equations - genetic programming and sparse regression. Genetic programming is a type of evolutionary algorithm that uses the principles of biological evolution to find the solution to a complex problem. Sparse regression uses the sparsity-promoting techniques and machine learning and is based on the observation that most dynamical equations are sparse in the space of possible functions. These methods are tested using the numerical data from the dynamical systems whose exact governing equations are known such as Lorenz system and van der Pol equation.

References:

[1] Bhumika Thakur and Abhijit Sen, “Collective dynamics of globally delay-coupled complex Ginzburg-Landau oscillators”, Chaos 29, 053104 (2019).

[2] Neeraj Chaubey, S. Mukherjee, A. N. Sekar Iyengar, and A. Sen, “Synchronization between two coupled direct current glow discharge plasma sources”, Phys. Plasmas 22, 022312 (2015).