Seminar

Institute for Plasma Research

Title : The study of the dynamics of delay coupled nonlinear oscillators and some model applications

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Time : 03.00 PM

Venue : Seminar Hall, IPR

Abstract :

Networks of coupled nonlinear oscillators can display a wide spectrum of collective behavior ranging from synchronization to spatio-temporal chaos, and serve as a useful paradigm for collective phenomena in a variety of applications in physical, chemical, biological systems as well as social sciences. A few fascinating applications among these are in semiconductor lasers, nanomechanical oscillators, and neural oscillator models for circadian pacemakers. Motivated by the amazing complexities exhibited by these seemingly simple oscillator networks, we explore their dynamics further when the interaction between the interacting units is not instantaneous but time-delayed as is the case with most real systems. Arising from a variety of reasons, the presence of time delay introduces significant changes in the collective behavior of oscillator networks by influencing the onset thresholds as well as the extents of the parametric domains of various collective regimes such as amplitude death and phase-locked states. In the present work, the time delay is shown to introduce very distinct effects depending on the internal details of networks. In the three examples studied here, the delay affects (i) degrees of network frustration, (ii) multisensory perception and (iii) robustness of networks.

The first problem investigates the effects of time delay on the collective dynamics of frustrated networks of phase oscillators. Here we quantify the amount of frustration in the system by a suitably defined frustration parameter and find a universal scaling behavior in its variation with time delay. The results relate to dynamics of vertebrate segmentation clock which is widely modeled by delay coupled theory.

The effects of delay on the dynamics of networks are analyzed further in our second problem that proposes a dynamical systems model for multisensory perception consisting of two unisensory and one multisensory subsystem represented by phase oscillators in our model. The study focuses on the effect of lag between onset of auditory and visual stimuli on audio-visual integration captured by the time-delay parameter in our model. The extent of multisensory integration is quantified by the degree of synchronization of the dynamical system represented by its order parameter. A proposed extension of the model uses two dimensional lattices of oscillators instead of a single oscillator representing the dynamics of a cortical area to provide a more realistic description of multisensory perception by bringing in spatio-temporal aspects into the dynamics.

The third part of the study addresses the robustness of coupled-oscillator systems against deterioration, such as due to some elements turning non-self-oscillatory, which can be interpreted as aging of the system. We find that the presence of time-delay hastens the aging of the system. Among the possible biological applications of this model system are neurodegenerative diseases that are characterized by progressive neuron fall out.

The results of the study highlight the significance and diversity of time-delay effects on the collective dynamics of oscillator networks with a range of relevant applications in real systems.
