Complexity and Dynamics in Neuroscience

Overview

Understanding perception, information processing, learning and other higher cognitive functions in brain by nonlinear dynamics and complexity theory has a long history of success. Dynamical modeling allowed for predicting and explaining rhythmic behaviors in neural circuits, normal and abnormal, stretching to control strategies of epileptic seizures. Even simplest models that have only remote physiological relevance shed light on the role of synchronization, competition and transient dynamics in these processes. More realistic models of the Hodgkin-Huxley type as well as capturing dynamics of synaptic coupling, including plasticity, rendered the dynamical analysis more sophisticated, yet more persuasive for biologists. The big step to complexity was made in the last two decades, when the importance was realized – and it became computationally possible – to address the impact of the network architecture of brain, with irregular and long-distance connectivity. The new rising challenge is due to the mounting experimental evidence of the key role of glial cells in modulating synaptic connections between neurons and affecting their activity, beside the previously attributed function of a passive medium. The collective nonlinear dynamics of such multiplex networks is still to be elucidated. The proposed course will take the audience on a tour from the fundamentals of nonlinear dynamics and network science, the overview of the mathematical modeling of brain to the cutting edge problems and open questions of computational neuroscience.

In this course we will introduce a variety of mathematical tools based on algebraic graph theory, linear algebra and dynamics that constitutes a basis for the analysis of large scale complex interconnected systems.

The Objective of this course is to familiarize and equip the attendees with the state-of-art mathematical concepts of neuroscience, starting from the nonlinear dynamics framework and network theory to the cutting-edge research on collective behavior of neuro-glial brain networks. At the end of the course the students will acquire the basic tools that will allow them to embark on an academic level research project in the area of computational neurocience. The course is ideally suited for graduate students pursuing a research career in this field. Specifically, participants will learn and apply:

i) Fundamentals of nonlinear dynamics of complex networks,

ii) Paradigmatic mathematical models of neurons, synapses and astrocytes,

iii) Collective phenomena in neural and glial networks,

iv) Computational approaches, from methods to measurables.

The course will be divided into four modules that will be covered in a total of 14 periods spanning over five working days. The topics in Module A will expose the participants to the introduction and overview of nonlinear dynamics, attractors, stability, qualitative and quantitative methods. In Module B, collective phenomena will be emphasized. The topics in the module include synchronization and competition, paramount to complex dynamics of neural ensembles. Module C will be devoted to modeling neural ensembles, from single neurons and synapses to neural-glial interactions. In Module D, some dynamical phenomena in neuroscience will be disclosed, such as synchronization, rhythm generation, transient dynamics and its role in decision making and memory. Additionally, we discuss the network approach to modeling brain and evidence on statistic of connectivity. The dynamical role of neural-glial interactions and multiplex network concept will be highlighted. Open questions and outlook will conclude the course.

On each working day, there will be two lecture periods each of seventy five minutes duration and up to two problem solving classes, split between the morning and two in the afternoon. The time frame day will be the following:

First period: 9.00-10.15 am, Coffee break: 10.15-10.45 am, Second period: 10.45-12.00 noon

Third period: 1.30-2.45 pm, Coffee break:2.45-3.15pm, Fourth period: 3.15-4.30pm

Modules	**A: Introduction to Nonlinear Dynamics** **B: Synchronization and competition** **C: Modeling neural and glial networks** **D: Dynamical neuroscience and outlook** **Number of participants for the course will be limited to fifty.**
You Should Attend If…	▪ you are an Undergraduate, Master or PhD level scholar who would like to be introduced to the new and growing interdisciplinary area of Complexity and Synamics in Neuroscience. ▪ you are a young and budding member of the faculty at various Engineering and Computer Science departments wanting to learn the developments and further developing research programs in the respective departments. ▪ you are a scholar in governmental, industrial or consulting agencies who wishes to expand understanding the state of the art in this area.
Fees	The participation fees for taking the course is as follows: **Industry/ Research Organizations: Rs 10,000** **Academic Institutions (students): Rs 2,500** **Academic Institutions (faculty): Rs 4,000** The above fee include all instructional materials, computer use for tutorials and assignments, laboratory equipment usage charges, 24 hr free internet facility. The participants will be provided with accommodation on payment basis.

The Faculty

Prof. M. Ivanchenko completed his Ph.D. in Physics from the Lobachevsky University, Nizhny Novgorod, Russia in 2007. From 2007 to 2009 he was a lecturing Research Fellow at the School of Mathematics, University of Leeds, UK. In 2009 he returned to Lobachevsky University to work for the D.Sc. in Physics degree, which he received in 2012, along with a Professorship. From 2015 he is the Head of Applied Mathematics department. The research interests include nonlinear dynamics, chaos, complexity theory, mathematical biology, condensed matter and non-equilibruim systems. His main works are devoted to synchronization, localization, collective dynamics in neural and gene systems, and complex networks. He was awarded with the medal of Russian Academy of Sciences for the work on synchronization in multiple-timescale systems (2004).

Dr. Sarika Jalan has completed her PhD in Physics with specialization in nonlinear dynamics and Complex Systems from Physical Research Laboratory, India in 2005. She has six years post-doctoral experience at MPI-MiS, Leipzig ,MPI-PKS and NUS, Singapore. During this period she worked on spectral properties of complex systems as well as applications to biological systems. Upon joining IIT Indore In December 2010, she established Complex Systems Lab, which focuses on inter-disciplinary research, utilizing techniques from Physics, Mathematics, Bio-informatics and Computer Science. Using network theory, nonlinear dynamics and computational techniques, the lab on one hand works on developing tools pertaining to complex systems research and on other hand applies these techniques to real world systems coming from Biology and Social science.

Course Coordinator

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