Birla Institute of Technology and Science Pilani

K.K. Birla Goa Campus

CS F433 Course Handout – Part II

Academic Year 2022–23, Semester II

Course Name: Computational Neuroscience
Lecture Schedule: Monday Wednesday Thursday 15:00 – 16:00 hrs
Lecture Venue: DLT 5

Instructor-in-charge: Basabdatta Sen Bhattacharya
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Teaching Assistants:
HDTA: Chirag

Course Objective

The objective of this course is: (A) to introduce the biophysics underlying brain signals as well as the fundamental concepts and theory of neural computation. The key topics that will be covered are: biophysics of action potentials, local field potentials (lfp) and electroencephalogram (eeg), and their recording and analysis techniques; (B) modelling a neuron - starting with the Nobel-prize winning Hodgkin-Huxley model, and onto meso- and macro-scale neural population networks and their dynamics; (C) information processing in neural populations; synaptic mechanisms and learning by association.
Alongside theory, students will be introduced to software tools (using python/Matlab based on student preferences) to simulate neural computations and models.

Course Plan

- Cellular Mechanisms of spikes and overview of brain signals
    - Biophysics of a neural spike, Overview of spike recording techniques, Electromagnetic Fields of the brain, Introduction to: Local Field Potentials (LFP); Electroencephalography (EEG), functional Magnetic Resonance Imaging (fMRI), Transcranial Stimulation.
- Hodgkin-Huxley model
    - The ion channels, Equilibrium potentials, and RC circuits; The Hodgkin Huxley Model – mathematical framework and dynamics. Dendrites, Synapses and Compartmental Models.
- Leaky Integrate and Fire (LIF) Models
    - Leaky Integrate and Fire (LIF) neuron models, Exponential Integrate and Fire (EIF), Quadratic Integrate and Fire (QIF), Adaptive EIF, Firing Patterns, Spike Response Models, Introduction to Izhikevich's neuron models.
- Neural Information Processing
    - Spike train variability, Mean Firing Rate, Inter-Spike-Interval distribution and coefficient of variation, Autocorrelation function, Power Spectrum, Neural codes – rate based and time based, Reverse Correlation.
- Dynamics of Neurons
    - Threshold effects, Reduction to 2-D: Morris-Lecar and FizHugh-Nagumo models, Phase-plane analysis, Type I and Type II neuron models, Threshold and Excitability, Attractor dynamics and memory, Associative memory and Hopfield model, Bifurcation in neural dynamics

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- Synaptic Plasticity
    - Short- and Long- term synaptic enhancement, Synaptic Depression, Fundamentals of Hebbian Learning, Spike-Timing-Dependent-Plasticity (STDP), Variants of STDP, Unsupervised Learning
- Neuron Population Models
    - Neuron population dynamics, Balanced random networks, From microscopic to meso- and macro-scopic models, Lumped-parameter models and dynamics, Computational models of LFP, EEG, fMRI. Validating models for neurological disorders.

Main Textbooks

[T1] **Neural Dynamics: From Single Neurons To Networks And Models Of Cognition,** *W. Gernster, W. Kistler, R. Naud, L. Paninski*, Cambridge University Press, 1st ed, 2014, ISBN-13: 978-1107635197, ISBN-10: 1107635195.

Supporting Resources

[S1]

Course Notices

All notifications during the course will be:
(1) In-person during Class interaction
(2) Online Google Classroom

It is the sole responsibility of the students to keep track of all notifications related to assignments, coursework, exams and all other matters related to the course.

This would imply that if you are missing out on any assessment or class material, *requests for repeat will not be entertained.*

Exceptions will be made according to the Make-up Policy (see below).

Marking Scheme

- **35% Assignment**
- **25% Mid-semester Exam** (18th March Saturday 2:00 – 3:30 pm)
- **40% Comprehensive Exam** (TBC)

Malpractice Policy

Any student found to be engaging in any sort of malpractice during the examinations and assessment in the CS F320 course will be dealt with in the following way:

(1) He/She will not be evaluated for the exam, i.e. their score will be NIL for that component, and will be given the first and final warning.

(2) If found guilty of malpractice for a second time:

(a) they will not be allowed to continue on the course;

(b) their names will be revealed to the respective Departments as well as to any other Institutional monitoring committee.

All the above are bound to impact their activities in the immediate future, for example references.

Make-up Policy

No request for make-up will be entertained except for the following two cases:

(a) Medical emergency: where the notification of hospitalisation or emergency needs to be communicated via the Instruction Division. Any close relative may communicate this to the office.

(b) Family emergency that may prevent normal coursework commitments: where a student needs to get such leave of absences authorized by the HoD, via email, upon being able to resume normal classes.

To note that it is your sole responsibility to keep track of assessment dates, assignment deadlines, and examination timelines.

Make-up CANNOT be granted if you are not following the classes and announcements outside of above-mentioned emergencies.

Attendance Policy

Attendance is strongly recommended as lecture notes *will not be* uploaded online. Engaging with all class activities, evaluative or non-evaluative, is mandatory. Supporting resources will be provided on Google Classroom and it is important that students who miss lectures do check those out in good time.