Birla Institute of Technology & Science, Pilani
K K Birla Goa Campus

COMPUTATIONAL NEUROSCIENCE READING COURSE
BITS F382 SECOND SEMESTER, AY 2020-2021

1. **Course Description:**
This course is designed 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; modelling a neuron - starting with the Nobel-prize winning Hodgkin-Huxley model; information processing in neural populations; synaptic mechanisms and learning by association; meso- and macro-scale neural population networks and their dynamics; modelling of neurological disorders as observed in higher level brain signals such as the lfp, eeg, functional magnetic resonance imaging (fmri); validation of neural models with data. Alongside theory, students will be introduced to software tools (using python/Matlab/C based on student preferences) to simulate neural computations and models.

2. **Textbook(s):**

Textbook [Tx]:

A. **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.

B. **Biophysics of Computation: Information Processing in Single Neurons**, *Christof Koch*, Oxford University Press, 1999, ISBN-13: 978-0195104912, ISBN-10: 0195104919.

Reference Textbook [Rx]:

C. **Principles of Neural Coding** (Eds.) *Rodrigo Quian Quiroga, Stefano Panzeri*, CRC Press, 1st ed, 2013, ISBN-10: 1439853304, ISBN-13: 978-1439853306.

D. **An Introductory Course to Computational Neuroscience,** *Paul Miller*, MIT Press, 1st ed, 2018, ISBN-13: 978-0262038256, ISBN-10: 0262038250

Laboratory: Laboratories will not be structured/time-tabled. These will be conducted bythe TA s in their convenient times. And will largely be software based – as follows:

1. Python Exercises accompanying Textbook in TA.
2. Matlab Exercises accompanying Textbook in TD.
3. The above can also be done using C(++) based on student preferences

Course Plan:

No. of Lectures	Topics	Sub-topics	Learning Outcomes	Chapter in the Text Book
6	Cellular Mechanisms of spikes and overview of brain signals.	Biophysics of a neural spike, Overviewof spike recording techniques, Electromagnetic Fields of the brain, Introduction to: Local Field Potentials (LFP); Electroencephalography (EEG), functional Magnetic ResonanceImaging (fMRI), Transcranial Stimulation.	**LO-I**	TA:Ch1 TB, RC
6	Hodgkin-Huxley model	The ion channels, Equilibrium potentials, and RC circuits; The Hodgkin Huxley Model – mathematical framework and dynamics. Dendrites, Synapses and Compartmental Models.	**LO-II**	TA:Ch2, part Ch 3,4 TB, RD
6	Leaky Integrateand 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, Introductionto Izhikevich's neuron models.	**LO-III**	TA:Ch 5,6 TB, RD
6	Neural Information Processing	Spike train variability, Mean Firing Rate,Inter-Spike-Interval distribution andcoefficient of variation, Autocorrelationfunction, Power Spectrum, Neural codes – rate based and time based, Reverse Correlation.	**LO-IV**	TA: Ch 7, TB, RC: (TBC)
6	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	**LO-V**	TA: Ch 4.

6	Synaptic Plasticity	Short- and Long- term synaptic enhancement, Synaptic Depression, Fundamentals of Hebbian Learning, Spike-Timing-Dependent-Plasticity (STDP), Variants of STDP, UnsupervisedLearning	**LO-VI**	TA: Ch 19 TB: Ch 13
6	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.	**LO-VII**	TA: Ch. 12RC: TBC Other sources : TBC