Faculty common course 2021

Brain-inspired Computing

Course title: Brain-inspired Computing

Credits: 5

Responsible: Dr. Zhibin Zhang, Division of Solid-State Electronics, Department of Electrical Engineering, The Ångström Laboratory. 070 4250 820; zhibin.zhang@angstrom.uu.se

Dates and time: Sep. – Oct. 2021, see the schedule below

Virtual classroom: online with Zoom, https://uu-se.zoom.us/j/ 658 758 7424

Main fields of study: Electronics, engineering sciences, physics, computer science, neuroscience

Participants: 20

Prerequisite: basic physics including electronics, university mathematics (calculus, linear algebra)

Languish: English

Course materials: presentation, assignments, a limited amount of articles

Content: This course introduces biophysical models of neurons and explores working principles of computation in biological and artificial neural networks. The contents of the course include a series of lectures and hands-on exercises in (1) the essence, history, strength, applications and the science base of the brain-inspired neuromorphic computing, (2) the biological facts and physical models of individual neurons, (3) the phase plane analysis of physical models of neurons, (4) the biological facts and physical models of synaptic connections, (5) the learning mechanisms with the dynamics of synapse, (6) the physics of neuronal population, (7) the dynamics of cognitive processes, e.g., perception, memory, recognition, (8) the fundamentals and learning rules of SNN, and (9) the architectural design of neuromorphic chips with IBM TruethNorth or Intel Loihi as examples. Assignments following all lectures. The main course materials include "Neuroscience" (by Dale Purves etc., Oxford University Press for biological facts about the brain), "Neuronal Dynamics" (by Wulfram Gerstner etc., Cambridge University Press for the physics of neuronal systems), and a list of review and research articles.

Outcomes: Upon completion of the course, the student shall be able to (1) understand the biological aspects and the physical models at different levels of individual neurons, (2) calculate and predict neuronal activities using the leaky integrate-and-fire (LIF) model of neurons, (3) master the mathematical tools of phase plane analysis to describe the dynamics of neurons, (4) explain the biological aspects and physics of synaptic connections and their roles in learning process, (5) describe population activities, (6) discuss the physics underlying the cognitive processes in the brain, e.g., memory, perception and feature recognition, (7) know how the knowledge of neuroscience is applied to develop the new generation AI computation model, spiking neural networks (SNN), and (8) understand how the state-of-the-art neuromorphic hardwares implement the principles of SNNs by using e.g., IBM TrueNorth chip and Intel Loihi as examples.

Schedule

All the lecturing starts at 10 am sharp.

Date	**Time**	**Preliminary topics**	**Instructors**
Lecture	10:00, 2h, Sep 6	Background, and mathematical preliminaries	Zhibin Zhang
Lecture	10:00, 2h, Sep 13	Spiking neuron models	Libo Chen
Tutorial	10:00, 1h, Sep 14	Spiking neuron models	Libo Chen
Lecture	10:00, 2h, Sep 20	The synaptic connections and learning	Chenyu Wen
Tutorial	10:00, 1h, Sep 21	The synaptic connections and learning	Chenyu Wen
Lecture	10:00, 2h, Sep 27	Neuronal populations, assemblies and cognitions	Zhibin Zhang
Tutorial	10:00, 1h, Sep 28	Neuronal populations, assemblies and cognitions	Zhibin Zhang
Lecture	10:00, 2h, Oct 4	Computation models with spiking neural networks and hardware implementation	Mauricio Perez
Tutorial	10:00, 1h, Oct 5	Computation models with spiking neural networks	Mauricio Perez

Recommended readings:

1. *Neuroscience,* Dale Purves, etc., 6th, 2018, ISBN 9781605358413
2. *Neuronal Dynamics*, Gerstner, Wulfram, 2014, ISBN 9781107635197
3. *An Introductory Course in Computational Neuroscience*, Miller, Paul, 2018, ISBN 9780262038256