Computational Neuroscience Course

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September 2020

1 Syllabus

Course contains 13 lectures, 1 seminar, 12 lecture quizes, 4 homeworks and a final exam.

1. LECTURE 1. (Georgy G.) Intro
   - What is neuroscience and what to compute here
   - Scope of interest
   - What will be in this course
2. LECTURE 2. (Sofia K.) Biological perspective
   - Functions that NS performs, what is different about NS as compared to other organismal systems
   - Which properties of a neuron allow it to perform its functions
   - Glial cells and their functions
   - Interaction between neural cells and between neural and glial cells
   - Basic principles of neural tissue functioning and development
   - Integration with other systems of an organism
   - How NS evolved (evolutionary perspective)
   - Curious cases from other (non-model) organisms, self-awareness and emotions in non-human animals, potential implications
   - What we still don't know (questions like: what makes consciousness? what was its evolutionary benefit?(or is it some by-product?), some others)
3. LECTURE 3. (Dmitriy B.) Neuron physiology and biophysics
   - Neuron morphological and functional structure
   - How does neuron transmit signals
   - Currents and potentials
   - Nernst equation
   - Osmotic effects
   - Ion gradients
4. LECTURE 4. (Dmitriy B.) Neuron models
   - Single-Compartment models
   - Integrate-and-Fire models
   - Voltage-Dependent conductances
   - The Hodgkin-Huxley model
   - Modeling channels
   - Synaptic conductances
   - Synapses on Integrate-and-Fire neurons

   HOMEWORK 1: Hodgkin-Huxley model
5. LECTURE 5. (Vladislav M.) EEG: how to work with it
   - What is LFP and EEG in particular
   - Imaging data from bottom to top (Spikes - LFP - ECoG - EEG/MEG)

- The origin of LFP and EEG
- What can we get from this data
- Pros and cons of different imaging techniques
- Methods to work with EEG
- Applications (Neuralink, large scale models)

HOMEWORK 2: EEG practice

6. LECTURE 6. (Dmitriy B.) Conductances and morphology models
   - Levels of neuron modeling
   - Conductance-based models
   - The cable equation
   - Multi-compartment models
7. LECTURE 7. (Georgy G.). Neurotransmitters and receptors
   - Ionotropic receptors
   - Vesicles and neurotransmitter release
   - Role of Ca^{2+} ions in neurotransmission
   - Synaptic space
   - Extrasynaptic signaling/volume transmission
   - MAO and its role
   - Reuptake
   - Retrograde signaling

   HOMEWORK 3: Chemical synapse model
8. SEMINAR 1. HW1-3
9. LECTURE 8. (Dmitriy B.) Neural encoding
   - Stimulus, response, spike train
   - Spike train statistics
   - The neural code
10. LECTURE 9. (Dmitriy B.) Plastisity and learning
    - Hebbian theory
    - Biological mechanisms
    - Spike-timing dependent plasticity
    - Synaptic homeostasis
    - Learning
11. LECTURE 10. (Vladislav M.) Spiking networks: biology and application
    - Networks
    - Biological structures
    - Firing-rate network models
    - Spiking network (SNN) models
    - SNN applications

    HOMEWORK 4: Spiking network models
12. LECTURE 11. (Georgy G.) Regulation of neuron functioning
    - Metabotropic receptor in detail
    - Biochemical cascade "from membrane to nucleus"
    - Neuroplasticity and its role in higher neural functions
    - Overview of monoamine systems

- Endogenous and exogenous ligands

13. LECTURE 12. (Sofia K.) Neural tissue development
    - Fundamental aspects of developmental biology
    - Embryogenesis
    - Neurogenesis
    - Axon guidance and synaptogenesis
14. LECTURE 13. (Vladislav M.) ML and computational neuroscience
    - ML, AI and neuroscience.
    - NS inspirations for ML
    - ML applications in neuroscience
15. Final exam/Final Q&A

2 Assessment criteria

In this course students can get a maximum of 10 points in total. Each task is graded based on a scale from 1 to 10, where 1-3 is unsatisfactory, 4-5 is satisfactory, 6-7 is good, 8-10 is excellent.

Lecture quizzes, home works and the final quiz do not block each other. That means a student can complete some quizzes, some home works and the final exam to get a passing grade (how many of each exactly - calculate yourself)

Task	**Coefficient**	**Quantity**	**Total**
Lecture quiz	0.01	12	0.12
Homework 1: Hodgkin-Huxley Model	0.1	1	0.1
Homework 2: EEG practice	0.1	1	0.1
Homework 3: Chemical synapse model	0.1	1	0.1
Homework 4: Spiking network model	0.2	1	0.2
Final quiz (mandatory)	0.38	1	0.38
			1.0