Testi del Syllabus

Resp. Did.	**GIUGLIANO MICHELE**	**Matricola: 028874**
Docente	**GIUGLIANO MICHELE, 3 CFU**	

Anno offerta:	**2022/2023**
Insegnamento:	**931SV - PRINCIPLES OF COMPUTATIONAL NEUROSCIENCES**
Corso di studio:	**SM54 - NEUROSCIENZE**
Anno regolamento:	**2022**
CFU:	**3**
Settore:	**BIO/09**
Tipo Attività:	**D - A scelta dello studente**
Anno corso:	**1**
Periodo:	**Primo Semestre**
Sede:	**TRIESTE**

Testi in italiano

Lingua insegnamento	English
Contenuti (Dipl.Sup.)	- Introduction to Neural Computation and Overview (live class) Blended (online, self-paced, recommended as compulsory for all) part Learning Module 1: mathematical preliminaries and refreshers - Mathematical functions and their graph - Adding a constant or multiplying by a constant - Notable functions: straight lines, exponentials, and logarithms - Intuition for derivatives and elementary functions - Indefinite and definite integrals - The Dirac's Delta-function - The Convolution Integral - Trains of Deltas and the Sampling of a function - Algebraic versus differential equations - First order differential equations: the inhomogenous case - Numerical solutions - The Euler's forward method - Taylor's expansion and comparison with the analytical solution Live, in-class, learning Module 2: - Neuroelectronics: the building blocks of quantitative neurobiology - The Hodgkin-Huxley Model of Excitability: an intuitive analysis - Simplified point-neuron Models: reducing the complexity - Models of Synaptic Transmission: connecting neurons - Simplified Models of Networks: from microscopic to mesoscopic Practical part: - An elementary introduction to numerical simulations - in the "computer room"; exercise together Advanced topics:

- Non-deterministic Excitability: ion channel flickering and noise
- Models of Synaptic Plasticity: connecting neurons

Testi di riferimento	Essentials (chapters from): Slides/overhead of MG (ahead of time, 1 day ahead - all of them available) Sterratt et al. (2011) Principles of Computational Modelling in Neuroscience. Cambridge Univ. Press. [Chapter .., .., .., ..] Longstaff A (2011) "BIOS Instant Notes: Neuroscience", 3rd ed., Garland Science. [Chapter .., .., .., ..] ==Optional readings: Weiss TF (1996) Cellular Biophysics, Vol. 1 and 2, Bradford Books, The MIT Press. Gerstner (2014) Neuronal Dynamics: From Single Neurons to Networks and Models of Cognition, Cam. Univ. Press. Abbott LF, Dayan P (2001) Theoretical Neuroscience. Cambridge, MA: MIT Press. Kandel et al. (2012) Principles of Neural Science, 5th ed., McGraw Hill. Bear MF, Connors B, Paradiso MA (2006) Neuroscience: Exploring the Brain (chapter 1-4). Alberts et al. (2009) Essential Cell Biology, 3rd ed., Garland Science.
Obiettivi formativi	Students will be exposed to and learn a selection of elementary topics in Computational Neuroscience, and will understand the motivations behind a mechanistic dissection on how the mammalian nervous system works. Students will become knowledgeable in this domain and will be able to apply their knowledge in grasping at a quantitative and modelling components of cutting-edge scientific publications. Students will start making quantitative judgements along the lines of Cellular Electrophysiology and Biophysics, analysing how significant discoveries could be made in these domains and where the availability of solid theoretical and computational tools revealed to be extremely fruitful. Students will become fluent in this language and skills. Students will be presented by a quantitative style of analysis of neural systems, as an opportunity to expand their learning skills beyond "enumeration" in biology and towards "synthesis" and "analysis". Which practical part can they do by their own computer? They will be indepndent in simulating simple models (HH, inegrate-and-fire, network).
Prerequisiti	- strong interests for interdisciplinary scientific topics - an active and passive knowledge of (international) English - a modest proficiency on the use of a PC and Internet and curiosity to learn more - a passive knowledge of English - basic concepts of elementary math, algebra, and calculus - basic concepts of elementary electrostatics - basic concepts of elementary cell biology
Metodi didattici	- Class, contact teaching - Practice sessions - Personal work - Exercises - Directed self-study - Projects
Modalità di verifica dell'apprendimento	Oral/Written examination (closed- and open-questions, with exercises of biophysics) OR - A limited number of individually tutored mini-research exercises (voluntary; first-in-first-served) involving the development of simple computer simulations with a final 10 min presentation + my own questions to them The students overall show that they gained knowledge on how the neurons, synapses, and networks mechanistically works, are able to

	dissect its (dys)functions at the cell and microcircuit level, and demonstrates a thorough knowledge and insight in the discussed quantitative Cellular Electrophysiology and Biophysics language, models and skills.
Programma esteso	Introduction Definition of Computational Neuroscience - The Concept of a (mathematical) model - Large-scale projects in Neuroscience Mathematical Refresher Definition of O.D.E. and relationship with an algebraic equation - Solution and graph of the first order O.D.E. with constant coefficient: d f(x)/dx = a f(x) - Homogeneous and non-homogeneous O.D.E. and superposition of effects - Explicit Euler Numerical Method and Interpretation of the Euler Method by Taylor's expansion Neuroelectronics Charge carriers in (semi)conductors and in electrochemical solutions - Silver-chloride junction: formula, electrical equivalent model, use - Elementary Neurobiology: cellular excitability and the membrane bilayer Lipid bilayer: organization, electrical equivalent circuit element, definition of capacitance Ionic membrane permeability, electrical equivalent circuit element, definition of resistance Definitions and conversions between density and concentrations Ionic gradients across a biological membrane Mobility of a particle in an aqueous medium, under an external force field Definition of 1-dimensional flux, under a force field Diffusion force field and Fick's law of diffusion Conservation of mass: 1-dimensional Equation of (electro) diffusion Drift force field, under external electrical potential gradient 2-compartments, permeable membrane, sigle ion specie, equilibrium: Nernst equation, electrical equivalent circuit element 2-compartments, permeable membrane, single ion specie, non-equilibrium: ohmic approximation 2-compartments, permeable membrane, single ion specie, non-equilibrium: Goldman equation and non-ohmic approximation 2-compartments, permeable membrane, several ion species, non-equilibrium: the existence of a membrane potential, the Goldman-Hodgkin-Katz equation The Hodgkin-Huxley model Phenomenology of an Action Potential - Full equations of the HH model and their intuitive understanding - Ions exchanged during an Action Potential (AP) - Ion channels: gate model, chemical reactions, mass action law, and (Markov) kinetic schemes - Fast-inactivating sodium channel and its gate model - Delayed rectifier potassium channel and its gate model Relationship between injected current and time-to-spike: intuitive explanation and quantitative explanation - Potassium calcium-dependent ion currents: their impact on neuronal firing Dependency on the extracellular potassium concentration on a AP - Effect of selective toxins on a AP Synaptic Transmission Electrical synapses: features and electrical equivalent circuit element Chemical synapses: features and electrical equivalent circuit element Synaptic receptors: nomenclature, ionotropic, metabotropic receptors, features and modelling Two-state gate-model of chemical synaptic transmission: definition and analysis NMDA-receptor and its membrane potential dependence: definition and modeling Simplification of the two-state model by Dirac's Delta neurotransmitter pulses Elementary analysis of input-output properties of a synapse Short-term synaptic plasticity Short-term depression and facilitation: features and frequency-dependent impact Model of short-term plasticity and simplest model of short-term depression Simplified Spiking Neuronal Models Motivations for reducing complexity

Integrate-and-Fire model neurons: analysis and simulation
Frequency versus Current (F-I) curve: analytical derivation
Absolute refractory period and its effect on the F-I curve
Simple model of spike-frequency adaptation
Connecting two Integrate-and-Fire neurons by a chemical model synapse
Conductance-driven and Current-driven model synapses
Firing-Rate Population Models

Obiettivi Agenda 2030 per lo sviluppo sostenibile

- 3 Salute e Benessere

Questo insegnamento approfondisce argomenti strettamente connessi a uno o più obiettivi dell'Agenda 2030 per lo Sviluppo Sostenibile delle Nazioni Unite".

Obiettivi per lo sviluppo sostenibile

Codice	Descrizione

Testi in inglese

English

- Introduction to Neural Computation and Overview (live class)

Blended (online, self-paced, recommended as compulsory for all) part

Learning Module 1: mathematical preliminaries and refreshers
- Mathematical functions and their graph
- Adding a constant or multiplying by a constant
- Notable functions: straight lines, exponentials, and logarithms
- Intuition for derivatives and elementary functions
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- Algebraic versus differential equations
- First order differential equations: the inhomogenous case
- Numerical solutions
- The Euler's forward method
- Taylor's expansion and comparison with the analytical solution

Live, in-class, learning Module 2:
- Neuroelectronics: the building blocks of quantitative neurobiology
- The Hodgkin-Huxley Model of Excitability: an intuitive analysis
- Simplified point-neuron Models: reducing the complexity
- Models of Synaptic Transmission: connecting neurons
- Simplified Models of Networks: from microscopic to mesoscopic

Practical part:
- An elementary introduction to numerical simulations
- in the "computer room"; exercise together

Advanced topics:
- Non-deterministic Excitability: ion channel flickering and noise
- Models of Synaptic Plasticity: connecting neurons

Essentials (chapters from):
Slides/overhead of MG (ahead of time, 1 day ahead - all of them available)
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==Optional readings:
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Students will be presented by a quantitative style of analysis of neural systems, as an opportunity to expand their learning skills beyond "enumeration" in biology and towards "synthesis" and "analysis".

Which practical part can they do by their own computer?
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- an active and passive knowledge of (international) English
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- Class, contact teaching
- Practice sessions
- Personal work
- Exercises
- Directed self-study
- Projects

Oral/Written examination (closed- and open-questions, with exercises of biophysics) OR
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Introduction
Definition of Computational Neuroscience - The Concept of a (mathematical) model - Large-scale projects in Neuroscience
Mathematical Refresher
Definition of O.D.E. and relationship with an algebraic equation -

Solution and graph of the first order O.D.E. with constant coefficient: d f(x)/dx = a f(x) - Homogeneous and non-homogeneous O.D.E. and superposition of effects - Explicit Euler Numerical Method and Interpretation of the Euler Method by Taylor's expansion

Neuroelectronics

Charge carriers in (semi)conductors and in electrochemical solutions - Silver-chloride junction: formula, electrical equivalent model, use - Elementary Neurobiology: cellular excitability and the membrane bilayer

Lipid bilayer: organization, electrical equivalent circuit element, definition of capacitance

Ionic membrane permeability, electrical equivalent circuit element, definition of resistance

Definitions and conversions between density and concentrations

Ionic gradients across a biological membrane

Mobility of a particle in an aqueous medium, under an external force field

Definition of 1-dimensional flux, under a force field

Diffusion force field and Fick's law of diffusion

Conservation of mass: 1-dimensional Equation of (electro) diffusion

Drift force field, under external electrical potential gradient

2-compartments, permeable membrane, sigle ion specie, equilibrium: Nernst equation, electrical equivalent circuit element

2-compartments, permeable membrane, single ion specie, non-equilibrium: ohmic approximation

2-compartments, permeable membrane, single ion specie, non-equilibrium: Goldman equation and non-ohmic approximation

2-compartments, permeable membrane, several ion species, non-equilibrium: the existence of a membrane potential, the Goldman-Hodgkin-Katz equation

The Hodgkin-Huxley model

Phenomenology of an Action Potential - Full equations of the HH model and their intuitive understanding - Ions exchanged during an Action Potential (AP) - Ion channels: gate model, chemical reactions, mass action law, and (Markov) kinetic schemes - Fast-inactivating sodium channel and its gate model - Delayed rectifier potassium channel and its gate model

Relationship between injected current and time-to-spike: intuitive explanation and quantitative explanation - Potassium calcium-dependent ion currents: their impact on neuronal firing

Dependency on the extracellular potassium concentration on a AP - Effect of selective toxins on a AP

Synaptic Transmission

Electrical synapses: features and electrical equivalent circuit element

Chemical synapses: features and electrical equivalent circuit element

Synaptic receptors: nomenclature, ionotropic, metabotropic receptors, features and modelling

Two-state gate-model of chemical synaptic transmission: definition and analysis

NMDA-receptor and its membrane potential dependence: definition and modeling

Simplification of the two-state model by Dirac's Delta neurotransmitter pulses

Elementary analysis of input-output properties of a synapse

Short-term synaptic plasticity

Short-term depression and facilitation: features and frequency-dependent impact Model of short-term plasticity and simplest model of short-term depression

Simplified Spiking Neuronal Models

Motivations for reducing complexity

Integrate-and-Fire model neurons: analysis and simulation

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Obiettivi per lo sviluppo sostenibile

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