Step by step exams (tot. 4 in the full semester)

Available time per step by step exam: 15 min

STEPbySTEP1: MOTOR CONTROL

1) Define the inverse model.
2) Which elements of the primary motor cortex can be associated to the inverse model functions?
3) Provide and describe an experimental example, which demonstrates the existence of the direct model.

STEPbySTEP2: REHABILITATION ROBOTICS

1) List and explain the advantages and disadvantages of myocontrol in rehabilitation robotics.
2) Describe an algorithm for myocontrol in a rehabilitation robotic device.
3) What does IIa, B mean in the AHA (American Heart Association) guidelines?

STEPbySTEP3: NEUROPROSTHESES

Consider a motor prosthesis for hand grasping controlled through EEG (i.e. BCI) and one controlled through EMG. The actions to be controlled are: open the hand; close the hand.

Suppose to use the neuroprosthesis to restore hand grasping in:

1. a SCI patient;
2. a post-stroke subject in post-acute phase
3. an amputee

For each patient (1., 2., 3.) discuss the advantages and disadvantages of the two control strategies (BCI vs EMG-based) , explaining the issues that need to be faced to evaluate the appropriateness of the solution.

STEPbySTEP4: NEUROENGINEERING FOR BIOLOGY

1) Consider the following types of *in vitro* neuronal models: dissociated cultured neuronal networks and brain slices. Describe the two models and discuss their advantages and disadvantages.
2) Suppose to acquire extracellular activity from dissociated cultured neurons with MEA. Compare temporal and spatial resolution with respect to patch-clamp. Explain at least two methods that could be used to increase spatial resolution.

1st full exam (09/01/2019)

Instructions:

- For step-by-step: answer 1 of the 4 questions on the step-by-step topic you missed/want to repeat; available time: 15 min
- For full exam: answer 3 of the 4 questions; available time: 45 min

---

1. MOTOR CONTROL: THE CEREBELLUM
   1) Describe the cytological architecture of the cerebellum.
   2) Define Spike-Time Dependent Plasticity (STDP). Where does STDP take place in the cerebellum?
   3) Describe how plasticity at PF-PC synapses takes place and contributes to cerebellum-driven motor learning.

2. REHABILITATION ROBOTICS AND ORTHOTICS
   1) Definition of rehabilitation robotics and orthoses.
   2) Provide an example of a device, which can be used only as orthotics. Describe the population, the mechanical concept and the control strategy. Discuss why it can't be applied to rehabilitation.
   3) Provide an example of a device, which can be used only as rehabilitation device. Describe the population, the mechanical concept and the control strategy. Discuss why it can't be applied as orthotics.

3. NEUROPROSTHESES: FUNCTIONAL ELECTRICAL STIMULATION
   1) What are the hypothesized principles at the basis of neuroplasticity effect of FES?
   2) What are the reason to use EMG-controlled FES? What are the technical issues and how these can be solved?
   3) In the following situations, is EMG controlled FES worthy to be used or not?
      A. A post stroke patient having no evident residual movement of the district to be trained
      B. A SCI (Spinal Cord Injury) patient having no evident residual movement of the district to be trained
      C. A post stroke patient showing spasms in the district to be trained
      D. A post stroke patient showing poor control in the district to be trained

4. *IN VITRO* NEUROENGINEERING: OPTICAL SOLUTIONS FOR RECORDING *IN VITRO* NEURONAL ACTIVATION
   1) Explain the principle of working.
   2) Provide a description of equipment and experimental solution using optical methods to record *in vitro* neuronal activity.
   3) Discuss advantages and disadvantages with respect to MEA.

2nd full exam (25/01/2019)

Instructions:

- Answer the 3 questions on the content of the course; available time: 45 min

---

1. MOTOR CONTROL
   1) Describe why motor control is a complex task
   2) List and explain the features of voluntary movement
   3) Motor learning: what does it mean? What are its features?

2. REHABILITATION ROBOTICS
   1) What are the key factors for motor recovery in post-stroke patients and the major limitations of current conventional therapy?
   2) What is neuroplasticity?
   3) What is intended with the term of Maladaptive plasticity?
   4) In case of assist-as-needed control strategy, is the EMG triggered solution more valuable than the myocontrolled one in terms of facilitating plasticity? Discuss your answer.

3. *IN VITRO* NEUROENGINEERING: OPTICAL SOLUTIONS FOR RECORDING *IN VITRO* NEURONAL ACTIVATION
   1) Explain the principle of working.
   2) Provide a description of equipment and experimental solution using optical methods to record *in vitro* neuronal activity.
   3) Discuss advantages and disadvantages with respect to MEA.

3rd full exam (22/02/2019)

Instructions:

- Complete ALL the 3 question requests on the content of the course; available time: 45 min

---

1. THE CEREBELLUM
   1) Identify the input and output pathways of the cerebellum within the motor control system, specifying the brain areas sending/receiving projections from the cerebellum.
   2) Describe the main role of the cerebellum in motor control and the cerebellar circuit properties that drive this role.
   3) Provide an example of a cerebellum-driven task.
   4) If you want to implement a closed loop neurorobot experiment driven by a bioinspired controller
      i. – discuss what are the conditions for using compartimental neuronal models.
      ii. – discuss what are the conditions for using single point neuron models.

2. NEUROPROSTHESES (NP)
   1) What is a myocontrolled NP?
   2) What are the technological problems to be solved in order to implement a myocontrolled neuroprosthesis?
   3) Explain possible technological solutions.

3. *IN VITRO* NEUROENGINEERING:
   1) What are the possible available solutions for applying stimulation of neurons *in vitro*?
   2) Describe the working principle of two alternatives.
   3) Compare the two selected alternatives (advantages and disadvantages).

4th full exam (27/06/2019)

Instructions:

- Complete ALL the 3 question requests on the content of the course; available time: 45 min

1. MOTOR CONTROL
   1) Define the function and input/output signals of forward and inverse models in the motor control system
   2) Describe an experiment demonstrating the existence of the internal forward model.
   3) Represent the motor control system in a block diagram, explaining the role of each involved structure. Specifically, identify which of them act as forward and/or inverse controllers.

2. THE CEREBELLUM
   1) Explain the function of the cerebellum within the motor control system.
   2) List and briefly describe the main neural populations in the cerebellar circuit.
   3) In designing computational models of the cerebellum, selecting the best model for single neurons is a critical issue. Explain how you would model the neural populations in 2.2 within a spiking neural network model of the cerebellar circuit, highlighting the advantages and limits of your solution.

3. REHABILITATION ROBOTICS
   1) List the advantages of using robots in rehabilitation
   2) Explain the limits of assistive controllers in robotic rehabilitation
   3) Suggest a solution to overcome the limits described in 3.2 during rehabilitation of the upper limb. Describe the design of the setup, the control strategy and a protocol to test the system.