UNIVERSITY OF GENOA
DEPARTMENT OF INFORMATICS, BIOENGINEERING, ROBOTICS AND SYSTEMS ENGINEERING
MASTER'S PROGRAM IN BIOENGINEERING

Thesis Project Form

Title (tentative): Machine Learning and computational models to characterize and optimize spinal cord stimulation

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Description

Motivation and application domain

The epidural stimulation of the lumbar spinal cord (in the following, spinal cord stimulation, or SCS) allows to substantially improve the gait of incomplete spinal cord injury (SCI) patients, and to elicit movements in complete ones. The benefits of stimulation are both immediate, allowing larger ranges of motion through the summation of the applied stimulation and the remaining descending commands, and long lasting, mainly through the conjunction of stimulation and rehabilitation.
While the clinical usefulness of spatiotemporally modulated SCS has been vastly documented, the impact of the optimization of the stimulation parameters, especially when constrained by hardware limits of commercial stimulators, needs further investigation.
The few attempts at automatizing such optimization have been performed in a data-driven way, treating the whole process of stimulation as a black box, and putting in relation the stimulation parameters with their effect on muscle activation or kinematics. Such processes ignore the state of the patient when the stimulation is applied, and risk to produce very noisy estimates of the effect of stimulation.
This thesis research will be aimed at generalizing the computational framework developed by the host laboratory for the optimization of peripheral nerve stimulation to the case of spinal cord stimulation.

General objectives and main activities

A first interesting task of the Thesis will consist of the integration of a time-dependent characterization of the state of the patient to single out the effects of the stimulation on the measured physiological variables in terms of learning and fatigue.
As an alternative, th EPFL laboratory has worked in the last years to a modular framework for the model-driven optimization of peripheral stimulation, whose fundamental building blocks could be generalized to SCS. Starting from the data collected to their implanted patients at San Raffaele Hospital in Milan, the Master student will try to deduce the functional anatomy of the implanted spinal cords and will work on the optimization of the applied stimulation protocols using computational models for neuromodulation.

Training Objectives (technical/analytical tools, experimental methodologies)

â€¢ Learning to use the existing computational framework for the optimization of the peripheral nerve stimulation.
â€¢ Formulating and implementing the volume conduction problem in the case of spinal cord stimulation.
â€¢ Formulating and implementing the neural response computation problem in the case of spinal cord stimulation.
â€¢ Training machine learning-based surrogate models to speed up model response evaluation.
â€¢ Formulating and implementing objective functions and optimization heuristics to optimize stimulation in silico.

Place(s) where the thesis work will be carried out: TNE laboratory at Ã‰cole Polytechnique FÃ©dÃ©rale de Lausanne, at the Biotech Campus in Geneva and at the San

Raffaele Hospital in Milan.

Additional information	
Pre-requisite abilities/skills:	MATLAB programming skills, signal processing, statistics, attitude to computational work
Maximum number of students:	1