Three lecture titles and short abstracts

Neurons in the loop: from neurorobotics to neuroprosthetics

Keywords: in vitro, MEA, hybrid, neuromorphic, real-time, bi-directional, network, burst, coding, decoding.

Abstract. Starting from the 20s, researchers have begun to explore the possibility to create 'hybrid' systems in vitro at the interface between neuroscience and robotics, thus providing an excellent test bed for designing innovative, bi-directional neural interfaces and neuroprostheses. The first-ever in vitro closed-loop system consisted of a lamprey brainstem bi-directionally connected to a small wheeled robot. Inspired by that pioneering study, we developed a bi-directional system involving neocortical networks grown in vitro onto Micro Electrode Arrays and a small robot. A closed-loop paradigm was also exploited to develop a novel concept of a 'neuromorphic prosthesis', constituted by an all-hardware real-time system hosting a Spiking Neural Network able to replace the function of a missing neuronal connection or sub-network.

Neuroengineering solutions for restoring brain functions

Keywords: plasticity, closed-loop, intracortical microstimulation, neuroprosthetics, spike, motor areas, lesion, neural interface, behavior, translation.

Abstract. Neuroengineering is a multidisciplinary field at the boundaries between neuroscience and engineering. Its primary goal consists of developing instruments which allow a dialogue with a neuronal system, with a twofold perspective: i) to deepen the knowledge on the functioning of the nervous system; ii) to develop systems able to restore functions in case of disability. In our research, we exploit Neuroengineering approaches with the final goal of developing innovative technologies either for 'replacing' (i.e. neuroprosthetics for the brain) or for 'retraining' (i.e. targeted neuromodulation) brain functions in case of neurological disorders. The results from two projects, related to the topics introduced above, will be presented: (i) restoration of the communication between damaged neuronal assemblies in vitro; (ii) closed-loop paradigms aimed at promoting Hebbian plasticity to repair brain functionality in vivo. Further developments and applications will be briefly introduced and discussed, highlighting also their translational potential.

Translational neurorehabilitation: towards a patient-centered approach

Keywords: brain-computer interface, motor impairment, neurologic disorder, neuromodulation, robotic rehabilitation, exoskeletons, electrophysiological biomarkers, personalization, design thinking, neuroethics

Abstract. Neurological diseases causing motor/cognitive impairments are among the most common causes of adult-onset disability. More than one billion of people are affected worldwide, and this number is expected to increase in upcoming years, because of the rapidly aging population. The frequent lack of complete recovery makes it desirable to develop novel neurorehabilitative treatments, suited to the patients, and better targeting the specific disability. To date, rehabilitation therapy can be aided by the technological support of robotic-based therapy, non-invasive brain stimulation, and neural interfaces. In this perspective, current and future approaches based on the combination of the above approaches should be introduced, to sensibly improve the amount of recovery with respect to traditional treatments. Furthermore, to maximize the outcome of a neurorehabilitation treatment, the personalization of the therapy based on patient and clinician needs and preferences should be always included, already starting from the design of a rehabilitation device or tool. A comprehensive overview of the above topics with a special focus on preclinical studies for developing neurostimulation-based therapies will be presented in this talk.