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Implementing a hybrid bi-directional communication between neuronal assemblies

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Abstract — Bioelectronic medicine aims at developing devices capable to deliver an electric therapy by stimulating the target organ in a controlled way, possibly with less side effects than standard pharmaceutical therapy. Neural stimulators and implantable systems exploit the bioelectronic technology to reduce neurological impairments. Here we present the prototype of a bi-directional brain prosthesis capable to restore the communication between damaged *in vitro* neuronal networks.

I. INTRODUCTION

The consequences of brain lesions represent a major economic and healthcare priority worldwide. One of the main challenges is to enhance the recovery of motor and cognitive functions following such insults. Sometimes pharmacological treatments and physical rehabilitation are not enough to regain a fully independent life [1]. Recent technological improvements in the field of neural interfaces are opening new frontiers to meet the growing demand for alternative solutions [2]. *In vitro* studies can provide an easy and low-risk model to explore promising intervention strategies.

Here we realized an *in vitro* platform for next generation brain-prostheses aimed at artificially link two previously connected neuronal assemblies.

II. METHODS

The experimental set-up consisted of a biological element and an artificial system (i.e. the neuroprosthetic device). We

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used dissociated cortical rat neurons plated over a 60-channel Micro-Electrode Array (MEA) characterized by two interconnected networks (i.e. bimodular), exhibiting spiking and network bursting (NB) activity. During experiments, we performed a laser ablation to cut the axonal connections between the two neuronal modules to mimic a focal lesion.

The neuroprosthetic device consisted of a neuromorphic board based on Field Programmable Gate Array (FPGA) and was able to perform real-time spike/NB detection. Upon detection, an activity dependent stimulation paradigm was applied from one module to the other and vice versa (Bi-directional Bridging, BB). When an artificial Spiking Neural Network was configured in the FPGA, we were able to implement a Hybrid Bidirectional Bridging (HBB) experimental paradigm, where the SNN was replacing one of the two modules of the biological network.

III. RESULTS

We first characterized the effect of a focal lesion on a bimodular network. After a few hours of recording, the firing of the network reached pre-lesion values thus proving the viability of the network. The correlation between the modules collapsed to zero proving both an anatomical and functional disconnection. We then implemented two neuroprosthetic strategies: BB and HBB. Through the BB strategy, we were able to partially recover the cross correlation features without imposing any preferred direction. The HBB protocol was performed when we aimed at replacing one entire module by means of a SNN. We used NB events to control the stimulation and also in this configuration, we obtained a partial recovery of the cross correlation without affecting the firing of the survived module.

IV. CONCLUSIONS

Our neuroprosthetic device is able to artificially restore the bi-directional interaction between two previously connected neural assemblies. The developed stimulation strategies can be seen as a starting point towards a new rehabilitation paradigm that can act directly at the CNS level.

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