FAST IMAGING AND NONLINEAR PHOTO-MANIPULATION IN NEURONAL NETWORKS

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It is well accepted that the brain is a highly complex and extensive network of neurons in 3D. This complexity introduces a large difficulty to the comprehension of the whole network, specifically the role of each node, the network dynamics, as well as the topology and robustness of the actual structure. The use of neuronal cultures [1] combined with network science [2] allows the implementation of controlled experiments to understand simplified patterns of neural activity. The easy manipulation and accessibility of these engineered networks allows experimental designs that could not be performed in actual living brains [3].

The basis for the study presented here is the detailed monitoring of neuronal activity in cultures. This is a first and crucial step to understand the network as a whole, and to unveil its structural and dynamic information. Our cultures consist of a series of neuronal aggregates that shape the nodes of a network. We consider fluorescence calcium imaging as the main technique, which uses a fluorescence probe to detect calcium transients upon neuronal firing [3]. The fast detection of the fluorescence generated during the neuronal firing allows the fast, parallel acquisition of nodes’ activity, and independently of the underlying structure of the network. The analysis of the acquired data is used to unveil important features of the network [4].

The experimental system that we have developed combines a large field of view, fast imaging, and non-linear photo-manipulation with high-precision. This platform is aimed at perturbing the physical structure of the network (either nodes or connections) in a controlled manner, and to assess how these perturbations affect the collective dynamics of the network. The ultimate goal of our tool is to study the behavior and characteristics of in vitro neural networks upon perturbations or strong damage. Additionally, the use of non-linear photo-manipulation [5] guarantees the controlled interaction with the sample and reduces potential unwanted effects that can occur using other type of manipulations. The flexibility of the setup opens a large window of experiments that can be used to better understand the huge complexity of neuronal networks.