Functional Analysis Of Neuronal Networks: Neurons Segmentation and Activation Maps

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Abstract

In the last few decades, neuroscience has tried to go beyond the analysis of single isolated neuronal structures, toward the study of their mutual functional interaction over time. In this work we propose a new approach for studying in vitro neuronal networks, by understanding their morphology (detecting neurons nuclei) and providing activation maps, obtained by exploiting the information of the neurons electrophysiological signals.

Introduction

Recent efforts in neuroscience have been conveyed towards the integration of multidimensional datasets and standard microscopy to understand systems functional behavior. Recently introduced Active Pixel Sensor Multielectrode Arrays (APS-MEA) [1] try to match such requirement, allowing fine-scale description of neurons signaling. APS-MEAs consist of a 64x64 grid of CMOS electrodes for directly measuring cultured networks activity. Fluorescence microscopy is also adopted to depict the network morphology. This novel technology opens new challenges in the neuronal networks analysis field, providing a way to infer relevant information on cell signaling.

Proposed Approach

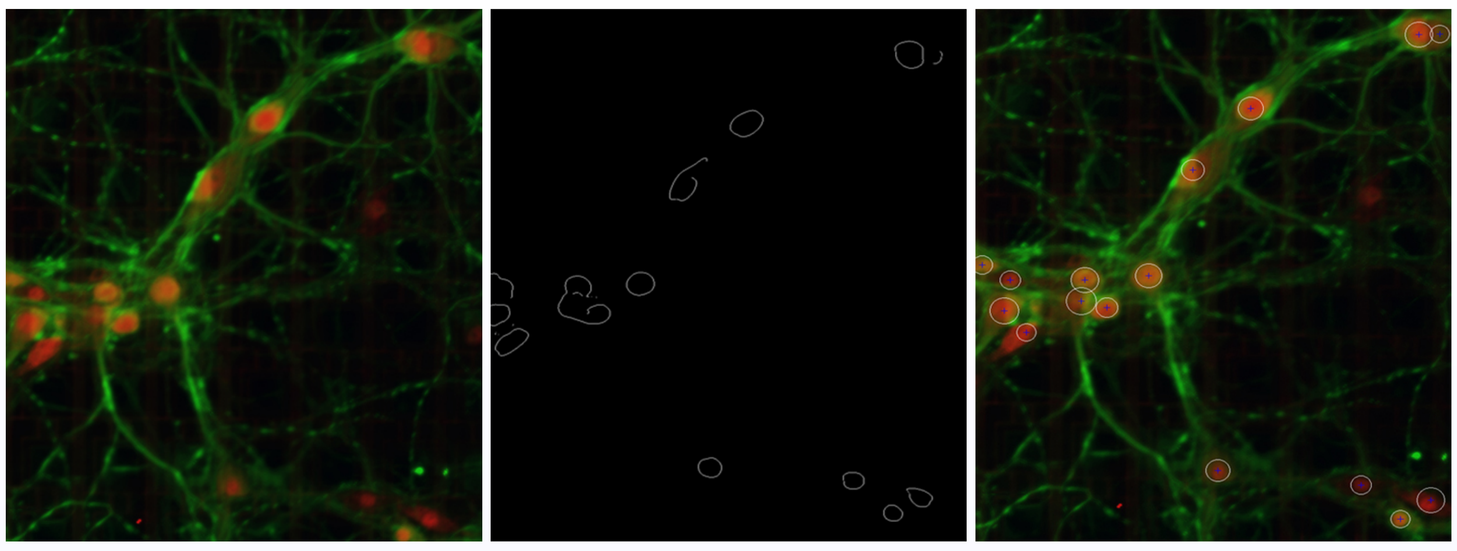
The proposed work addresses two main goals: a) detecting neurons, b) analyzing the electrophysiological signal to detect active channels and obtain *activation maps*. Neurons are segmented using the Circular Hough Transform [2], constrained with the prior knowledge of the nuclei radium variation range. For active channels detection both spikes recurrence and amplitude of neural activity are taken into account. Activation maps are computed by reconstructing the electrodes grid, using the image correlation with a given CMOS image template. Active channels information are finally overlayed on the segmented image to obtain a global mapping between network morphology and functionality.

References

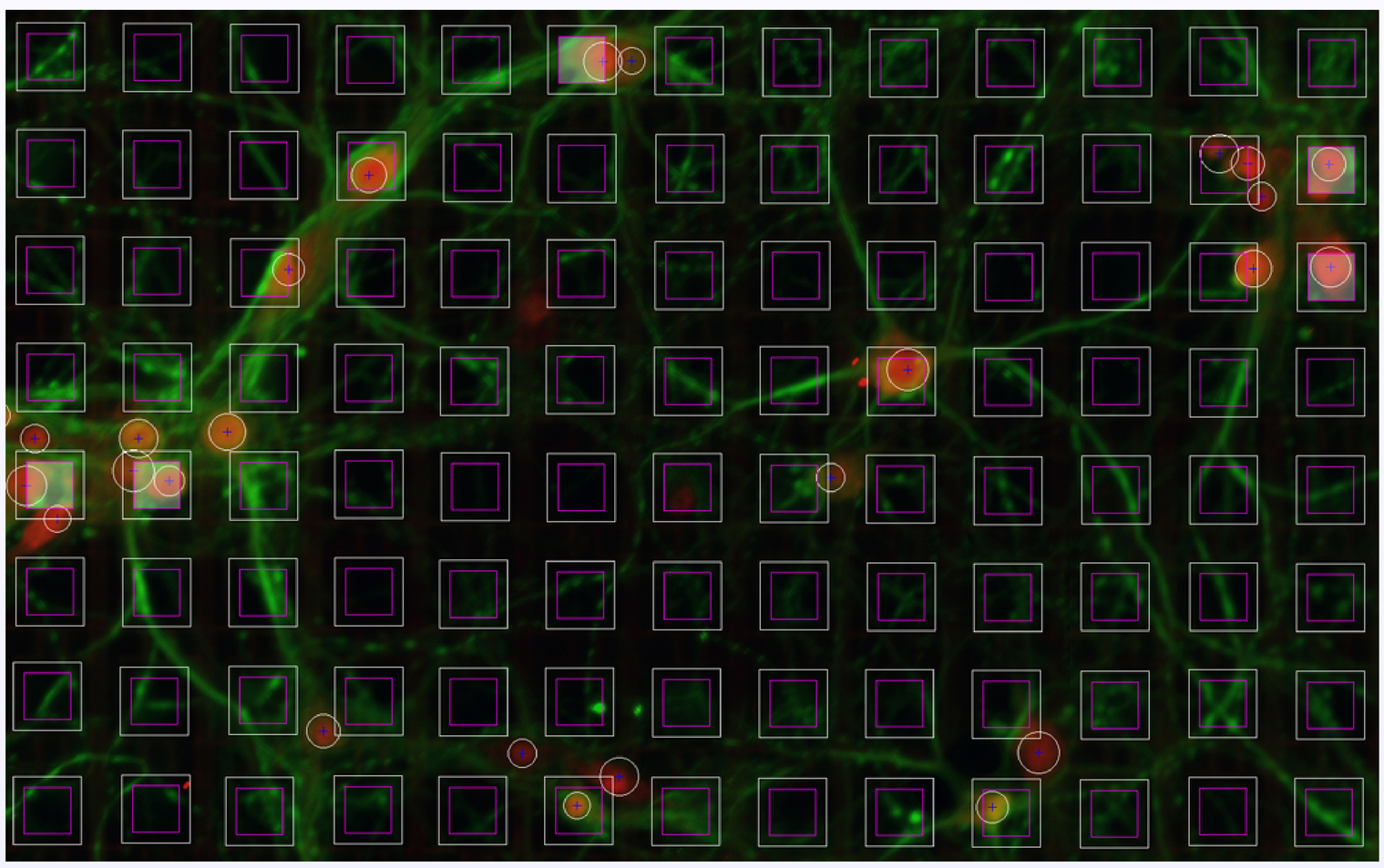
[1] L. Berdondini, K. Imfeld, A. Maccione, M. Tedesco, S. Neukon, M. Koudelka-Hep, S. Martinoia, Active pixel sensor array for high spatio-temporal resolution electrophysiological recordings from single cell to large scale neuronal networks, *Lab on a chip, Vol. 9, No. 18, 2613-2744*, 2009

[2] S.J.K. Pedersen, Circular Hough Transform, *Aalborg University, Vision, Graphics, and Interactive Systems*, 2007

Results



From left to right: a) Fluorescence image describing neuronal network morphology, b) Canny edges map, c) Neurons nuclei detected by CHT.



Activation map overlayed on the segmented image. The grid of CMOS electrodes is reconstructed through a correlation process. RANSAC interpolation is performed for detecting the occluded electrodes. The magenta square indicates the actual CMOS boundary while the white one takes into account the surrounding insulating material. Light gray electrodes represent active channels, i.e. channels in which neurons activity has been detected during the recording process.

Future Work

Future work will address functional estimation of neurons clamps, trying to better understand how spikes wave forms are correlated with the number of cells, and connectivity estimation, with the aim of studying inhibitory and excitatory circuits.