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Computational methods for quantitative studies of synaptic plasticity processes in confocal images: How to efficiently extract morphological parametrization

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The morphology of dendritic spines and the architecture of the neuronal nuclei are in scope of many researchers studying the processes of synaptic plasticity. In most of the experiments in which synaptic plasticity is studied, only the subtle changes or the changes occurring in a small subset of studied structures are observed. In turn, it is required to analyze the large amount of data in order to conclude that certain regularities are observed in overall statistics. However, the precise analysis of even one confocal stack is a challenging task; therefore the specialized computational tools are necessary. The important factor is to find the balance between the accuracy of the method and the user's bargain. We desire to have the fully automated image reconstruction methods, however often they are not accurate enough to detect subtle changes. Given the large number of artifacts contained in confocal images, the overall ratio of false positive and false negative detections may be high enough to opt for manual analysis. In case of dendritic spines, we observe the objects of size close to the limits of confocal microscopy resolution. The architecture of neuronal nuclei presents another challenge: These nuclei are tightly packed, especially in hippocampus. The arising challenge is the proper segmentation and three-dimensional reconstruction of nucleus interior, which is crucial to have the proper morphological parametrization that allows studying quantitatively the processes of synaptic plasticity and epigenetics. We focus on the various bottlenecks in quantitative analysis of confocal images, and discuss why the particular computational methods were developed to perform the automatic analysis of confocal images, or to aid the manual analysis and the data post-processing. We also address the sampling issues in quantitative analysis of dendritic spines morphology, outlining the scheme of efficient extraction of morphological parametrization from confocal stacks.

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