SENSEI: Segmentation of Neurons using Standard and Super-Resolution Microscopy

Main area: Reconstruction of neuronal morphology from microscopic image data
Keywords: neuronal segmentation algorithm; super resolution microscopy; membrane probes; animal models; human brain
Duration: 36 months
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Abstract

Accurately mapping the brain at the micro- and nano- scale is a challenge in cellular neuroscience.

In the light of this challenge, SENSEI will deliver novel image processing tools along with innovative imaging modalities dedicated to advancing breakthroughs in 3D neuronal segmentation and morphometrics. The consortium brings together teams with long-standing expertise in signal and image processing (UNIPI, Italy), basic neuroscience in mouse models, live and super-resolution imaging analysis (INSERM, France) and development of new imaging modalities for high-content and super-resolution microscopy (KUL, Belgium).

SENSEI's objectives are to accurately quantify neuronal morphology at tissue and molecular levels through the development of intelligent segmentation-based image processing algorithms and to improve the quality of neuronal imaging using new membrane probes for conventional and emerging super-resolution imaging technologies. Specifically, we will develop an algorithm for isolating single neurons from 3D datasets representing the intricacies of the brain micro-structure. The algorithm will be tested for accuracy and reproducibility using different imaging techniques and protocols to show its ability to deal with data at different spatial scales (from tissue to molecular range). This project will study several species (human, rat, mouse) both in vitro for 2D (hippocampal, cortical neurons) and in situ for 3D (tissue slices and clarified brains) in cortex, cerebellum and hippocampus. Once optimized on rodents, new imaging modalities and segmentation protocols will be tested on human brain tissues coming from surgical resections. Samples will be imaged both with confocal microscopy, accounting for 80 % of user needs, and advanced imaging modalities, thus bringing either high resolution details on fixed dendritic spines (i.e. STED, STORM) or on live neurons (i.e. 3D SOFI). In addition to the sub-diffraction resolution, an optical device encoding probe information in the microscope point-spread function will be constructed, allowing the fast acquisition of cellular nanostructuring in full-3D.

Microscopy will be done on dual set-ups allowing correlation with confocal and super-resolution. This will allow extending the segmentation algorithm, already developed for confocal datasets, to super-resolution ones. Images and software will be stored in a database through a Data Management system allowing use by other Flagship representatives or external groups.

SENSEI will dramatically facilitate 3D reconstruction of neuronal morphology and circuitry, aiding neuro-anatomical mapping, and generating models which can be used for making predictions about higher-level brain organization. The detailed analyses of neurons will shed new light on the normal development of dendritic and axonal arbours and on how these processes are altered in neuro-pathologies.

Consortium

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