NeuRA

The Neuron Reconstruction Algorithm

The mammalian brain consists of several billions of neurons. These are interlinked in complex manner through billions of so-called synapses. Changes in the link pattern of the cells are an essential element for the flexibility of the brain and enable learning processes. Present anatomical studies base on the reconstruction of only a few neurons. An understanding of the information processing in the brain can only be made possible through the study of the networking of many cells. A neuronal cell consists of a dendritic tree which collects information and an axonal tree across which processed information is transmitted over longer distances.

New developments in microscopy, e.g. two-photon microsopy, enable highly resoluted fluorescence images of neurons in vivo, i.e. within the inatct brain of living animals. These advances are the prerequisities for the automatic reconstruction of neuronal morphologies. In practice however, some preprocessing is necessary before e.g. geometry and dendritic branching patterns can be extracted.

For this goal the software NeuRA was developed as a toolbox for the automatic reconstruction of neurons. NeuRA comprises the required preprocessing steps und provides interaction possibilities for the scientist.
The reconstruction proceeds as follows:
1. Filtering of the raw data
2. Segmentation of the filtered data
3. Reconstruction of the geometry

The signal-to-noise ratio of data sets obtained from two-photon microscopy is low for the most part because the tissue is recorded in living animals. Therefore a reconstruction directly from the raw data is not reasonable. NeuRA filters the data with an anisotropic nonlinaer difusion filter. This filter identifies one-dimensional substructures in the 3-D image, closes gaps in these and sharpens them. The filter uses the structure tensor for the recognition of structures.

The succeeding segmentation which is based upon local threshold values assigns each voxel clearly either to the structure or to the background. This process is coupled iterativley with the filtering. Eventually a discrete representaion of the neuronal geometry is generated with the aid of piecewise cylinders. The so originated tree is then output in common file formats.

This sophisticated method for the automatic reconstruction of neurons is completely new in its way and in this field of application. With this method neuron geometries from data obtained by two-photon microscopy and having therefore a low signal-to-noise ratio can be reconstructed automatically for the first time.

This enables the monitoring of marked cells in the neocortex of living animals (rats). Our development is therefore essential for the investigation of neuronal plasticity, i.e. geometrical changes in brain evolving from learning processes.