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COMPUTATIONAL SOFTWARE

NeuronSeg_BACH: Automated Neuron Segmentation Using B-Spline Based Active Contour and Hyperelastic Regularization

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Abstract. The vast diversity in neuron cell morphology has led to an increase in automated algorithms which can accurately reconstruct neurons from microscopy images. The poor quality of brightfield and fluorescence microscopy images and the thin branch-like fibrous structure of neurons make the process of manual segmentation challenging. We propose a novel automatic neuron segmentation framework using a B-spline based active contour deformation model with hyperelastic regularization, and develop a MATLAB software tool named "NeuronSeg_BACH". In NeuronSeg_BACH, initialization of the contour is done automatically by detecting cell body and neurites separately. This boundary-extraction based algorithm utilizes cubic B-splines to deform active contours to match the neuron cell surface accurately. Using adaptive local refinement, finer level deformation of the active contour is captured using truncated hierarchical B-splines in a multiresolution manner. By introducing hyperelastic regularization, we allow large nonlinear deformations of the active contours. Unlike other existing methods which represent boundaries as piecewise constant functions, we provide a more accurate and smooth representation of the neuron geometry. In the level set segmentation framework, the implicit level set function is defined using C^2 continuous B-splines. Improved segmentation results are shown for 2D and 3D synthetic and microscopy images as compared to other methods.

AMS subject classifications: 68U10

Key words: Neuron morphology, image segmentation, active contour models, hyperelastic regularization, truncated hierarchical B-splines.

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Program summary

Program title: NeuronSeg_BACH
Nature of problem: This software performs 2D and 3D automatic segmentation of neuron cell fluorescence microscopy images using B-Spline based active contour and hyperelastic regularization.
Software licence: BSD 3-Clause License
CiCP scientific software URL: `https://github.com/arpawar/NeuronSeg_BACH`
Programming language(s): Matlab and C++.
Computer platform: x86-64.
Operating system: Linux, Windows and Mac OS X.
Compilers: Supported and compatible compilers for MATLAB 2019a and previous releases:

- `http://www.mathworks.com/support/compilers`
- `http://www.mathworks.com/support/sysreq/previous_releases.html`

RAM: 16 GB and higher recommended.
External routines/libraries: TREES Toolbox (`https://www.treestoolbox.org/`)
Running time: Running time will increase based on increasing size and complexity of the images.
Restrictions:
Supplementary material and references:
Additional comments:

1 Introduction

Computational neuroscience is one of the most prolific and exciting research areas in which the main focus is to utilize computational methods to provide a deeper understanding of the human brain. There have been several research initiatives such as the BRAIN Initiative [20], which focuses on multidisciplinary research towards developing technologies for the study of the human brain and its complex functions. The primary component of the brain is neuron which carries out the important function of recognizing stimulus and transmitting appropriate response through connections with other neurons, called as synapses. With over 86 billion neurons, all the complex functions are carried out in the human brain.

The characterization of neuron cells plays a crucial role in the study of the structure and function of the nervous system. Due to the vast diversity in the neuronal cell types coupled with a large number of imaging methods, achieving a better understanding of neuron morphology is still a very challenging task. The first natural step in obtaining more information on the neuron cell function begins with describing the cell morphology. An accurate representation of different components of the neuron such as dendrites, axon