PhD Thesis Proposition in 3D Image Processing

Title: Digital Reconstruction of 3D Neuronal Network Using Marked Point Processes

Project:
The project addresses the automatic 3D reconstruction of neuronal circuits in light microscopic images. Digital reconstruction of neuronal morphology and neuronal circuits along with their quantitative analysis are necessary to investigate the nervous system and for a better understanding of degenerative diseases. The size and the shape of the neuronal body, its extensions and projections (neuritis: axons and dendrites), as the quantification of the neuronal connectivity, provide essential information about the neuron type and function, the brain structure and its dynamics. Much effort has been recently done in developing (semi-)automatic methods for digital reconstructing of neuronal trees. Automated algorithms aim in facilitating and accelerating the tedious tracing and analysis task. Nevertheless, the approach used still remains partially manual.

The goal of the project is to develop an efficient Stochastic Marked Point Process (MPP) framework using the DIADEM database for first tests. MPP models are well adapted for analysing data with spatial repartition in images. They have been widely applied to the problems of multiple object extraction from 2D High-Resolution (HR) and Very High-Resolution (VHR) remote sensing images [2, 3, and 4]. In order to reconstruct and analyse 3D neuron circuits in microscopic image stacks, the aim is at developing an MPP model defined in the space of configurations, which consist of 3D simple-geometry objects for representing 3D neuronal structures. A probability distribution is then defined on the space of configurations of individual 3D objects and depends on their joint relations in the image scene and their relation to the image data. The objects sought compose an optimal configuration, the estimation of which is done by sampling using a Markov chain based on a discrete-time Multiple Birth-and-Death (MBAD) dynamics [1].

The project will consist of three main steps. The first, which is a continuation of previous work, is a further improving and adapting of a 3D MPP model for reconstruction of one neuron, which initially is an extension of a novel stochastic algorithm developed for road network detection in 2D remote sensing images [2]. The second step will consist in the definition of a 2D MPP model with arbitrarily shaped objects [3] for detecting and extracting of 3D somata (cell bodies) in the neuronal trees. Finally, a quantitative analysis along with the whole circuit tracing is to be done using the information on location and morphology of somata and the 3D MPP model for one neuron tree. The third step will consist in exploit an MBAD process as a base for the optimization scheme and its parallel application. The biggest asset of the MBAD algorithm is its ability to be parallelized that allows thinking about it as a future real-life application that can be then used for resolving more global Brain mapping problems.

Scientific challenge: Developing of an efficient stochastic 3D Stochastic Marked Point Process model for 3D neuron circuit reconstruction and analysis.

References

Conditions: The thesis is to be conducted in the IPAL (UMI CNRS 2955) international research lab of UPMC based in Singapore, in collaboration with the Institute of Information Transmission Problems (IITP) Russian Academy of Sciences (RAS) in Moscow. Salary is based of UPMC PhD contracts (3 years).

Requirements:
- Interest in image processing/analysis and parallel programming
- Programming experience in Matlab, C++ or Java
- Maths and statistics : good understanding of mathematical concepts, Bayesian thinking, MCMC methods
- Good level of English

Supervisors: Daniel Racoceanu (daniel.racoceanu@upmc.fr ) and Maria S. Kulikova (maria.kulikova@ipal.cnrs.fr)

Application: To apply for the position, a cover letter, a CV and three reference letters should be sent to the supervisors. For details contact either of supervisors.