Research Topic for the ParisTech/CSC PhD Program
(one page maximum)

****Field (cf. List of fields below):***

Mathematics and their applications, and Life and Health Science and Technology

Subfield: Medical imaging

Title:Enabling Cortical Cell-Specific Sensitivity on Clinical Multi-shell diffusion MRI Microstructure Measurements

ParisTech School:Ecole Polytechnique, Inria-Saclay

Advisor(s) Name: Demian Wassermann, Jing-Rebecca Li
Advisor(s) Email:Demian Wassermann (http://pages.saclay.inria.fr/demian.wassermann), Jing-Rebecca Li (http://www.cmap.polytechnique.fr/~jingrebeccali).
(Lab, website):This project is a close collaboration between a) the Parietal team (http://team.inria.fr/parietal) b) the Defi team (http://www.cmap.polytechnique.fr/~defi/) from INRIA (https://www.inria.fr/en/) and Ecole Polytechnique (https://www.polytechnique.edu/en), and c) Stanford Cognitive and Systems Neuroscience Laboratory, USA (http://med.stanford.edu/scsnl.html).

Short description of possible research topics for a PhD:
The proposed project attacks a new frontier of*in-vivo* microscopy through diffusion magnetic resonance imaging (dMRI). We propose a project on the edge of MR physics, machine learning, and human cyto-architecture by using dMRI for microstructure quantification, focusing on heterogeneous cellular tissue. There has been tremendous progress made in the past decades in axonal tracking and axonmicrostructure quantification in the human brain. The study of such problems in the human brain's white matter, which is composed of mostly axons, is facilitated by the cylindrical nature of the bundled axons. Such "simple" structure, unfortunately, is a particular characteristic of the white matter. The multiple-scale and anisotropic nature of general tissuecellular architecturemakes the microstructure quantification problem much more difficult in other areas of the brain.However, in an exciting preliminary work, we have shown that using multiple shell dMRIacquisitions has the potential to give quantitative information about cellular populations in tissue containing Von Economo neurons (VEN).In this PhD project, we will use numerical, analytical, and machine learning techniques to simulate and analyze the dMRI signal and design acquisition protocols to perform dMRI-based *in-vivo* non-invasive microscopy of the human brain.

Required background of the student:
The desired profile is someone who has obtained a Master's degree in Applied Mathematics or Computer Science and has the ability to program in Matlab or Python. This candidate should have a good level of understanding of methods of numerical solution of partial differential equations and the physics of diffusion.

A list of 5(max.) representative publications of the group: (Related to the research topic)
1.Wassermann D, Nguyen VD, Gallardo-Diez G, Li J-R, Cai W, Menon V (2018) *Sensing Spindle Neurons in the Insula with Multi-shell Diffusion MRI*, ISMRM.
2.O'Donnell LJ, Daducci A, Wassermann D, Lenglet C (2017) *Advances in computational and statistical diffusion MRI*. NMR in Biomedicine e3762:e3805. doi: 10.1002/nbm.3805
3. Haddar, Li, Schiavi (2017)*Understanding the time-dependent diffusion tensor measured by diffusion MRI: the intra-cellular case.* SIAM Journal of Applied Mathematics.
4. Nguyen, Li, Grebenkov, Le Bihan.(2014) *A finite elements method to solve the Bloch-Torrey equation applied to diffusion magnetic resonance imaging*.Journal of Computational Physics.