Mapping brain cell geometries by considering random paths of water molecules

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Jia Liu. Credit: University of Jyväskylä

In her doctoral thesis at University of Jyväskylä, M.Sc. Jia Liu has developed and implemented a series of new computational statistical methodologies to deal with diffusion-MRI data. The statistical problem of the thesis originates from clinical needs for diagnosing brain diseases like Lewy body dementia.

Water, the molecule of life, is omnipresent in all organisms. Diffusion plays an important role in all molecular interactions. By using modern

Magnetic Resonance Imaging (MRI) techniques, it is possible to measure, in a non-invasive way, features of the probability distribution of the random paths taken by water molecules diffusing inside our cells. By understanding the diffusion geometry in the brain, we are able to see the invisible: to discriminate between white and gray matter, to map nervous fiber tracts, and to extract statistical information about microscopic cellular structures.

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Diffusion-MRI data are "big-data" with typically 100.000 volume elements (voxels) in a full brain scan, and hundreds of data points for each voxel. Although the new generation of commercial MRI-scanners has considerably shortened the data acquisition times and prices are also coming down, still taking a diffusion-MRI scan from a patient is costly and time consuming, and certainly it is not possible to keep a patient in the MR-scanner for hours in order to acquire more detailed data.

On the other hand time and cost of data processing has dropped, and there is a great demand for advanced statistical techniques which can produce accurate results without increasing the amount of data. Potentially any improvement in the modeling and computation of diffusion-MRI statistics can have an impact on the diagnosis of brain diseases and other fields of neuroscience.

In her doctoral thesis, M.Sc. Jia Liu introduces novel data augmentation schemes to simplify the likelihood function by including into the model new latent observations, leading to more efficient and accurate computations. These ideas were implemented in different algorithms, as Expectation-Maximization (EM), Markov chain Monte Carlo (McMC)

and Variational Bayes (VB) under various diffusion-MRI parametrizations. The developed statistical methods perform better than the existing ones.

M.Sc. Jia Liu defends her doctoral dissertation "Data Augmentation under Rician Noise Model in Diffusion MRI with Applications to Human Brain Studies" at the University of Jyväskylä on Wednesday 5th of June 2019 at Mattilanniemi, Agora Alfa at 12-15 o'clock. The dissertation is held in English.

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