Quantitative DW-MRI analysis algorithms

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BME Biomedical Engineering TECHNION

TCML The Technion's Computational MRI Lab

Introduction

Tissue characterizations are strongly dependent on its health condition. Various diseases such as different types of cancer or inflammatory activities (e.g. Crohn's disease) may change tissue structure, thus changing its diffusivity. Intravoxel incoherent motion (IVIM) imaging is a non-invasive MRI technique sensitive to tissue diffusivity characteristics. It is modeled by 3 **IVIM parameters**: **diffusion coefficient** (D), which reflects the motion of molecules inside the tissue; **pseudo-diffusion coefficient** (D*), which reflects microcapillary perfusion; and **perfusion fraction** (f).

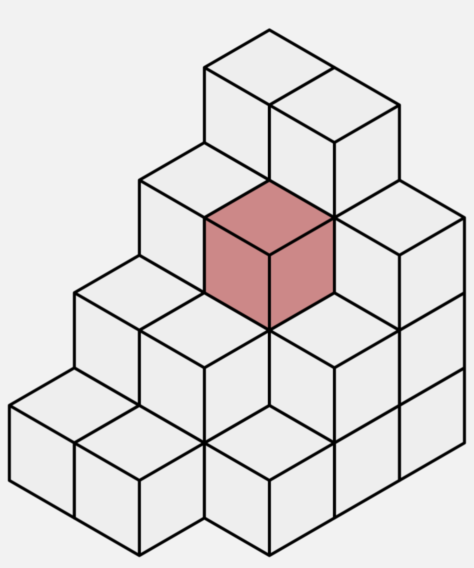
Implementing a post-processing tool that will quantify the IVIM parameters will provide a new, non-invasive, radiation-free diagnostics method in various clinical applications, such as diagnosis of diseases and prediction of treatment response.

Objective

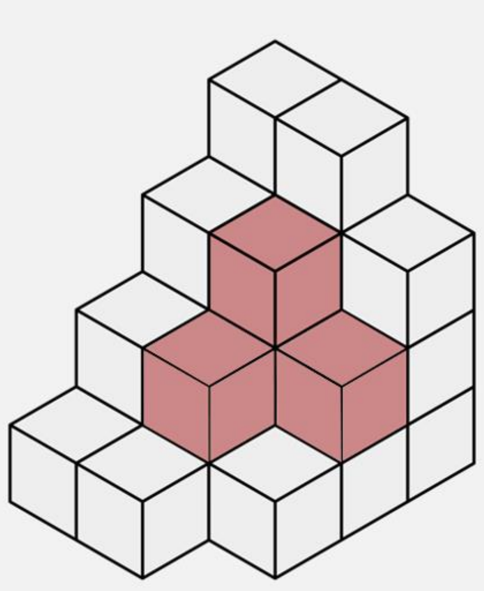
Creating a Python library that estimates IVIM parameters maps of DW-MRI images by different analysis algorithms, preforms error evaluation, and simulates DW-MRI images.

Methods

To quantify the IVIM parameters two approaches were used:



- **Least square fitting**
  Each voxels IVIM parameters are quantified irrespectively to the surrounding voxels. This approach includes three methods: **SEGb** - Segmented Doubly Linearized Least Squares, **SEG** - Segmented Partially Linearized Least Squares, **LSQ** - Full Nonlinear Least Squares.



- **Bayesian Modeling**
  Each voxels IVIM parameters are quantified respectively to given area of surrounding pixels. The method implemented is **BSP** - Bayesian modeling with a Gaussian shrinkage prior.

Results

Python library for intravoxel incoherent motion (IVIM)–based biexponential analysis of DW images was created.

Simulation results

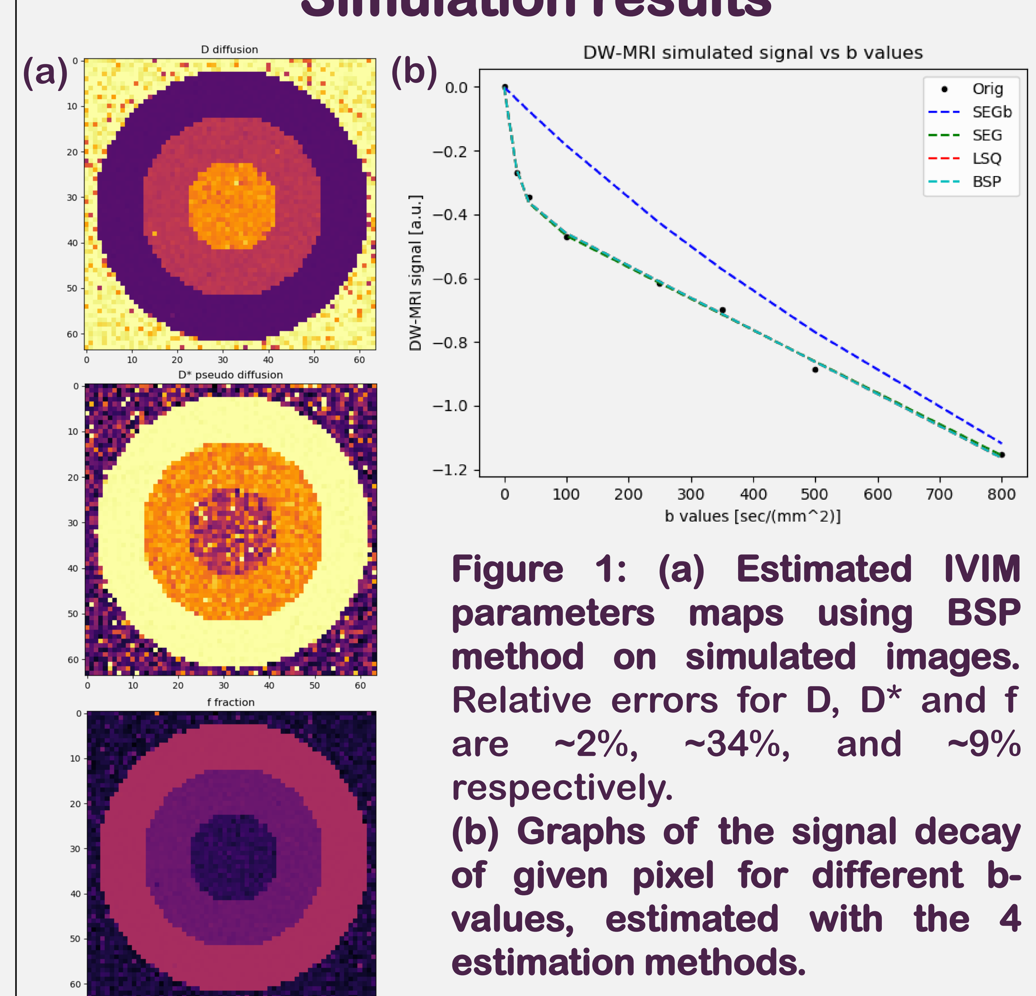


Figure 1: (a) Estimated IVIM parameters maps using BSP method on simulated images. Relative errors for D, D* and f are ~2%, ~34%, and ~9% respectively.
(b) Graphs of the signal decay of given pixel for different b-values, estimated with the 4 estimation methods.

DW-MRI images results

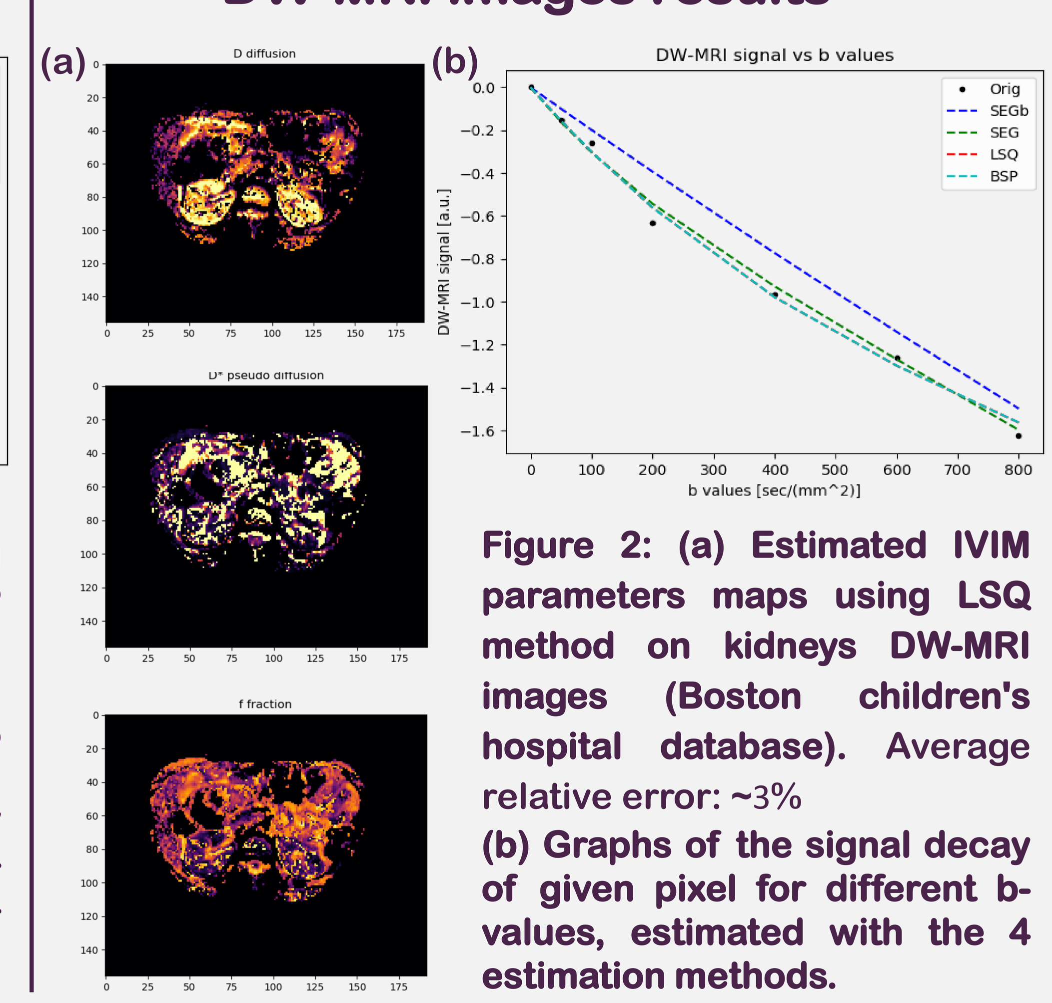


Figure 2: (a) Estimated IVIM parameters maps using LSQ method on kidneys DW-MRI images (Boston children's hospital database). Average relative error: ~3%
(b) Graphs of the signal decay of given pixel for different b-values, estimated with the 4 estimation methods.

QR Code

Take a picture to access Library GitHub

https://github.com/tcml-judit-marina/IvimParamsEstimLib

Conclusions

- A multi-purpose Python library was created which includes: 4 IVIM parameters estimation algorithms, phantom creating function, and error calculation functions. In addition, for efficiency and higher performance, the library uses vectorize programming, multiprocessing, assertions and exceptions.
- Quantification of fast and slow diffusion from DW-MRI data is challenging due to the low SNR and the large number of variables compared to the number of observations, but is possible using the approaches mentioned above. Bayesian modeling is capable of producing more visually pleasing IVIM parameter maps than least squares approaches, but their potential to mask certain tissue features demands caution during implementation.

References

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