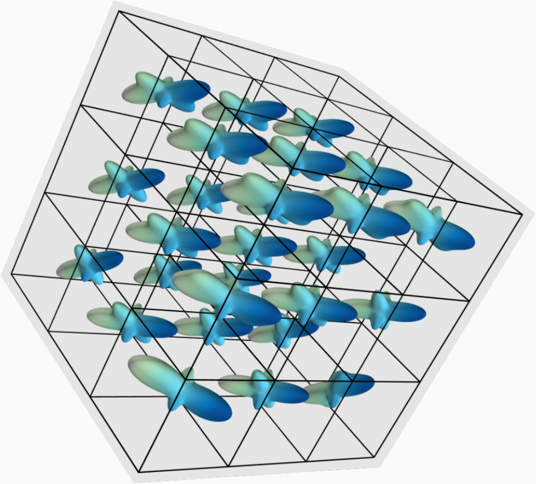

Self-Supervised Deep Learning Methods for Intra-voxel Structure Analysis From DWI

XXIII Reunión de Neuroimagen

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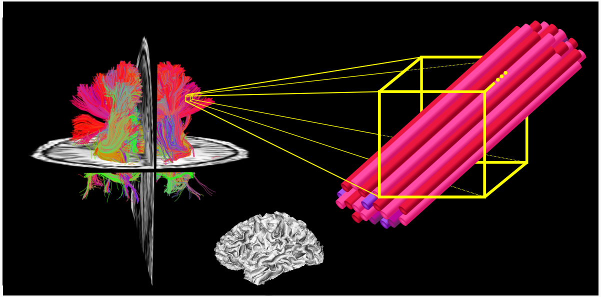
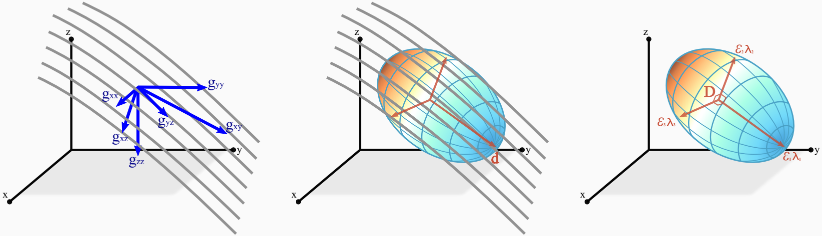
Diffusion-Weighted Magnetic Resonance Imaging



DW-MRI is a technique that measures the diffusion of water molecules in the human body and generates contrast images. Intra–voxel structure can be inferred from DWI, which has made it possible to study the brain. Tractography algorithms allow the construction of 3D models of brain
white matter.

Diffusion Tensor Imaging

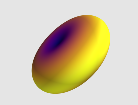
Diffusion is measured in the direction of the weighting gradient. Acquisitions from different gradients allows to compute the ellipsoid representing the diffusion in a region.

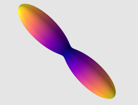


Diffusion Tensor Models

Diffusion Tensor

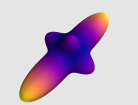
$$S_i(\mathbf{g}_i, b_i) = S_0 e^{\left(-b_i \mathbf{g}_i^\top \mathbf{D}\, \mathbf{g}_i\right)}$$





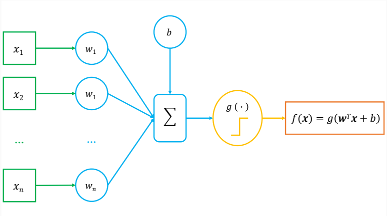
Diffusion Multi-Tensor

$$S_i(\mathbf{g}_i, b_i) = S_0 \sum_{j=1}^{t} \alpha_j e^{\left(-b_i \mathbf{g}_i^\top \mathbf{D}_j\, \mathbf{g}_i\right)}$$



Objective

Estimate the tensor directions and volume fractions given a diffusion signal.



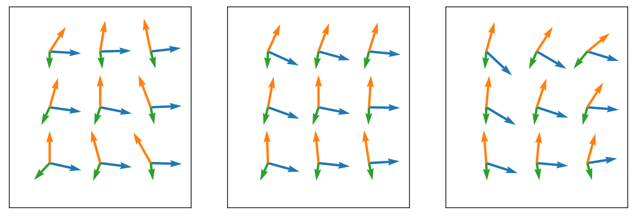
Motivation

- Deep learning approach has shown excellent results on a wide variety of problems in multiple research areas.
- Designing an appropriate strategy for the data management and the information representation is essential to take off this approach.

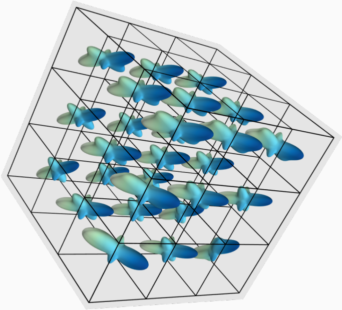
Synthetic data

Diffusion Multi-tensor Model allows to generate synthetic datasets.

Parameters

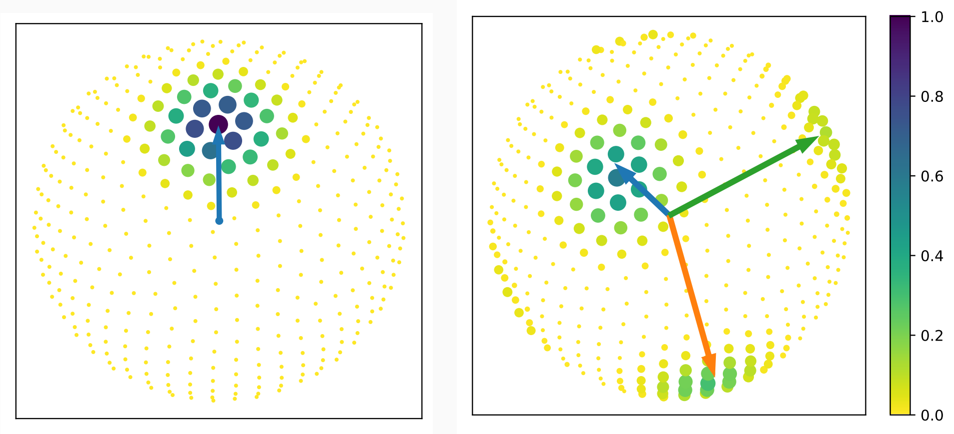


Neighborhood Signals



Supervised Scheme

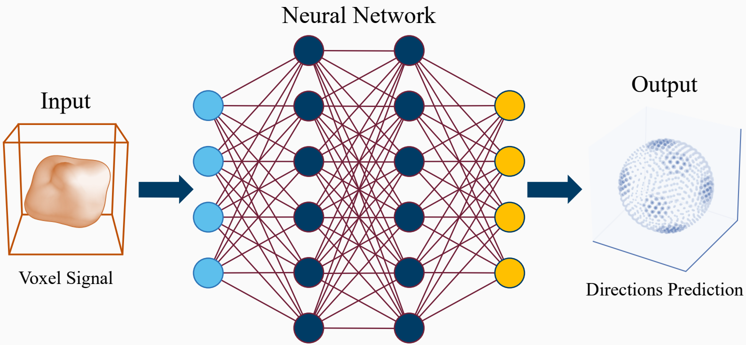
Nearest Elements (NE) and Gaussian Labels (Gσ)



Voxel Model (VOX)

Input : Single signal $\mathbf{S} \in \mathbb{R}^n$ of a voxel.

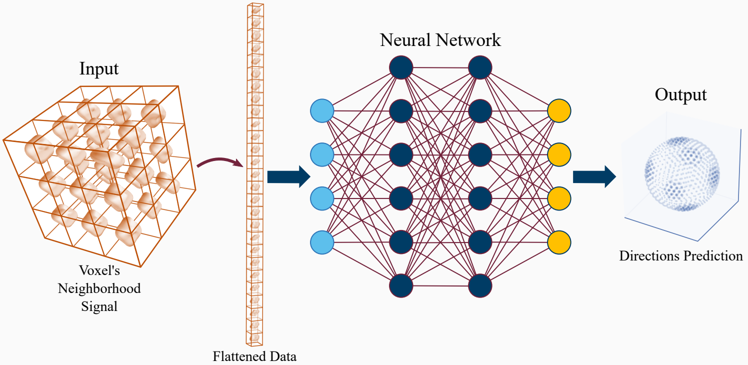
Output : $\mathbf{y} \in \mathbb{R}^m$ representation of the predicted directions.



Neighborhood Model (NBH)

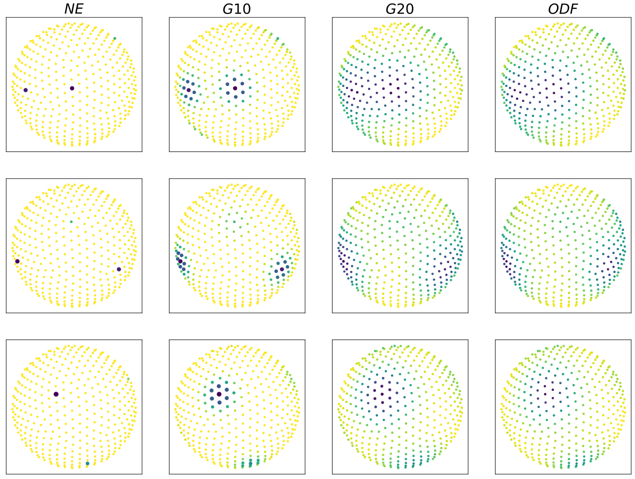
Input : Signal neighborhood $[\mathbf{S}] \in \mathbb{R}^{3\times3\times3\times n}$ cast into a vector $\mathbf{S} \in \mathbb{R}^{27n}$

Output : $\mathbf{y} \in \mathbb{R}^{m}$ representation of the prediction for the center voxel



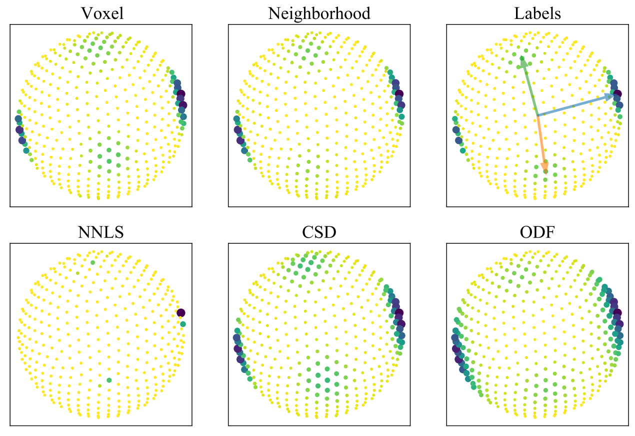
Labels Construction

Nearest Element and Gaussian Labels were compared with the ODF

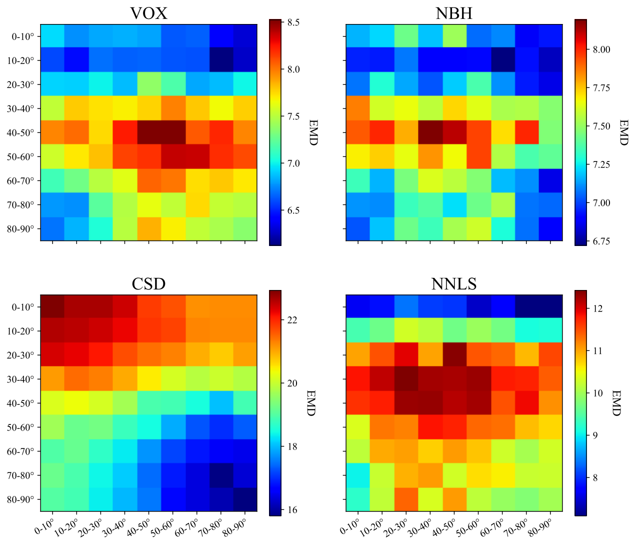


Models Predictions

The output of the models was evaluated on the test dataset qualitatively and quantitatively.

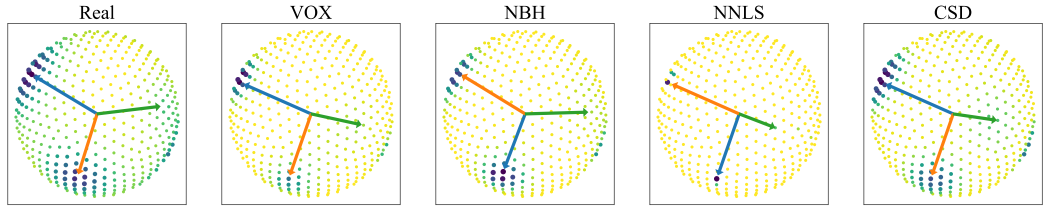


Models Predictions Error Heat Maps

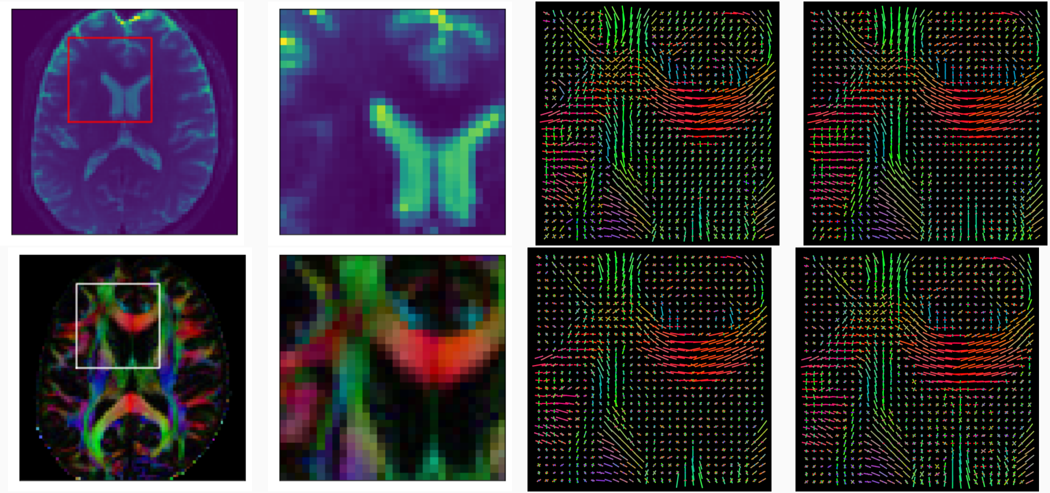


Peaks Detection

The peaks detection from the models prediction was also evaluated on the test dataset qualitatively and quantitatively.

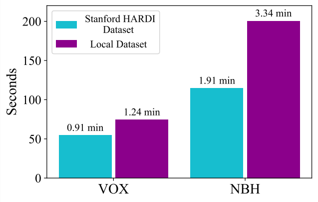


Stanford HARDI axial plane result

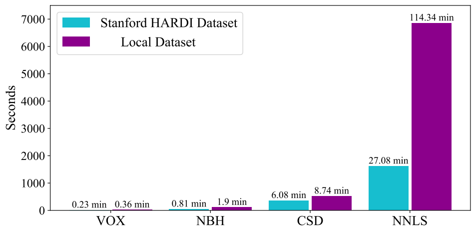


Computational Times

Training Times:



Prediction Times:



Conclusions

- It was introduced a self-supervised Deep Learning approach for DW-MRI intra-voxel structure analysis.
- Neural networks show potential to analyze diffusion-weighted signals information.
- Synthetic data is useful for training complex models with this aim.
- The proposed parameters encoding is helpful for the parameters prediction for this problem
- Voxel and Neighborhood proposed models results are comparable with the state of the art methods.

Thank you!