Self-Supervised Deep Learning Methods for Intra-voxel Structure Analysis From Diffusion Weighted Images

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Diffusion-Weighted Magnetic Resonance Imaging (DW-MRI) technique allows to capture in–vivo measures of water molecules diffusion in the brain, where Brownian motion is restricted by the axon bundles. The acquired measurements contain valuable information on the underlying microstructure; the processing of this using models such as the Diffusion Tensor (DT), allows inferring intra–voxel white matter structure. Then the reconstruction of 3D models of the brain is possible by tractography algorithms. Unfortunately this model does not consider the presence of complex fiber configurations in a volume voxel.

Objective

Nowadays several methods have been proposed to tackle this problem, nevertheless Deep Learning (DL) has hardly been explored in this approach, even when it has shown the potential to solve very complex problems. The objective of this work is to present some strategies that could be useful to tackle the problem in this way.

Methods

In this work we propose a self–supervised scheme through the use of synthetic data neighborhoods that simulate patches of real DW-MRI data. Synthetic datasets allow training two DL models to infer real axonal microstructure: Voxel Model (VOX), which predicts a single signal parameters taking it as input, and Neighborhood Model (NBH), which receives also the signal of all the adjacent voxels. Both models use a parameters encoding proposed as labels suitable for the problem. Results are evaluated by Earth Mover's Distance (EMD) which is also a proposal.

Results

Qualitative and quantitative results shows that our approach is competitive with two of the state–of–the–art methods: Non-Negative Least Squares (NNLS) and Constrained Spherical Deconvolution (CSD); with the advantage of needing shorter computational times. We present the results in a local level, analysing single voxels, for both synthetic and real datasets; and in complete regions of DW-MRI data. In each case is made an analysis, highlighting the particular advantages and disadvantages of each of the studied models.

Conclusions

This work establishes a first approach for estimating intra–voxel parameters of real DW-MRI image by the use of synthetic data and Deep Learning techniques. It opens some opportunity branches that should be considered as future work in the related area.