

Fibre Orientation Estimation with Deep Learning

TING GONG, PhD POST-ISMRM MIML WORKSHOP 13 May 2022



What is fibre orientation estimation & why

DW images



Local fibre orientations



In vivo tractography

1





How to estimate fODF conventionally





Constrained Spherical Deconvolution (CSD)

3

State-of-art CSD approach & challenges

- 1. Long acquisition time
- 2. Multiple processing steps



Pipeline of Multi-shell Multi-tissue (MSMT)-CSD Jeurissen B, et al. NeuroImage, 2014

How can DL help improve

- 1. Long acquisition time
- 2. Multiple processing steps

- Rapid acquisition with fewer DW measurements
- 2. End to end estimation



DL

Pipeline of Multi-shell Multi-tissue (MSMT)-CSD Jeurissen B, et al. NeuroImage, 2014 > Multi-output regression task **per voxel**: f(d) = x



Architecture: multi-layer perceptron (MLP)

Inputs: undersampled DWI measurements

Outputs: 45 SH coefficients at l_{max} =8

Training labels generated from MSMT-CSD with a rich sampled dataset

Gong T, et al. ISMRM, 2018

Reduced angular error when under-sampling 7

Evaluation reference: MSMT-CSD estimation from 150 measurements - including 14 b =0, 23 b=1000, 45 b=2000, and 68 b=3000 s/mm²



Gong T, et al. ISMRM, 2018

1. What is the right Input Information	 MLP [1][3][4] Patch-based CNN [2][5] 	 Gong T, et al. <i>ISMRM</i>, 2018 Lin Z and Gong T, et al. <i>Medical Physics</i>, 2019 Nath V, et al. <i>MRI</i>, 2019 Karimi D, et al. <i>Neuroimage</i>, 2021 Zeng R, et al. Medical Image Analysis, 2022
2. What to use as training labels	 MSMT-CSD [1-2][4-5] Simulation [2][4] Histology [3] 	
3. How to Handle protocol difference	 SH basis[2][3] Gradient resampling [4] fODF [5] 	

1. What is the right input information

> Making use of spatial information







Gong T, et al. ISMRM, 2019 Lin Z and Gong T, et al. Medical Physics, 2019





Zeng R, et al. Medical Image Analysis, 2022

MSMT-CSD estimation from rich-sampled in vivo data

- not always available
- training and evaluation bounded by the quality of estimation
- generalisation issue to pathological datasets

Simulation

- distribution matters
- including brain structures



MSMT-CSD estimation from rich-sampled in vivo data

- not always available
- training and evaluation bounded by the quality of estimation
- generalisation issue to pathological datasets

Simulation

- distribution matters
- including brain structures

> Histology

- hard to get
- gaps between in vivo and ex vivo
- gaps between MR signals and histology

Nath V, et al. MRI, 2019

13



3. How to handle protocol differences

- Differences in gradient directions
- Using SH basis

(Lin Z and Gong T, et al. Medical Physics, 2019; Nath V, et al. MRI, 2019)

- Resampling gradient

(Karimi D, et al. Neuroimage, 2021)





3. How to handle protocol differences

- Differences in gradient directions
- Using SH basis

(Lin Z and Gong T, et al. Medical Physics, 2019; Nath V, et al. MRI, 2019)

- Resampling gradient

(Karimi D, et al. Neuroimage, 2021)

- Difference in b values
- Using fODF

(Zeng R, et al. Medical Image Analysis, 2022)





DL based method can improve fODF estimation compared to the conventional method

- Choice of the Training dataset
- Protocol difference
- Generalizability issue