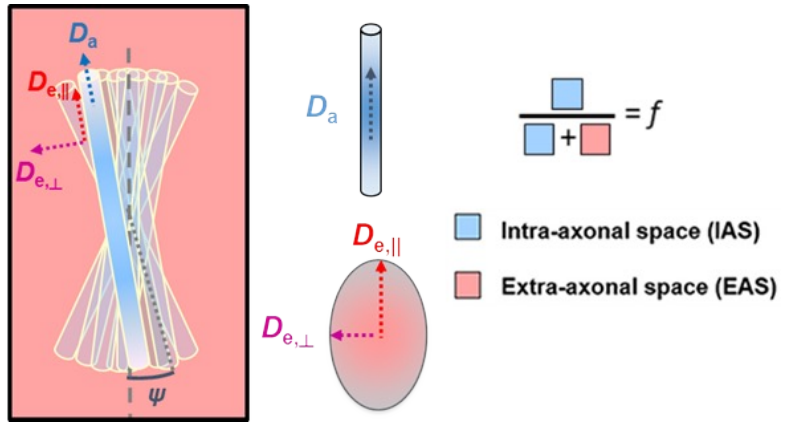
ESTIMATING BIOPHYSICAL MODEL PARAMETERS OF WHITE MATTER WITH DEEP NEURAL NETWORKS

Yujian Diao[1,2] and Ileana Jelescu[3]

1 Laboratory of Functional and Metabolic Imaging, EPFL, Lausanne, Switzerland
2 CIBM Center for Biomedical Imaging, EPFL, Lausanne, Switzerland
3 Department of Radiology, Lausanne University Hospital, Lausanne, Switzerland

STUDY

- Purpose: to establish a DL-based estimator
  - Applicable to various data without retraining, regardless of acquisition protocol or noise level
  - For White Matter Tract Integrity (WMTI)-Watson model[3,4]
    - Estimating model parameters from the diffusion and kurtosis tensors (DKI)[4]
    - clinically feasible and easily estimated from signal



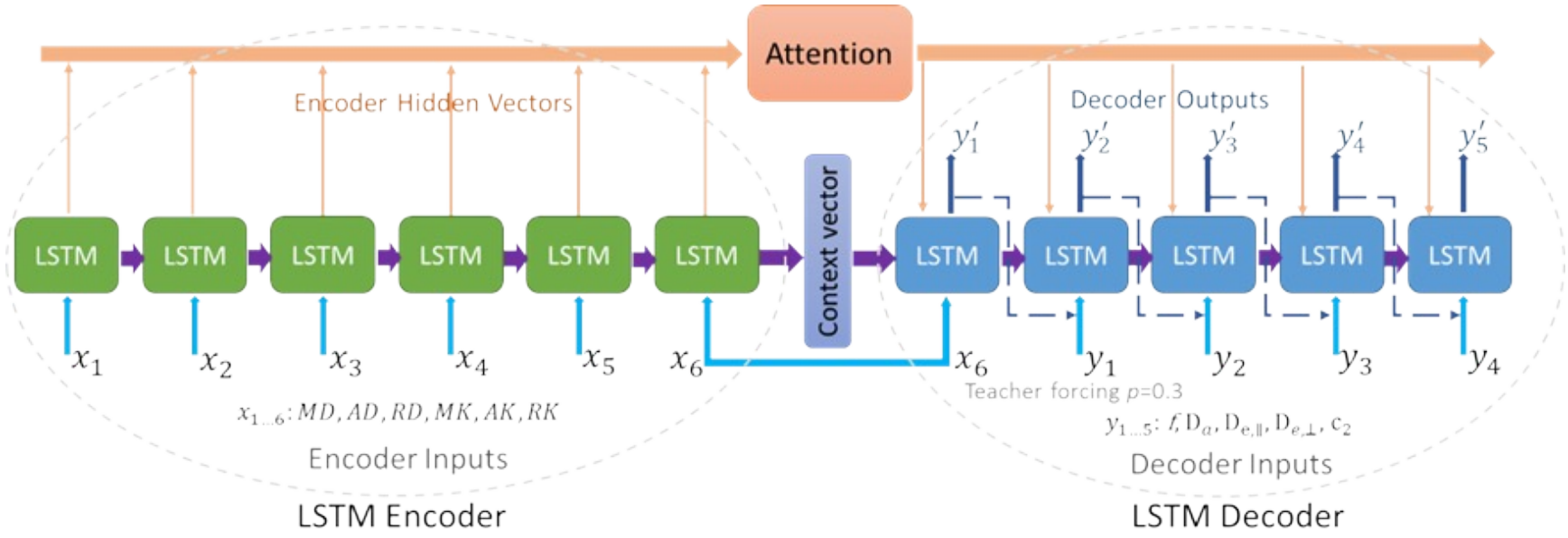
f : is axonal volume fraction.
D_a $[\mu m^2/ms]$: intra-axonal diffusivity.
$D_{e,\parallel}$, $D_{e,\perp}$ $[\mu m^2/ms]$: extra-axonal diffusivities.
$c_2 = \langle \cos(\Psi)^2 \rangle, \Psi$: orientation dispersion

1.Jelescu and Budde, 2017; 2.Harms et al., 2017;3.Fieremans et al., 2011; 4.Jespersen et al., 2018; 5. Sutskever et al., 2014

METHODS – RNN SOLVER

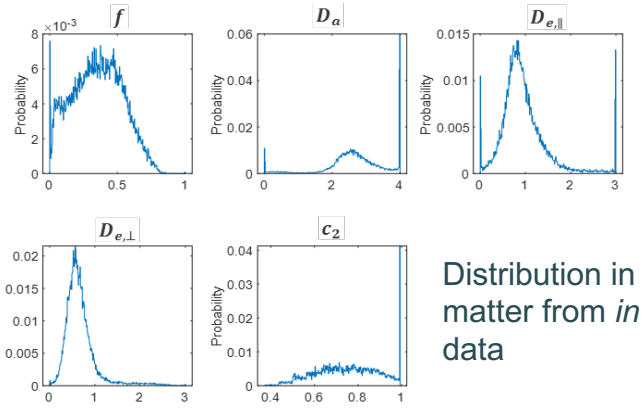
- Encoder-decoder RNN
  - Encoder & Decoder
  - Input sequence (DKI):

    MD, AD, RD, MK, AK, RK
  - Output sequence (WMTI): $f, D_a, D_{e,\parallel}, D_{e,\perp}, c_2$



METHODS – DL SOLVER

- Synthetic training data generation



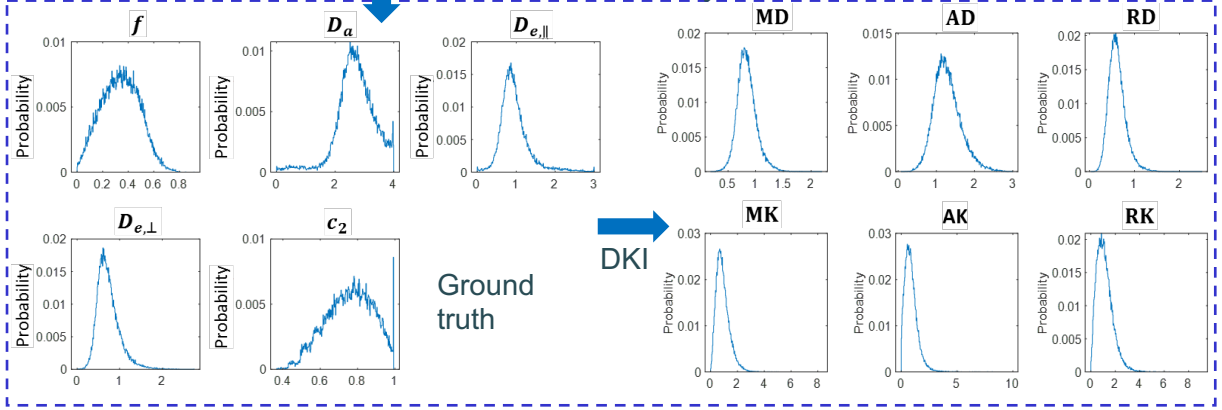
WMTI

Distribution in white matter from *in vivo* rat data

Samples

Filtering

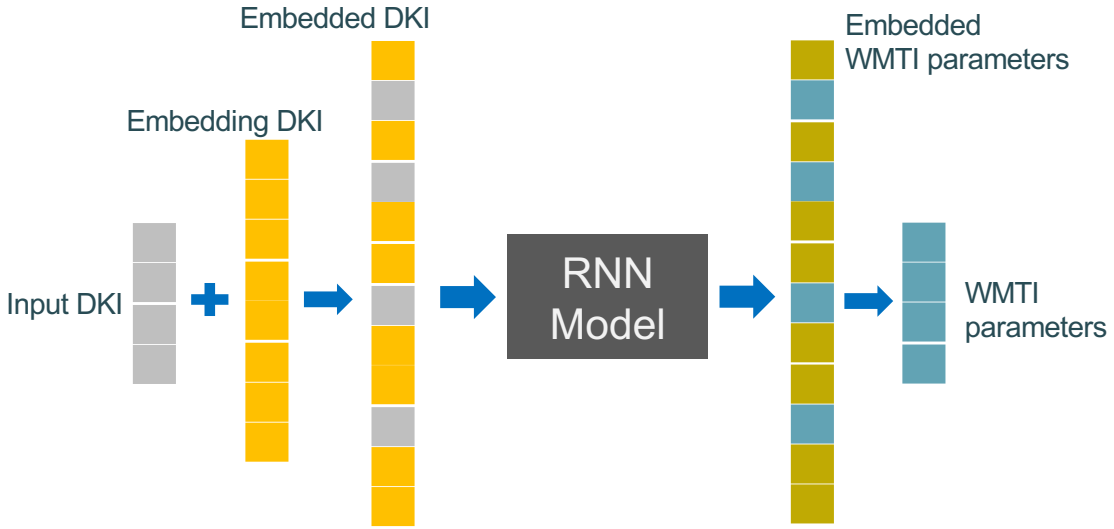
Synthetic dataset



Ground truth

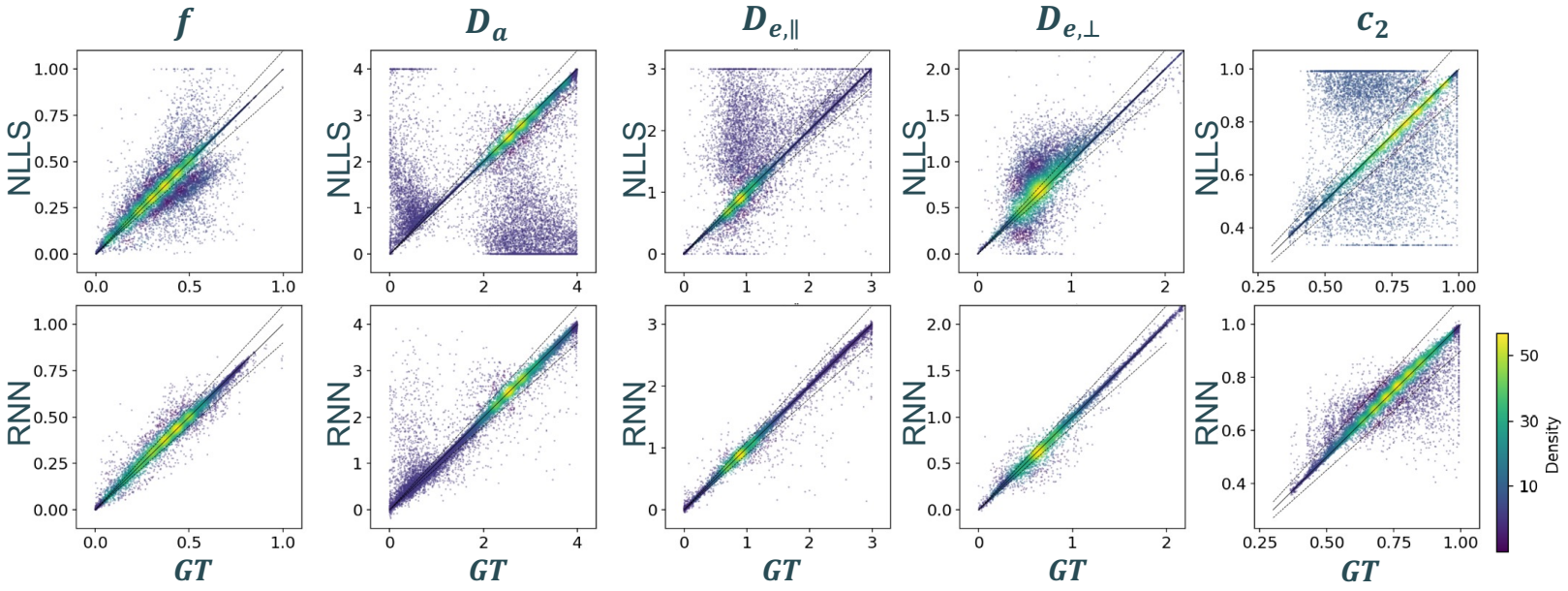
DKI

- Distribution matching
  - DL assumption:
    Test data & training data: same probability distribution
  - Distribution varies across experimental datasets
  - Performance degraded substantially
  - Match the distribution in new data to the training distribution through embedding



RESULTS

- Evaluation on synthetic test data



- Estimation time

Method	Data size	Fitting time [s]	Resource
NLLS	4×10^5	3.83×10^4	MATLAB, 32-core Intel Xeon 2.1 GHz CPU with 126 GB memory
RNN		8	Pytorch, 1 NVIDIA GeForce RTX 2080Ti graphic card with 11 GB memory

RESULTS

- Evaluation on *in vivo* data

Rat

Method	Agreement with NLLS (%)					Relative size (%)	Filtering
	f	D_a	$D_{e,\parallel}$	$D_{e,\perp}$	c_2		
RNN	**72.5**	**75.3**	**79.9**	**78.5**	**80.4**	**100**	NO
RNN	**92.6**	**94.2**	**95.2**	**95.1**	**95.9**	**75.9**	Based on DL estimation
RNN	**95.9**	**97.6**	**98.1**	**98.2**	**99.8**	**72.6**	Based on NLLS estimation

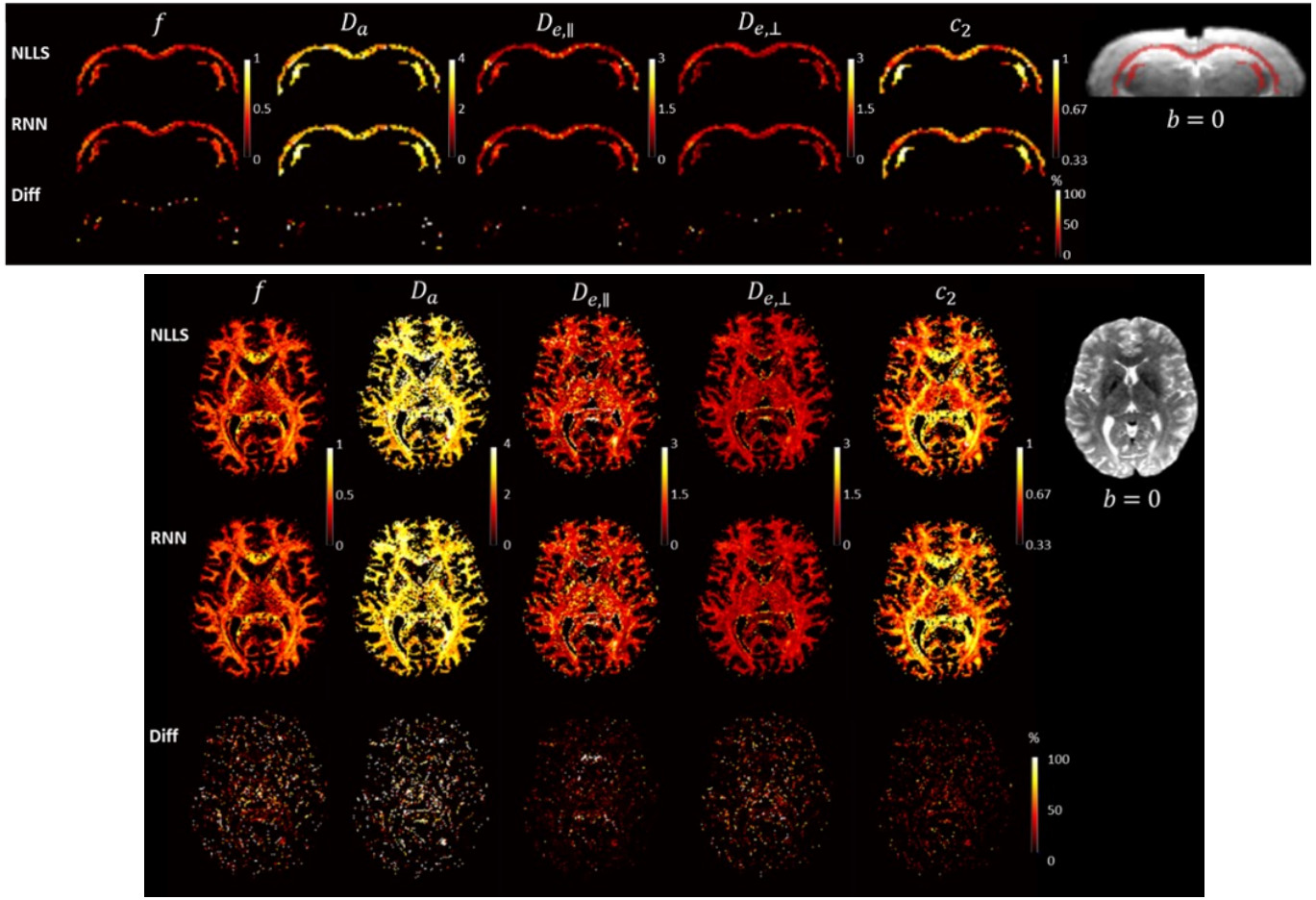
Embedding ratio = 10, test batch size = 2048

Human

Method	Agreement with NLLS (%)					Relative size (%)	Filtering
	f	D_a	$D_{e,\parallel}$	$D_{e,\perp}$	c_2		
RNN	**80.9**	**82.5**	**86.3**	**84.2**	**85.8**	**100**	NO
RNN	**94.9**	**96.2**	**96.3**	**96.3**	**97.3**	**83.7**	Based on DL estimation
RNN	**97.8**	**99.2**	**99.0**	**99.1**	**99.8**	**80.8**	Based on NLLS estimation

Embedding ratio = 10, test batch size = 2048

Parametric maps



MORE…

Yujian Diao and Ileana O Jelescu , 2022. Parameter estimation for WMTI-Watson model of white matter using encoder-decoder recurrent neural network. arXiv:2203.00595[physics]. (https://arxiv.org/abs/2203.00595)

Code: https://github.com/Mic-map/WMTI-Watson_DL

THANK YOU FOR YOUR ATTENTION