Lab Visualization and Medical Image Analysis
Intermediate Presentation

TractSeg - Fast and Accurate White Matter Tract Segmentation

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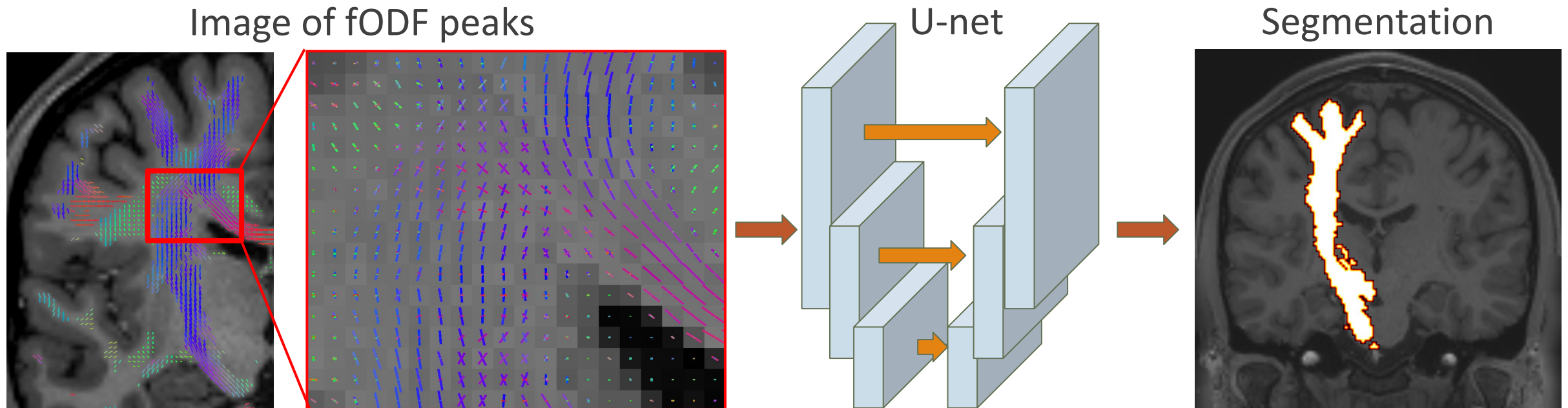bertan.karacora@uni-bonn.de

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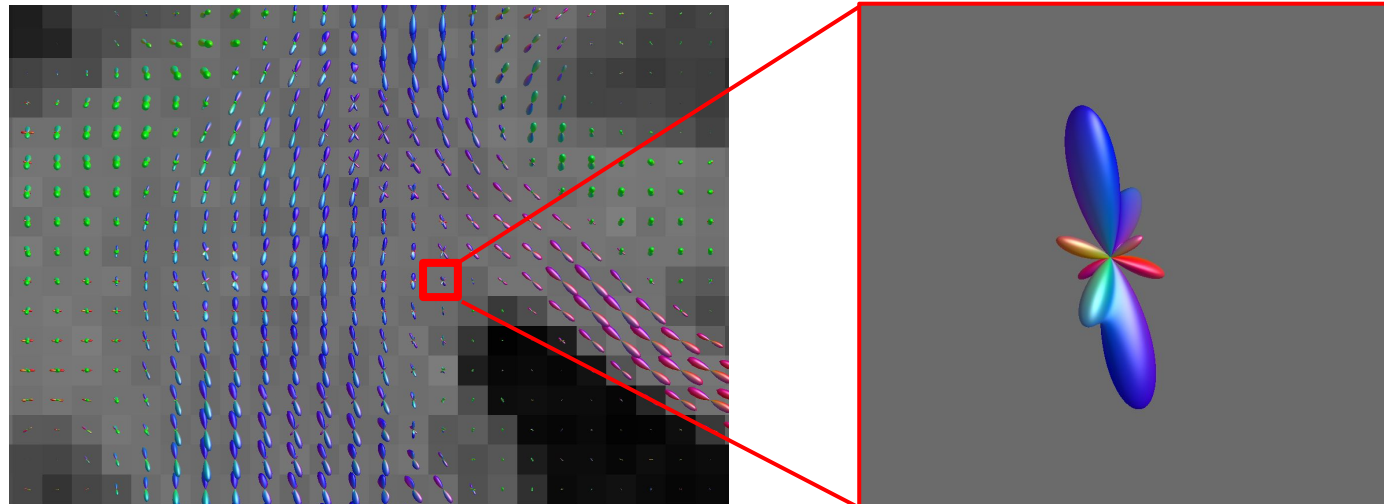1. **Introduction**
2. Methods
3. Current progress
4. Evaluation
5. Outlook

TractSeg - Overview

- Segmentation of white matter tracts in DWI
- More accurate and faster than tractography-based methods

Image of fODF peaks

U-net

Segmentation

Goal of this lab

1. Setup data and get the code running

2. Make the model learn from the entire fODFs instead of peaks
   - More complete information
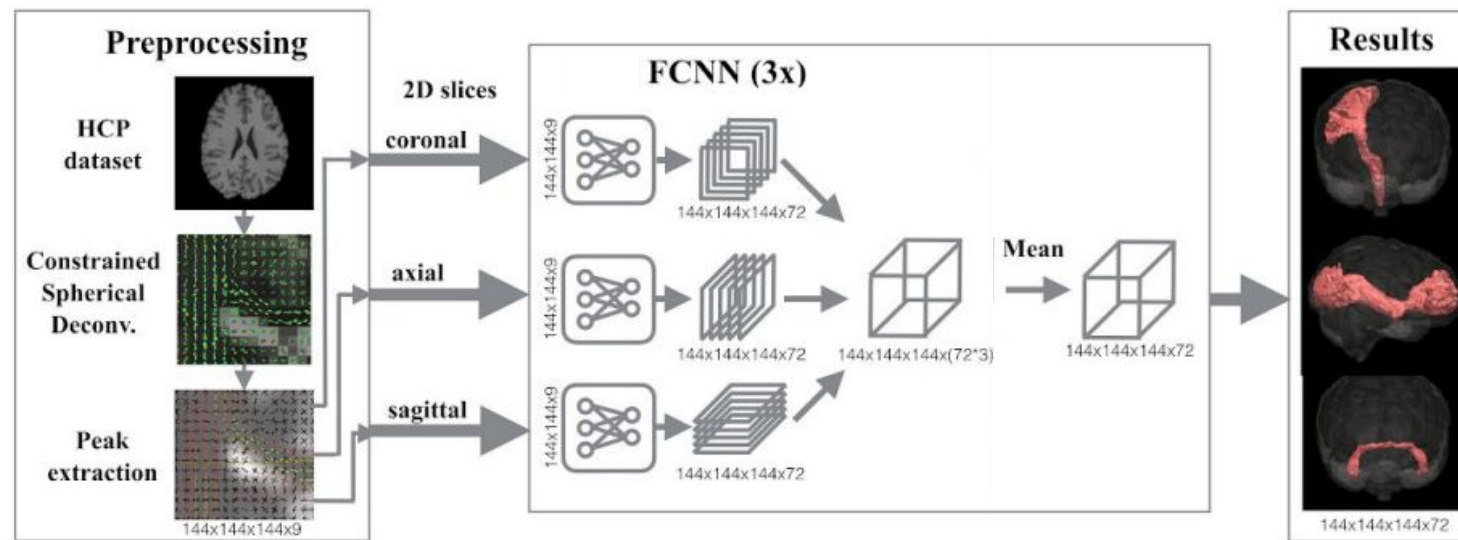   - Resolving the directional ambiguity

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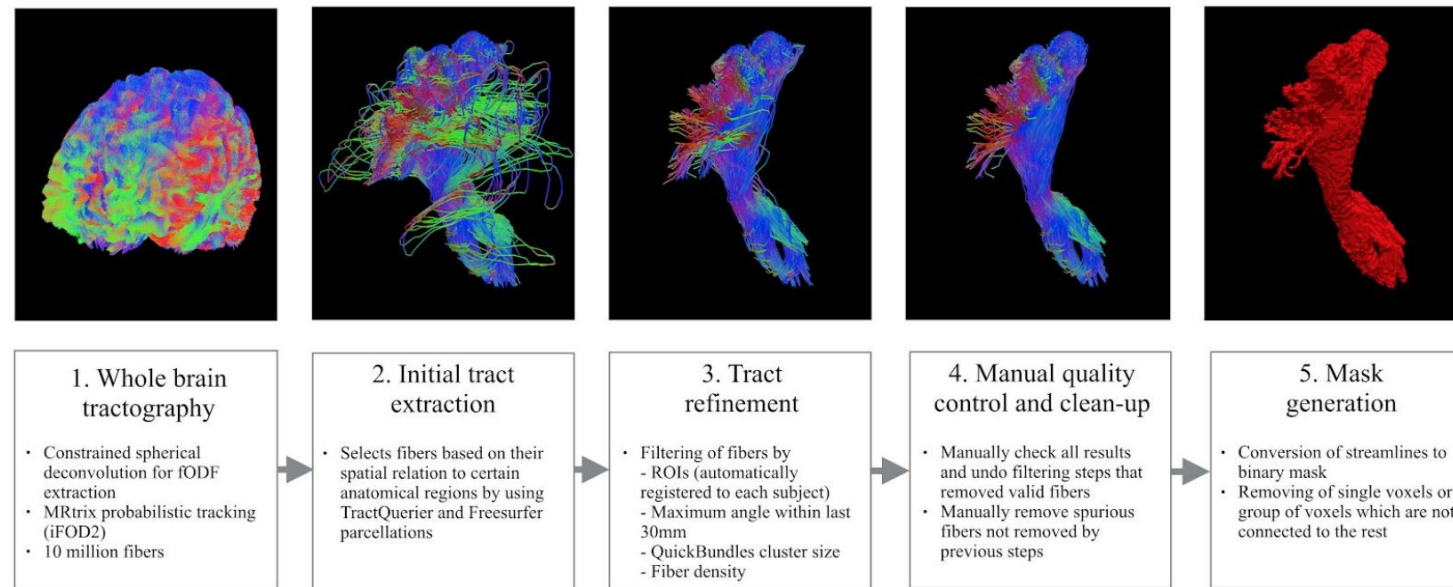4. Evaluation
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Segmentation pipeline

- 3 peaks per voxel to 72 independent probability maps

- U-net architecture with deep supervision

- Mean fusion of directional outputs

Supervision

- Reference segmentations of 105 HCP subjects, 5-fold CV

1. Whole brain tractography
- Constrained spherical deconvolution for fODF extraction
- MRtrix probabilistic tracking (iFOD2)
- 10 million fibers

2. Initial tract extraction
- Selects fibers based on their spatial relation to certain anatomical regions by using TractQuerier and Freesurfer parcellations

3. Tract refinement
- Filtering of fibers by
  - ROIs (automatically registered to each subject)
  - Maximum angle within last 30mm
  - QuickBundles cluster size
  - Fiber density

4. Manual quality control and clean-up
- Manually check all results and undo filtering steps that removed valid fibers
- Manually remove spurious fibers not removed by previous steps

5. Mask generation
- Conversion of streamlines to binary mask
- Removing of single voxels or group of voxels which are not connected to the rest

- 2D slice sampling from random axis

- Heavy data augmentation on peak images

Contents

My work so far

- Technical setup
  - Installation, fixing pre-existing bugs, writing utility scripts, etc.
  - Adjusting code to hardware constraints
- Preprocessing features and reference labels
  - Mask generation, concatenation, cropping, etc.
- Adjust model training for 3 experiments:
  - Peaks extracted using MRtrix multi-shell CSD (baseline)
  - Rank-3 approximation of fODFs extracted using bonndit
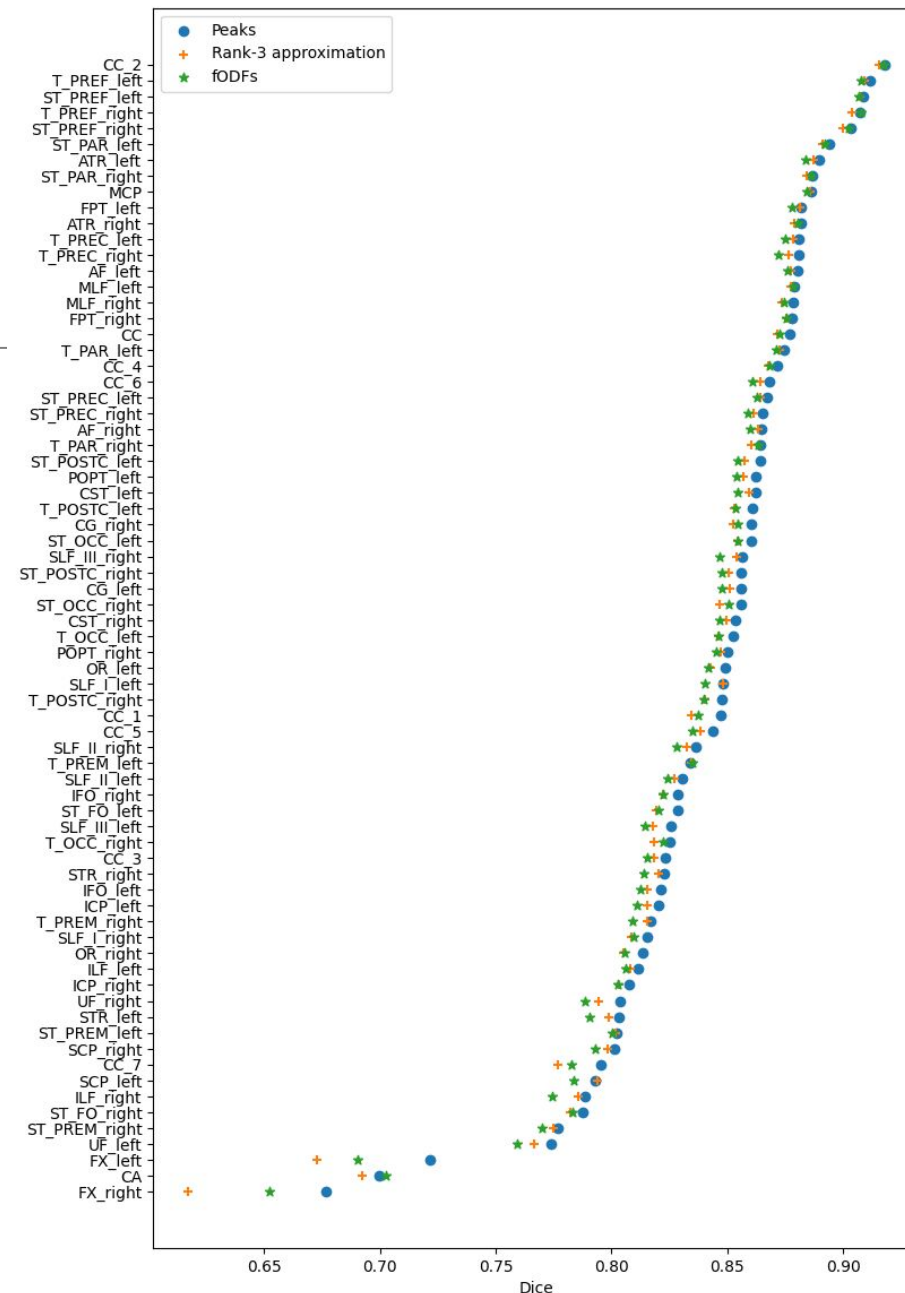 - 4th-order fODFs extracted using bonndit

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Quantitative evaluation
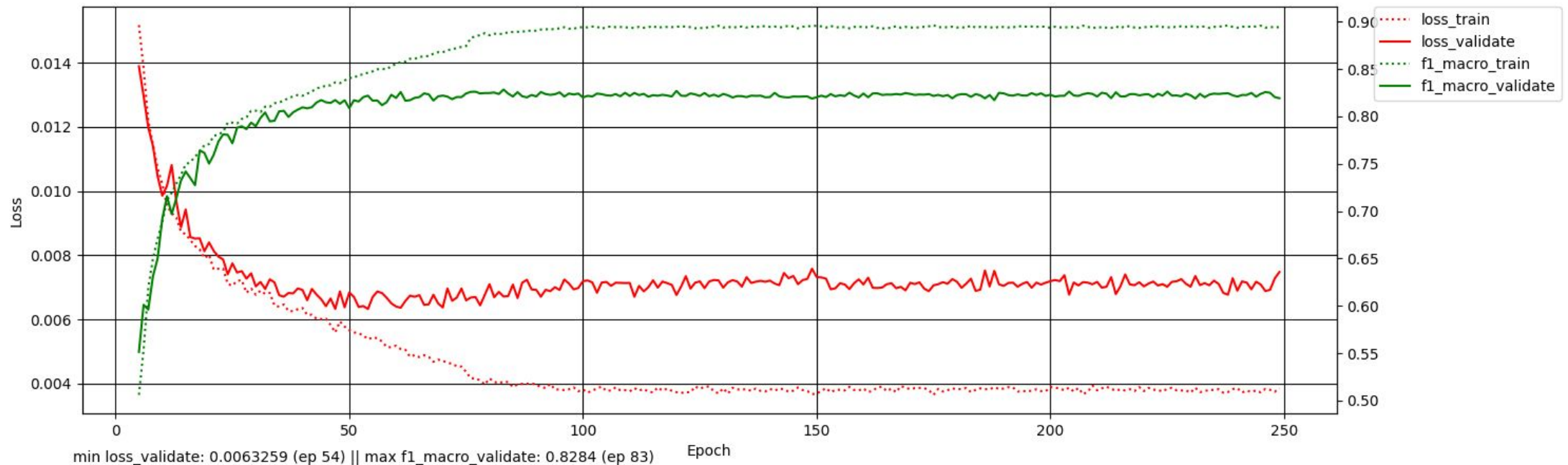
- Note: Results not final

- Mean Dice scores:
  - Peaks: 0.8426
  - Rank-3 approximation: 0.8368
  - fODFs: 0.8359

Overfitting with fODFs

- No data augmentation for fODFs yet
- Here: Overfitting effect mitigated by learning rate scheduler

min loss_validate: 0.0063259 (ep 54) || max f1_macro_validate: 0.8284 (ep 83)

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Outlook

- Augmentation of fODF representation

- Statistical evaluation (H: There are differences to baseline)

- Qualitative evaluation

- More experiments

  - Representing each peak as tensor (with data augmentation)

  - Raw DWI data from random gradient directions (similar to Kebiri et al., ArXiv 2023)
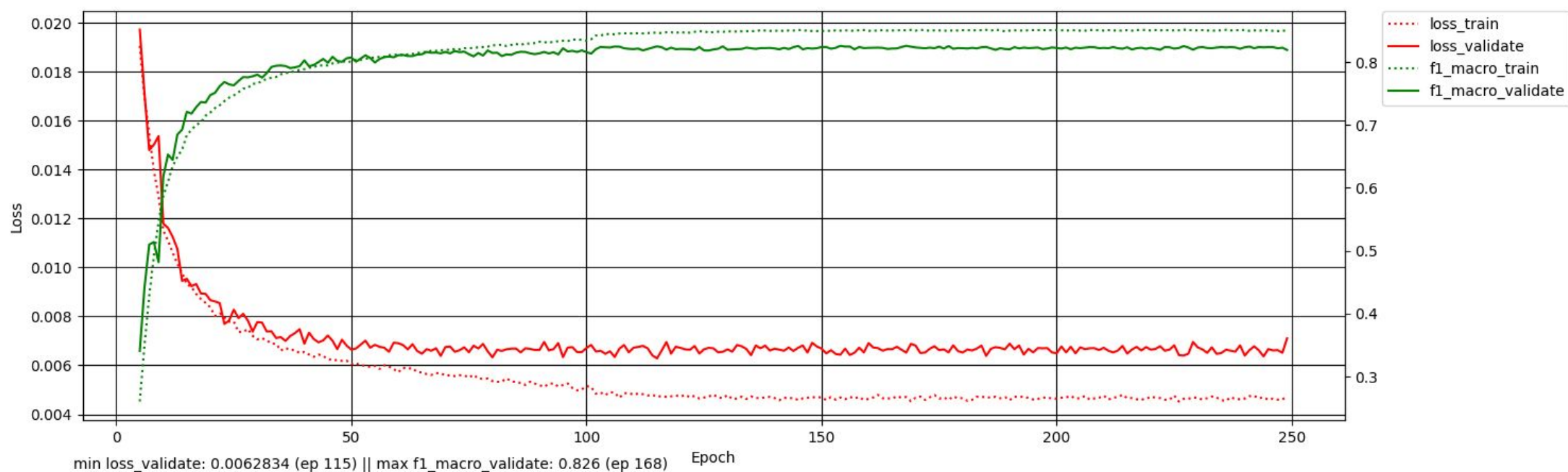
Thank you!

Additional Slides

Training with peaks

min loss_validate: 0.0059658 (ep 123) || max f1_macro_validate: 0.8357 (ep 195)
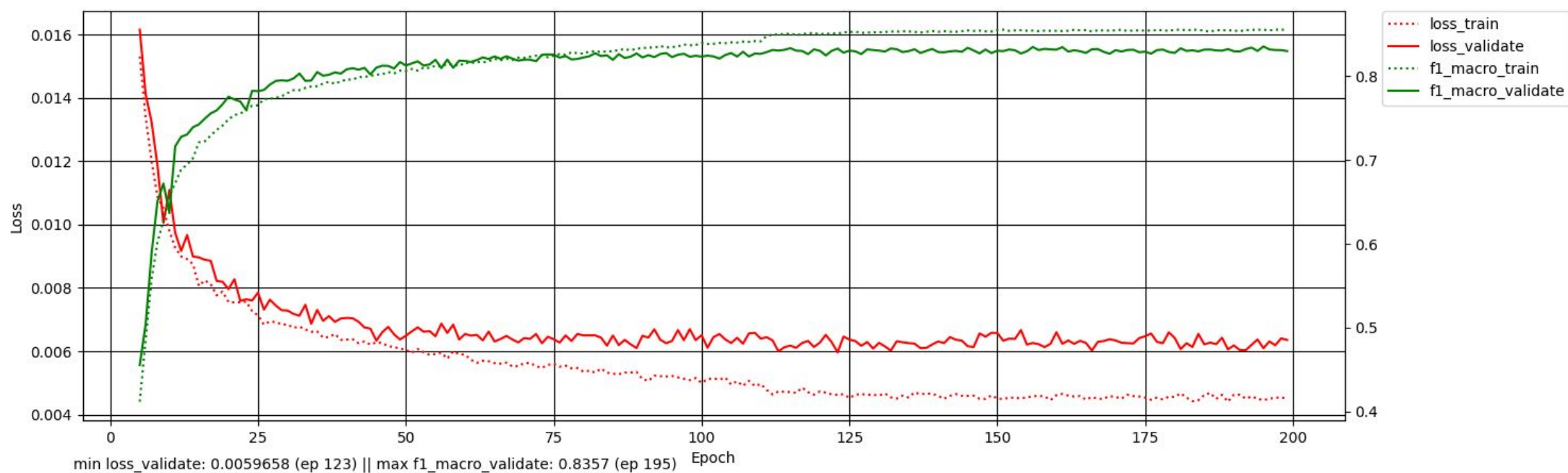
Training with rank-3 approximation

min loss_validate: 0.0062834 (ep 115) || max f1_macro_validate: 0.826 (ep 168)

TractSeg - Overview - With second FNN

- Segmentation of white matter tracts in DWI

- CNN approach based on U-net

- More accurate and faster than tractography-based methods

Image: Wasserthal et al., NeuroImage 2018
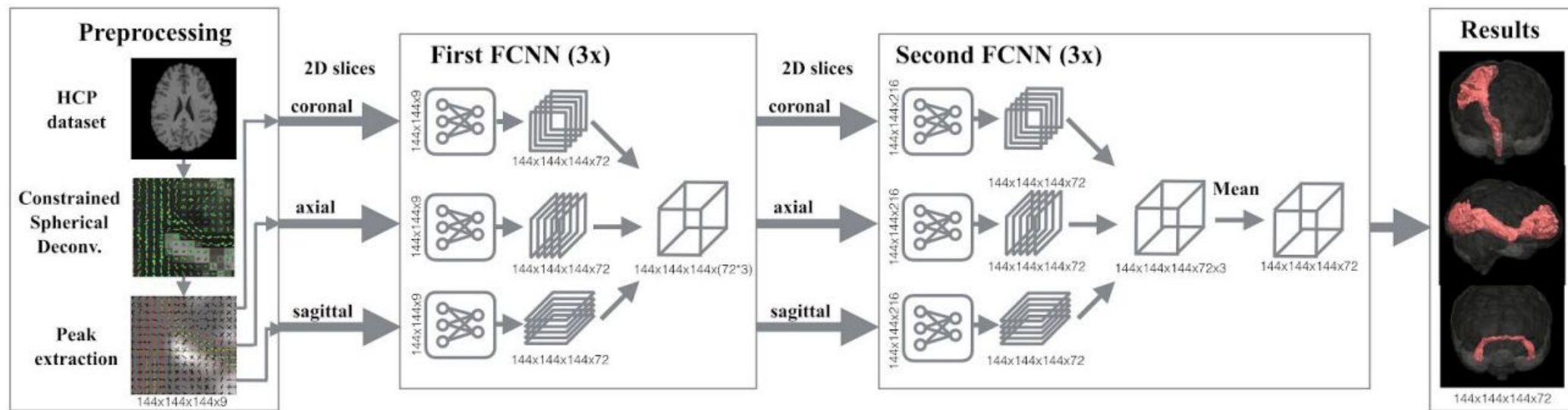
What happened to the second FCNN?

- "This is only training the first FCNN. Also the TractSeg version you can download via pip is also only using the first FCNN. The second one gives only very minor improvements but increases runtime a lot. Therefore, I actually never use it."

  Jakob Wasserthal

Applications of tract segmentation

- Brain characterization

- Identification of abnormal morphology in diseased brains

- Statistical analysis in tract areas (e.g., based on FA or MD)

- Neurosurgical planning (extend, position, shape of tracts)

- Tract Orientation Maps
  (TOMs) for tractography

Image: Wasserthal et al., NeuroImage 2018]