Learning Macroscopic Brain Connectomes via Group-Sparse Factorization

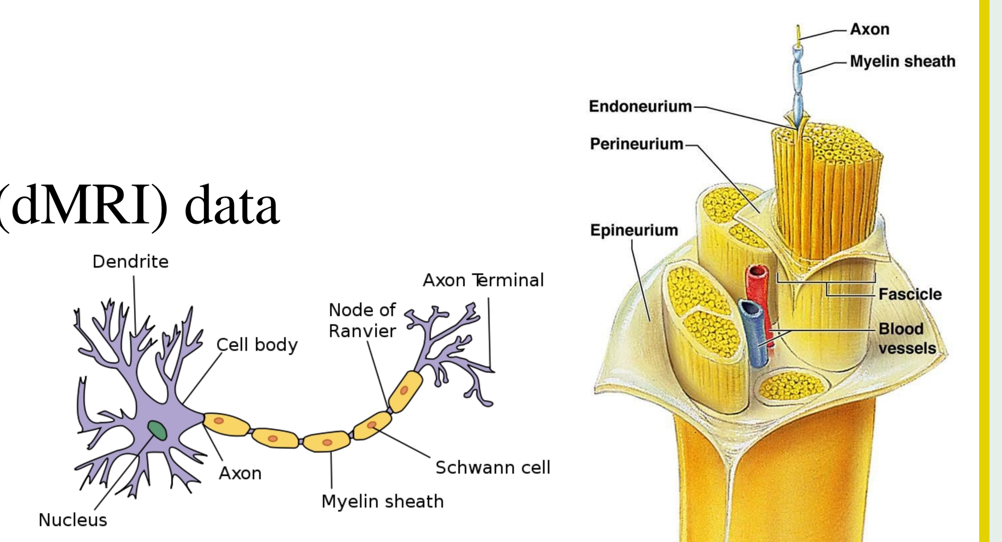
Farzane Aminmansour[1], Andrew Patterson[1], Lei Le[2], Yisu Peng[3], Daniel Mitchell[1], Franco Pestilli[2], Cesar Caiafa[4], Russell Greiner[1], Martha White[1]
University of Alberta[1], Indiana University[2], Northeastern University[3], Instituto Argentino de Radioastronom[4]

BACKGROUND & SETTING

1. Motivations

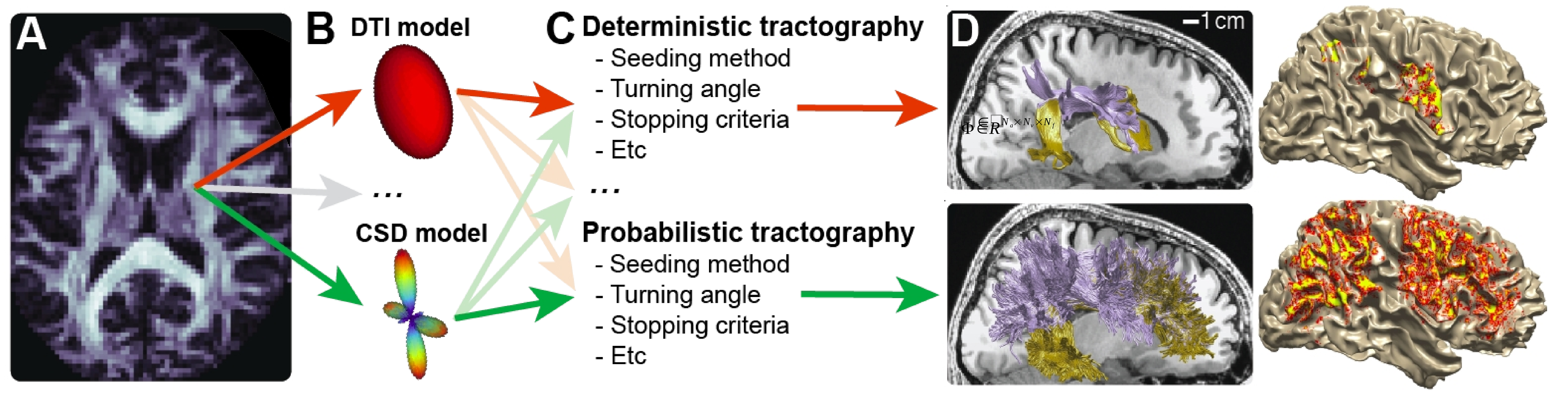
Goal:

- Given:
  - Diffusion magnetic resonance imaging (dMRI) data
- We want to:
  - Map structural brain connectome



Applications:

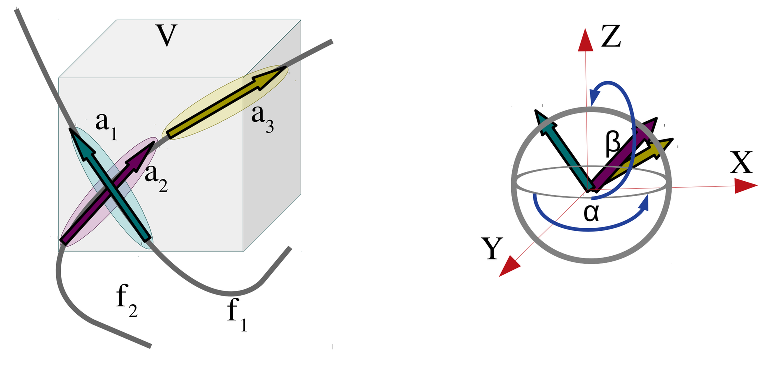
- Investigating white matter health and disease



2. Encoding Brain Connectomes as Tensors

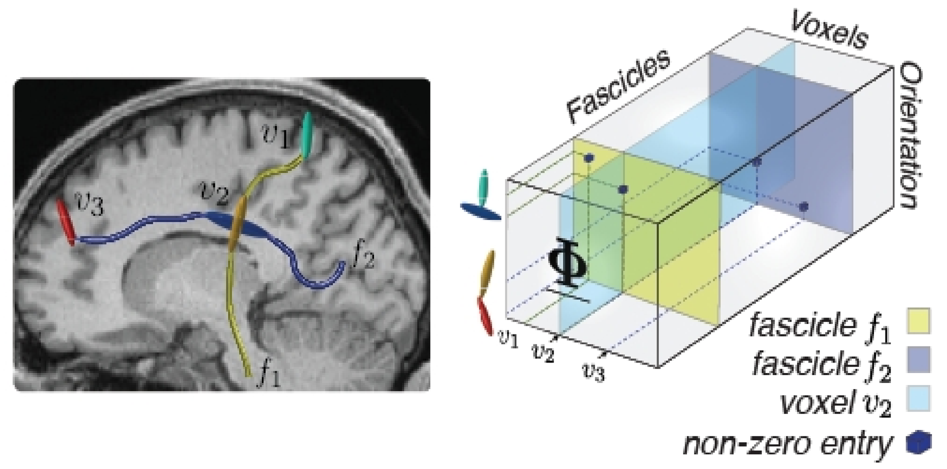
ENCODE:

- Represents brain structure by a 3D sparse tensor
  - $\Phi \in R^{N_a \times N_v \times N_f}$
    - N_a: #orientations, fascicles orientation at each position
    - N_v: #voxels, fascicles spatial position
    - N_f: #fascicles, indices of each fascicle



A. Encoding one voxel B. Discretizing space

- Unifies dMRI signal with connectome structure
  - Matrix of dMRI signal $Y \in R^{N_\theta \times N_v}$
    - θ is gradient direction
  - Factorizing **Y** into **Φ** and dictionary **D**
    - $D \in R^{N_\theta \times N_a}$
    - $Y \approx \Phi \times_1 D \times_3 W$, where $W \in R^{N_f}$



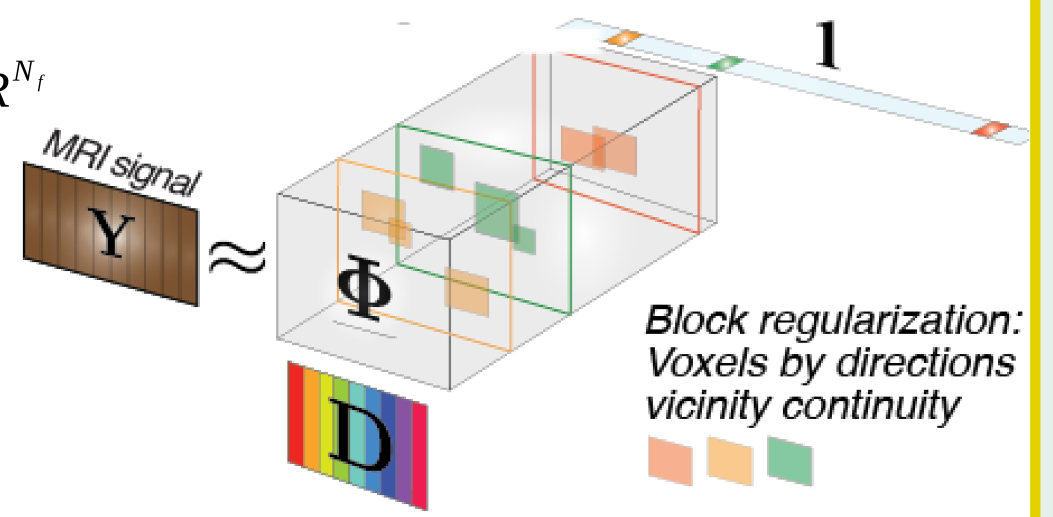
C. Natural brain space and tensor encoding

THEORY & ALGORITHMS

3. A Tractography Objective for Extracting Brain Connectomes

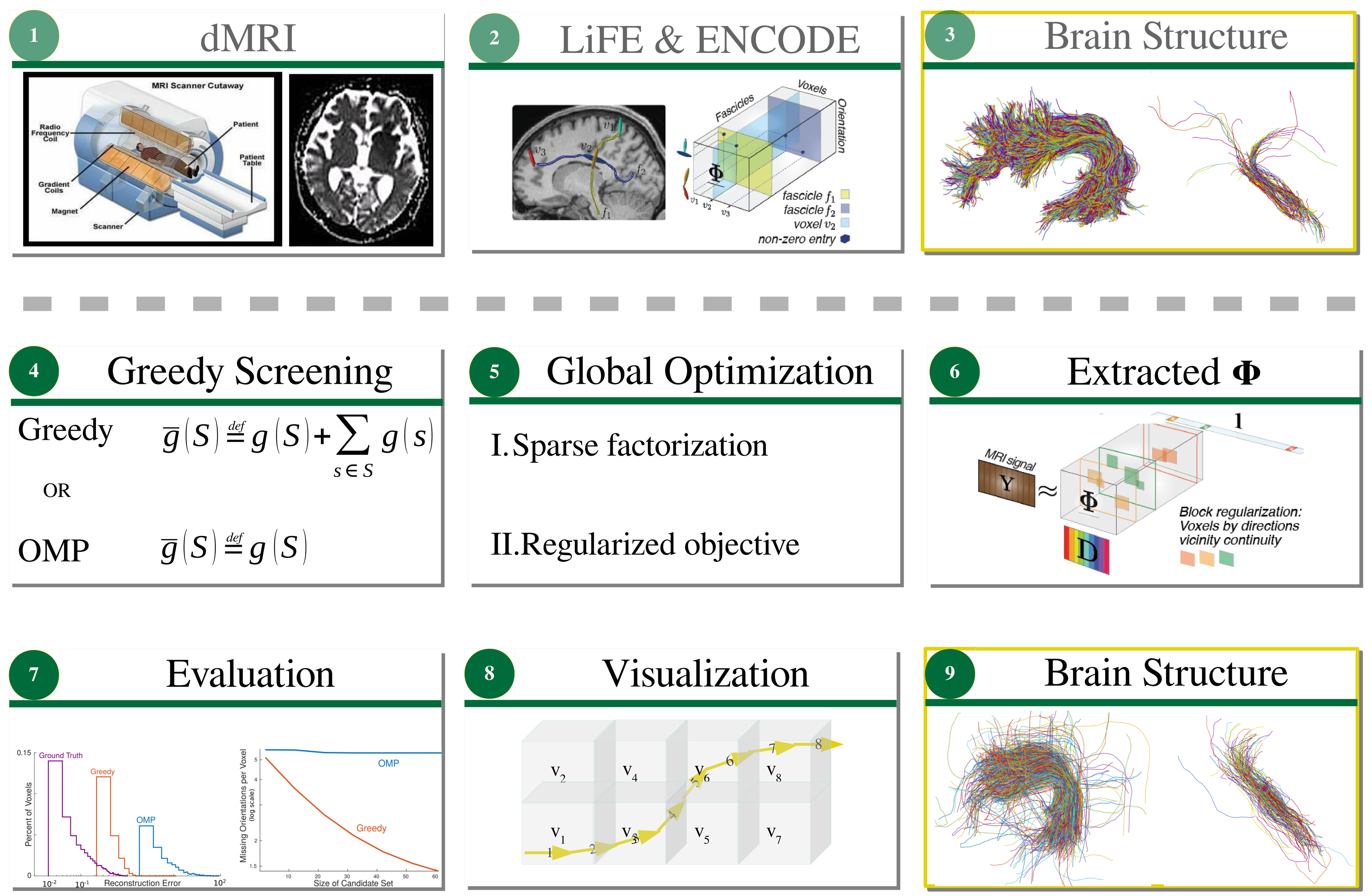
- Unconstrained objective to extract **Φ**
  - $\Phi = \mathrm{argmin}_\Phi \|Y - \Phi \times_1 D \times_3 1\|^2$, where $1 \in R^{N_f}$
- Regularizer – smooth, continuous, sparse
- Constrained objective to learn **Φ**
  - $\Phi = \min_\Phi \|Y - \Phi \times_1 D \times_3 1\|^2 + \lambda R(\Phi)$,

$$R(\Phi) = \sum_{f \in F} \sum_{\mathcal{G}_V \in V} \sum_{\mathcal{G}_A \in A} \sqrt{\sum_{v \in \mathcal{G}_V} \left(\sum_{a \in \mathcal{G}A} |\Phi_{a,v,f}| \right)^2}$$



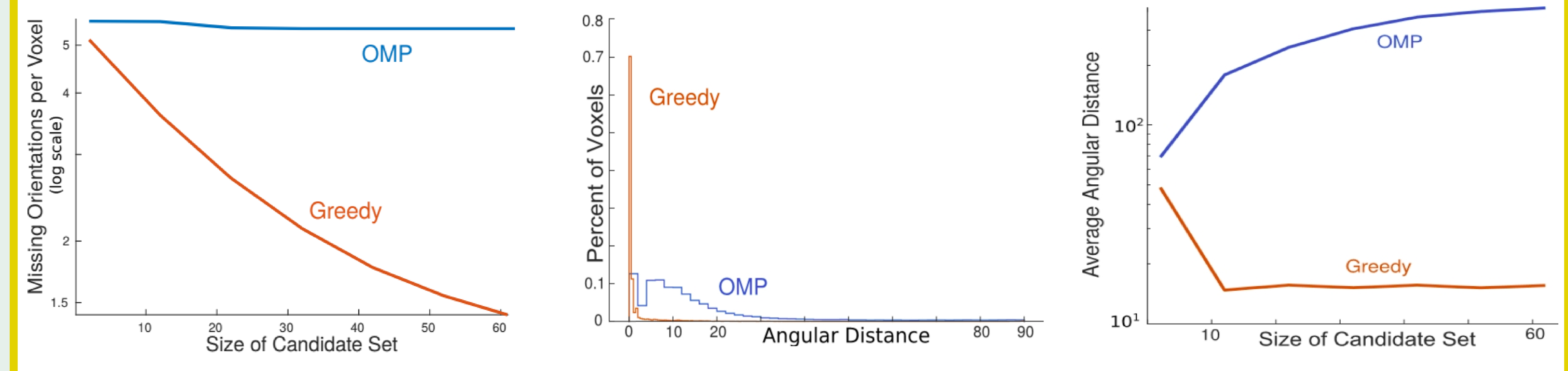
Model formulation and block regularizer

4. A Pipeline for Extracting Brain Connectomes

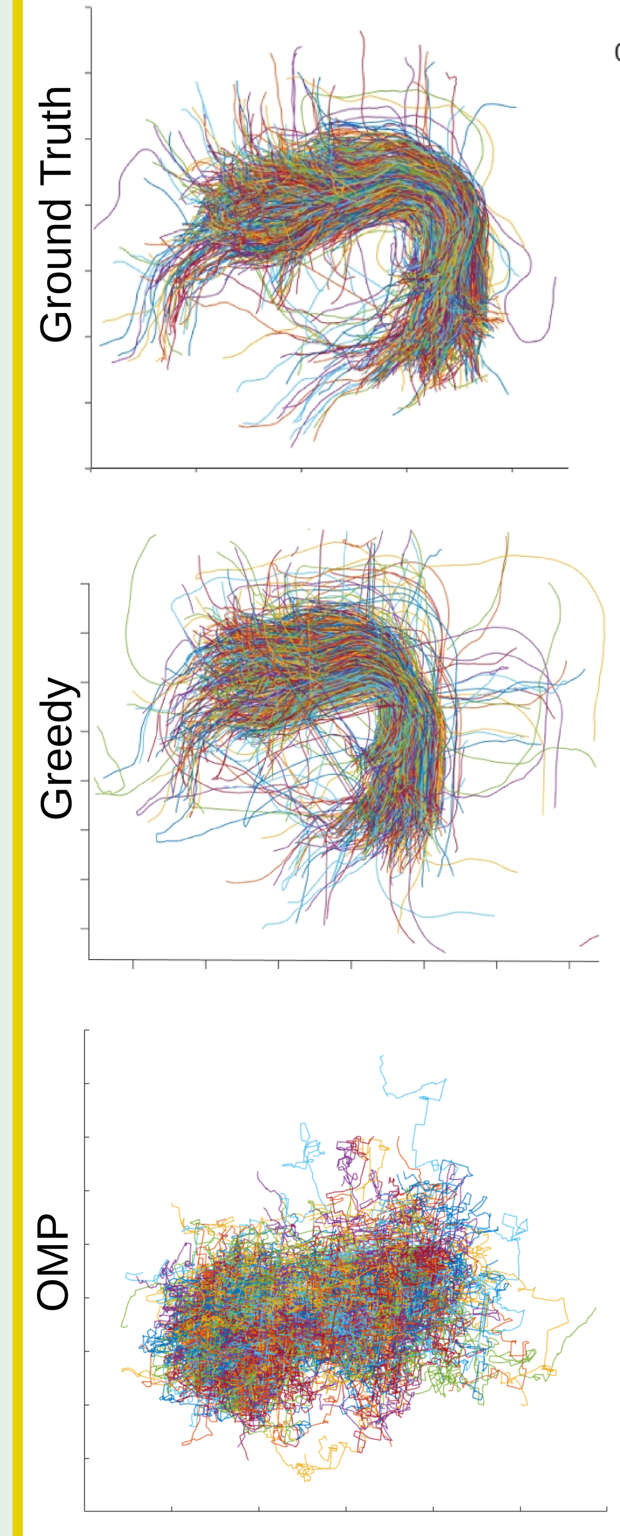


EMPIRICAL RESULTS

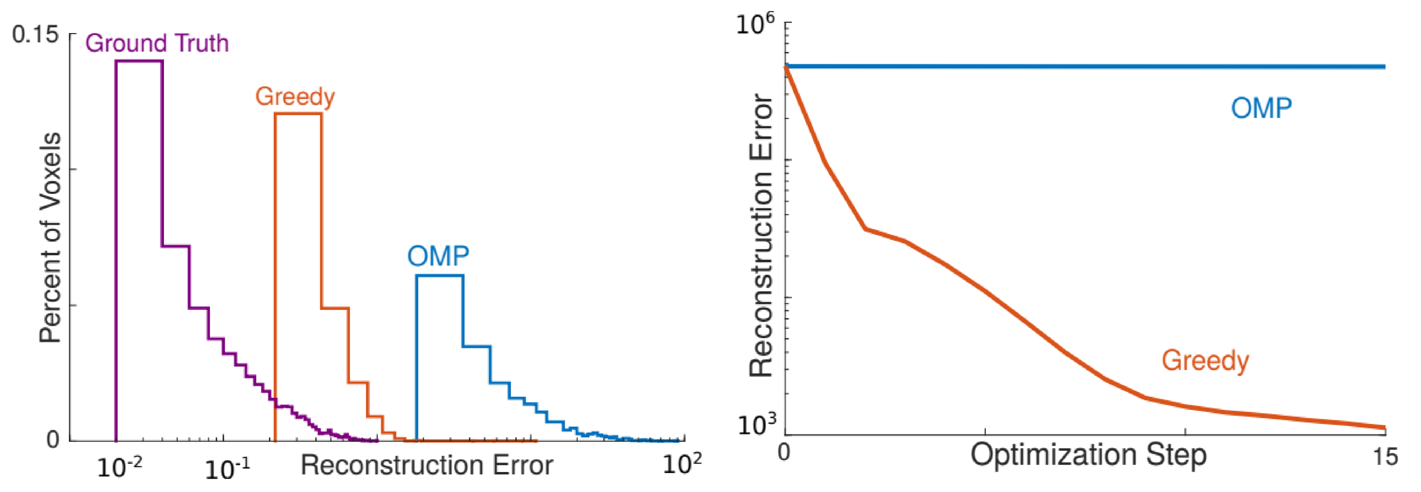
5. Reconstructing the Anatomical Structure of Tracts



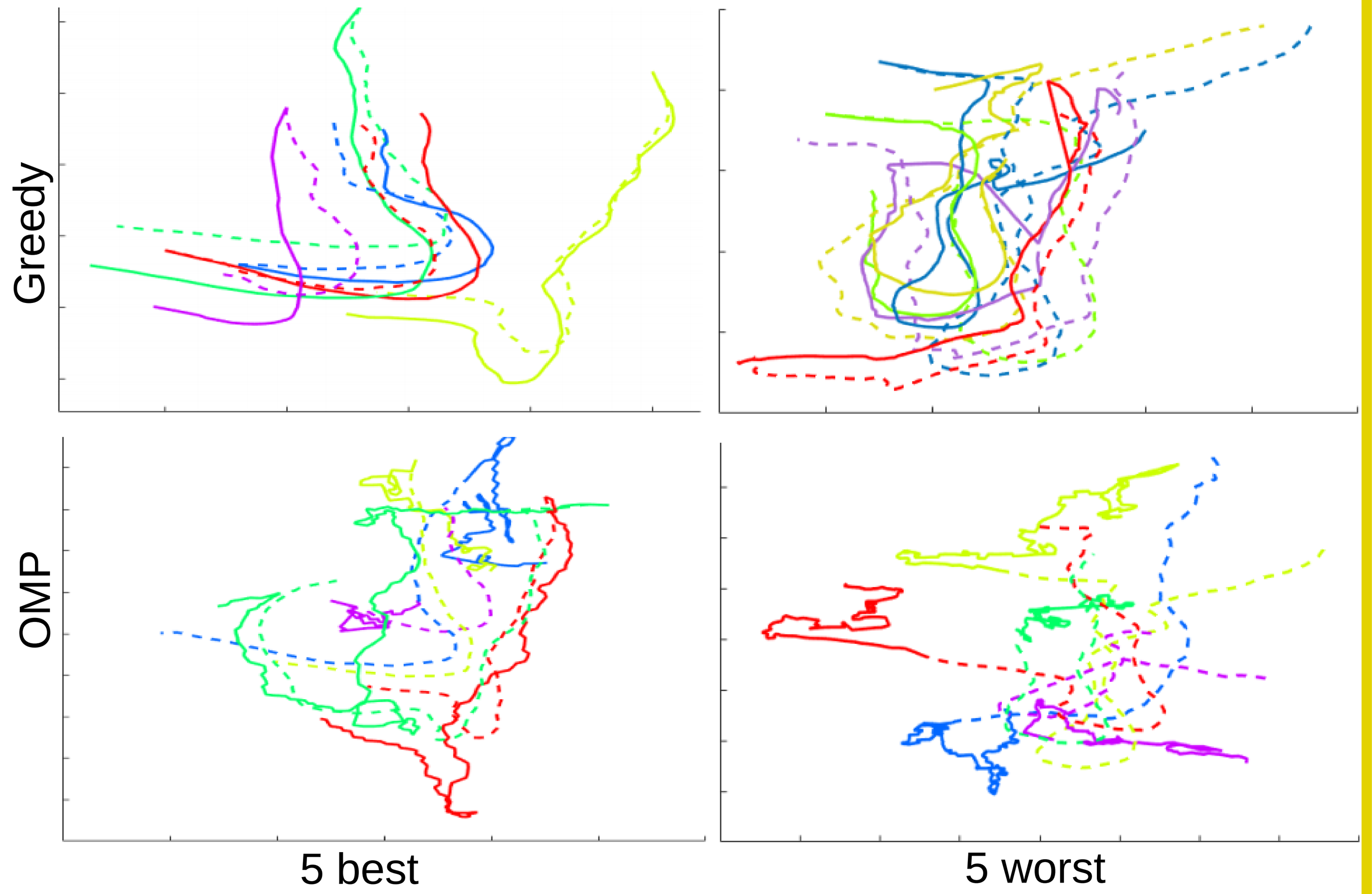
A. Screening: missing orientations vs. k B. Screening: pdf of voxels' angular distance C. Screening: avg. angular distance by k



F. Optimization: visualization of Φ



D. Screening: pdf of reconstruction error E. Screening: reconstruction error improvement



G. Optimization