Multi-Subject White Matter Fiber Clustering of Mouse Brain

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Abstract

Diffusion Tensor Imaging is a useful technique for describing white matter structure, through which it is possible to estimate the anatomical connectivity via tractography measurements. One problem related to the use of tractography is the large number of fibers estimated.

We present an unsupervised approach based on the **Dominant Sets** framework, which is rooted in the Game Theory, to **automatically segment white matter fibers into clusters for retrieving group-wise bundles of fibers.**

Goal

- Non invasive studies of **white matter fibers organization** for the localization of white matter bundles
- **Structural Connectome** for specific mental disease and group comparison of brain connectivity.
- **Atlas of group-wise white matter fiber bundles**.

Dominant Sets Clustering

Dominant Sets (DS) framework is a graph-theoretic method that generalizes the maximal clique problem to weighted graphs

Given a Weighted undiricted graph $G = (V, E, \omega)$ with no self-loop:

- each fiber corresponds to a node v_i
- ω_{ij} is the weighting function associated to the edge
- e_i is a measure of similiraty between pairs of fibers
- G is represented by a simmetric adjacency matrix $A = (a_{ij})$
- **x** as ***weighted characteristic vector*** and it quantifies the degree of partecipation of the i-th component to the determined DS.

<u>*Maximization problem*</u>: $\mathbf{x}^T A\mathbf{x}$ (1)

If **x** is a strict local solution of (1) then its support, defined as $\delta(\mathbf{x}) = \{i \mid x_i > 0\}$, is a **Dominant Set** cluster.

To find the solution, we use a Game Theory approach:

- ***Replicator Dynamics*** as solution that is a local iterative maximization of equation

$$x_i(t+1) = x_i(t)\frac{(A\mathbf{x}(t))_i}{\mathbf{x}(t)^T A\mathbf{x}(t)}$$

- ***Stability Condition***: stopping iteration if $||\mathbf{x}(t+1) - \mathbf{x}(t)|| < \epsilon$

- ***Peeling-Off Strategy:*** Once DS is determined it is removed from whole vertices V. In pratical cases a thresholding over **x** is needed to find Dominant Set

$$\tilde{\delta}(\mathbf{x}) = \{i \mid x_i > \theta * \max(\mathbf{x})\} \quad \theta \in [0,1]$$

Main Algorithm

Dataset:

8 Mouse Brain (C57BL/6J), Diffusion Tensor Imaging

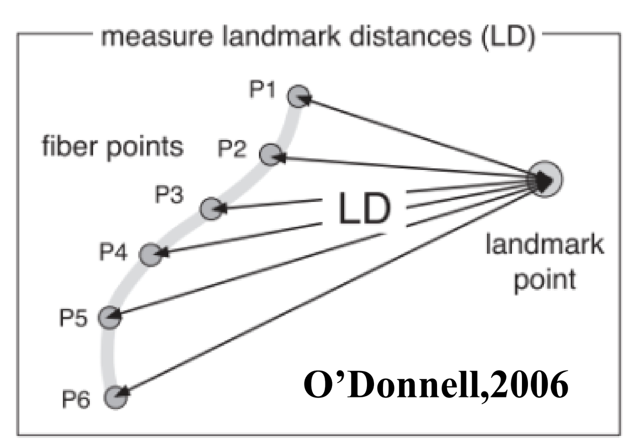
- ***Intra-Subject Clustering***:
  - Encoding fibers with the same number of equidistant points
  - Define similarity matrix to build matrix A

$$a_{ij} = \begin{cases} e^{-\frac{d(F_i,F_j)}{\sigma}} & \text{if } (i,j) \in E \\ 0 & \text{otherwise.} \end{cases}$$

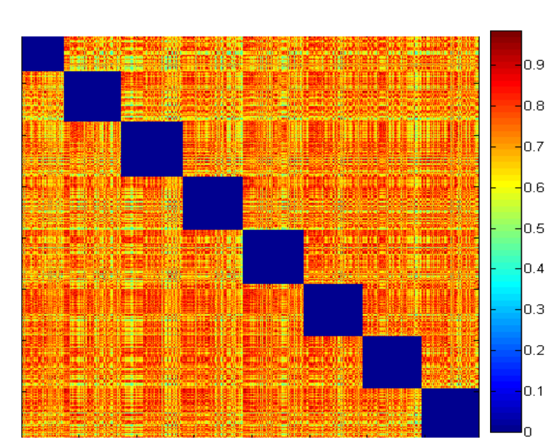
$$\sigma = \max_{i,j}(d(F_i, F_j))$$

  - DS clustering on each subject

- ***Cross - Subject Clustering***
  - Define Cortical Brain Areas
  - Landmark Definition: Centre of Gravity of each Label
  - Take the Centroids of previous clustering step and map them on Landmarks
  - **Feature Vector:** each centroid is a row vector : $C_i = N \times L$
    - N = number of points on the Centroid
    - L = Number of Landmarks



  - Compute similarity between centroids of different subjects building a new affinity matrix across datasets



Clustering Results

Intra-Subject Clustering

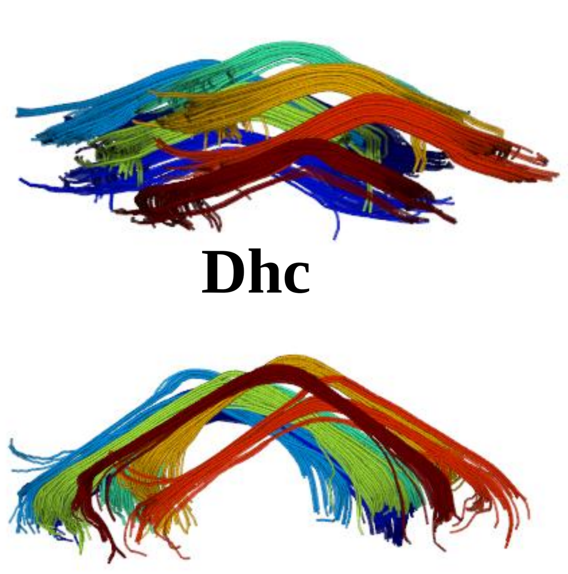
Inter-hemispheric View

Subj 1

Subj 2

Subj 3

Cross-Subject Clustering: *Each color is a different subject*



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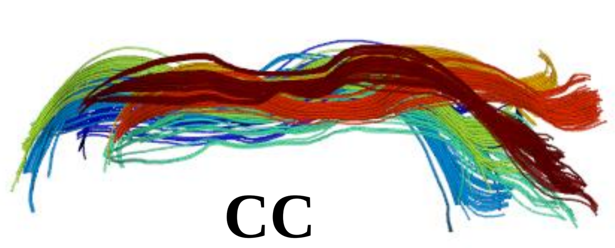

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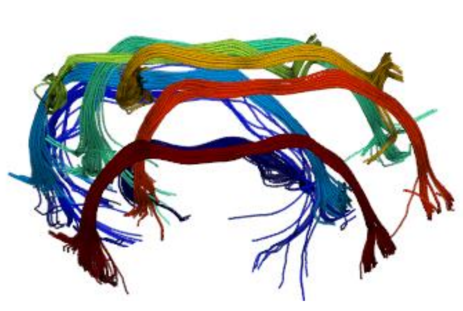

CRBL Tracts

Rostro-Caudal Tracts

References

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