EN.580.694: Statistical Connectomics
Final Project Proposal

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Searching for a brain parcellation atlas which maximizes test-retest reliability of same-subject MR connectomes

Opportunity   As a current state of the art, human connectomes can be estimated from Diffusion Weighted MR imaging (DWI, dMRI, DTI) and structural MR imaging (sMRI, MPRAGE). When estimating these connectomes, an argument can be made that voxel-level artifacts and imperfect registration procedures cause sufficient noise that full scale graphs are unreliable for node-wise analysis. For this reason, so-called small graphs can be produced which combine nodes in the full graphs, voxels in the structural image, into defined regions. These region sets are termed atlases.

Challenge   The atlases used are defined often with knowledge of functional or physiological data [1–3], without knowledge of structural connectivity data. As a result, it is difficult to know whether or not an atlas is an appropriate or useful parcellation of the brain for connectomics purposes. When analyzing the performance of these partitions for such connectivity data, difficult graph statistics must be employed.

Action   Test-retest (TRT) reliability is a measure which seeks to compare connectomes estimated for the same subject across different scans to the remainder of the dataset. A successful TRT test results in the same subject graphs being more similar to one another than all other graphs. Here, we propose and test several methods TRT in order to evaluate the performance of three commonly used atlases; Desikan [1]; Destrieux [2]; DKT [3].

Resolution   We will gain insight into which of the tested atlases best partitions estimated connectomes, and thus which atlas should be used to assess the quality of estimation and for basic classification tasks. We will also see which TRT metric is best suited for comparing the resulting connectomes.

Future Work   One likely difficulty of this project will be developing TRT metrics that are not biased heavily by sparse data (few edges within the graph). As we seek to answer two questions, it may be possible to gain more insightful solutions by attempting to answer each question independently in future.

Statistical Decision Theoretic

There are M graphs, meaning that there are $M/2$ subjects. The graph for each subject, (A, P), with nodes P and adjacency matrix A, is parcellated by an atlas, k_i, and produces the resulting small graph with nodes $P_i \in \mathcal{P}_{k_i}$. The decision rule class is the mapping of the adjacency matrix with vertices P to the set of vertices belonging to atlas k_i. The loss is determined by the comparison of graphs. One method, the Frobenious Norm, is shown here though other methods will be proposed as well. The risk is the in/correct matching of same-subject graphs.

Sample Space $(A, P) \in \mathcal{A}_M \times \mathcal{P}_M = \mathscr{G}_M$, where Adjacency Matrices: $A = \{0, 1\}^{N \times N}$ and Vertex Positions: $P = \{P_i\}$, where $P_i = (x_i, y_i, z_i) \in \mathbb{R}^3$.

Model $\{SBM_M^{k_i}(\rho, \beta) : \rho \in \Delta_{k_i} \ \beta \in (0, 1)^{k_i \times k_i}\}$

Action Space {Desikan,Destrieux,DKT}

Decision Rule Class $f : \mathcal{A}_M \to \mathcal{W}_M$

Loss Function $\ell(\hat{W}_i^k, \hat{W}_j^k) = ||\hat{W}_i^k - \hat{W}_j^k||_F^2$

Risk Function $R = \sum\limits^{M} r_i/M \ ; \ r_i = \begin{cases} 0 & \text{argmin}_j \ell(\hat{W}_i^k, \hat{W}_j^k), i \sim j \\ 1 & otherwise \end{cases}$

References

[1] Rahul S Desikan, Florent Ségonne, Bruce Fischl, Brian T Quinn, Bradford C Dickerson, Deborah Blacker, Randy L Buckner, Anders M Dale, R Paul Maguire, Bradley T Hyman, Marilyn S Albert, and Ronald J Killiany. An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. *NeuroImage*, 31(3):968–80, July 2006.

[2] Bruce Fischl, André van der Kouwe, Christophe Destrieux, Eric Halgren, Florent Ségonne, David H Salat, Evelina Busa, Larry J Seidman, Jill Goldstein, David Kennedy, Verne Caviness, Nikos Makris, Bruce Rosen, and Anders M Dale. Automatically parcellating the human cerebral cortex. *Cerebral cortex (New York, N.Y. : 1991)*, 14(1):11–22, January 2004.

[3] Arno Klein and Jason Tourville. 101 labeled brain images and a consistent human cortical labeling protocol. *Frontiers in neuroscience*, 6:171, January 2012.