Solving the Cross-Subject Parcel Matching Problem: Comparing Four Methods Using Extrinsic Connectivity

Nathalie T H Gayraud, Guillermo Gallardo, Maureen Clerc, Demian Wassermann

Solving the Cross-Subject Parcel Matching Problem: Comparing Four Methods Using Extrinsic Connectivity

Nathalie T.H. Gayraud *† Guillermo Gallardo *† Maureen Clerc † Demian Wassermann †

Introduction

Matching parcels across different subjects is an open problem in neuroscience. Even when produced by the same technique, parcellations tend to differ in the number, shape, and spatial localization of parcels across subject. To the best of our knowledge, no technique has been able to tackle this problem. In this work, we propose and compare four different methods to match parcels across subjects based on their extrinsic connectivity fingerprint. We test their performance by matching parcels of the Desikan atlas [4] across subjects, as its parcels have been shown to have consistent connectivity profiles across subjects [6]. Then, we repeat the experiment for a pre-existing groupwise parcellation based on structural connectivity [5], which has been show to be consistent across groups of subjects. The outline of our work can be seen in Figure 1. Our results show that our methods based on Optimal Transport (OT) and Kullback Leibler (KL) divergence achieve more than 99% of correct matches.

Table 1: Desikan Atlas

	Optimal Transport	Euclidean Distance	Cosine Distance	KL Divergence
Correct Matches (%)	**98.56 ± 1.88**	82.06 ± 10.6	94.65 ± 3.03	88.98 ± 5.01
Average Matching Time (s)	1.10	0.31	0.42	20.20

Table 2: Groupwise Parcellation

	Optimal Transport	Euclidean Distance	Cosine Distance	KL Divergence
Correct Matches (%)	**99.75 ± 1.28**	72.23 ± 18.0	98.33 ± 2.40	99.61 ± 1.03
Average Matching Time (s)	1.05	0.30	0.25	10.55

Methods

We randomly select 60 subjects from the HCP500 dataset of the Human Connectome Project. Every subject possesses a coregistered cortical mesh of approximately 32k vertices per hemisphere. For each subject, we compute the cortico-cortical connectivity matrix with probabilistic tractography using the vertices of the subject's cortical mesh. Each row in the matrix is a vertex connectivity vector, representing the probability that a connection exists between that vertex and the rest of the cortexe's vertices. We compute the connectivity fingerprint of a parcel by averaging its vertex connectivity vectors. Our criterion to compute the parcel matching between two subjects is the similarity between connectivity fingerprints.Due to the distance bias that occurs in tractography, a parcel tends to be highly connected to the vertices that compose it. To prevent the matching to be influenced by this bias, we disconnect them from the parcel.

To compute the parcel matching for a pair of subjects we consider one as origin and the other one as target. We then calculate the pairwise distance matrix across the parcel connectivity fingerprints, and match each origin parcel to its closest target parcel, using the measures: Euclidean distance; cosine distance; and KL divergence. The first two distances are commonly used to compare connectivity fingerprints, while the KL divergence is a dissimilarity measure between distributions. Additionally, we compute pairwise parcel matchings using Optimal Transport (OT) [3]. We produce an OT-based joint probability matrix as in [2] using the parcel's connectivity fingerprints as feature vectors. The rows of this matrix indicate the amount of probability mass of a feature vector in the origin space which is transported onto each feature vector in the target space. We then match each origin parcel to the target parcel with the highest joint probability.

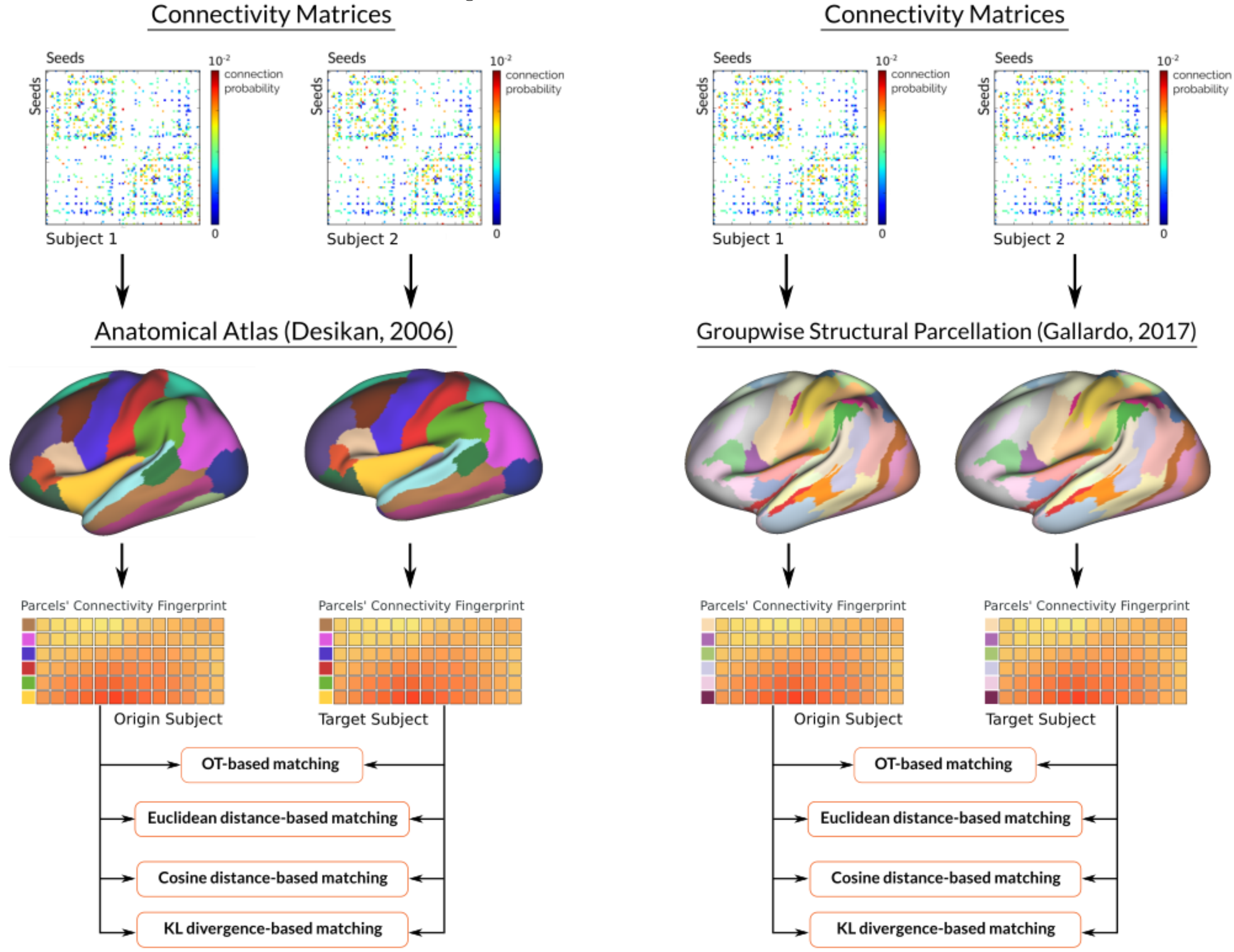
We apply all of these methods to match the Desikan atlas across every subject pair, and repeat the experiment for the groupwise extrinsic connectivity parcellation. To quantify the result of each technique, we compute the accuracy in terms of percentage of correctly matched parcels per pairwise matching.

Results

Table 1 shows the average accuracy and matching time of each method for 3540 pairwise experiments using the Desikan atlas. Table 2 displays the same results over the groupwise structural parcellation. For both experiments, the techniques based on OT and KL achieve the highest accuracy, although the KL based takes one order of magnitude more in time. The cosine distance based method achieves a XX% of accuracy while being the most time efficient.

*Both authors contributed equally in this work.
†Université Côte d'Azur, Inria

Figure 1: Outline of our methods



Conclusions

In this work, we propose and compare four different method to match parcels across subjects based on their connectivity fingerprint. Two of the methods achieve more than 98% of accuracy while still being time efficient.

Acknowledgment

This work has received funding from the European Research Council (ERC) under the Horizon 2020 research and innovation program (ERC Advanced Grant agreement No 694665 : CoBCoM - Computational Brain Connectivity Mapping)

References

[1] Jbabdi, S. et al. Long-range connectomics. *Annals of the New York Academy of Sciences*, 2013.

[2] Gayraud, N.T.H. et al. Optimal Transport Applied to Transfer Learning For P300 Detection. *7th Graz Brain-Computer Interface Conference 2017*, 2017.

[3] Villani, C. *Optimal transport: old and new* (Vol. 338). Springer Science & Business Media, 2008.

[4] Desikan, R. S. et al. An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. *NeuroImage*, 2006.

[5] Gallardo, G. et al. Groupwise structural parcellation of the whole cortex: A logistic random effects model based approach. *NeuroImage*, 2017.

[6] de Reus, Marcel A., and Martijn P. Van den Heuvel. "The parcellation-based connectome: limitations and extensions." Neuroimage 80 (2013): 397-404.