Edge selection preserving the topological features of brain network
Hyekyoung Lee1, Moo K. Chung2, Hyeyeon Kang3, Bung-Nyun Kim3, Dong Soo Lee4
1Seoul National University, Seoul, Republic of Korea, 2University of Wisconsin, Madison, WI

Introduction

Network construction

Regions of interest Connectivity Matrix Adjacency Matrix

Threshold

1. Filling the threshold.
2. Filling the opening.

Number of selected edges (%)

There is no widely accepted rule for thresholding.

Distance ≈ 1, positive correlation

We propose the edge selection method which preserves the topological features of brain network based on the computational topology.

Methods

Betti number

Given the topological space, connected components holes

• the zeroth Betti number β0 = 1
• the first Betti number β1 = number of connected components
• the first Betti number β1 = number of holes
(Zomorodian and Carlsson, 2005)

Filtration

Given a node set X consisting of p regions of interest (ROIs), the binary brain network, B(X) is constructed by connecting two ROIs i and j by an edge if their distance di,j = |xi−xj| is smaller than ε. A sequence of binary networks for increasing ε is called a filtration. During the filtration, the topological characteristics of binary network, B(X), is quantified by the 0th and 1st Betti numbers, β0 and β1, and visualized by the barcode as shown in Fig. 1 (b) and (c).

Edge Selection Procedure

By increasing ε, the edge is added one by one and the binary network, B(X, ε) and its Betti numbers, β0 and β1 are estimated. If β1 and β1 are changed when the edge is added, it is collected (See Fig. 1 (a)). Then, the set of selected edges can represent the topological characteristics of network as shown in Fig. 1 (b). And the shortest path lengths along the selected edges approximates the original distance matrix in (e-g).

Validation

1. Estimate the number of selected edges and mean error and compare the existing methods, MST (Lee et al., 2001) and threshold slicing (Basset et al., 2006), to the proposed method.
2. Test the difference of number of holes between groups.
3. Estimate the Gromov-Hausdorff (GH) distance between the true shortest path length matrices (W), between the approximated W, and between single linkage matrices and the bottleneck distance of the zeroth and first Betti numbers, and cluster each matrices into 3 classes using the estimated GH distance.

Results

Datasets

We used the FDG-PET data set 24 attention deficit hyperactivity disorder (ADHD), 26 autism spectrum disorder (ASD) children and 11 pediatric control (PedCon) subjects. FDG-PET images were preprocessed using Statistical Parametric Mapping (SPM) package. After spatial normalization to the Korean standard template (Kang et al., 2004), the single linkage clustering was performed. The ADHD, ASD and PedCon datasets have 42, 34 and 46 holes.

1. Selected Edges

We illustrated the filtration and barcodes of ADHD, ASD and PedCon in Fig. 2. The total number of selected edges of ADHD, ASD and PedCon are 144, 136 and 148 in Fig. 3. The ADHD, ASD and PedCon networks have 42, 34 and 46 holes.

2. Number of holes

We generated 24 ADHD, 26 ASD and 11 PedCon datasets using the jackknifed resampling method. We estimate the number of holes for each datasets and obtain the distribution of number of holes and the statistical significance of their differences using Wilcoxon rank sum test.

3. Clustering accuracy

We compared the discriminative ability of the proposed method and the existing methods, MST, single linkage clustering, and the proposed method.

References