Automatic neurological disorder diagnosis using fractal-based manifold learning with resting-state fMRI

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

Resting-state Functional Magnetic Resonance Imaging (rs-fMRI) BOLD data is high dimensional temporal signals. There are several tools available for embedding high-dimensional data for automatic classification and visualization in low-dimensional space. Fractal Analysis, as assessing fractal characteristics of data, has played an important role in the analysis of time-dependent biological signals. In addition, a nonlinear dimensionality reduction technique called Uniform Manifold Approximation and Projection for Dimension Reduction (UMAP) was introduced for high-dimensional data analysis, but is mainly applied to time-independent data.

AIM

The goal of this study is to use integrated Fractal Analysis and Uniform Manifold

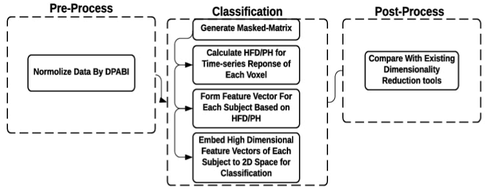
Approximation and Projection (UMAP) methods to identify neurological disorder diseases automatically based on 4D rs-fMRI data. Special focus is on the capability to automatic diagnostics for neurological disorder, i.e., Parkinson's disease.

METHOD

1. An innovation method was proposed that rs-fMRI data are de-noised and normalized using the well-known rs-fMRI processing toolbox DPAPI.
2. Higuchi's Fractal Dimension (HFD) D for each voxel is calculated by Eq. (1) $L_m(k) = \frac{\{(\sum_{i=1}^{\lfloor \frac{N-m}{k} \rfloor} |X(m+ik)-X(m+(i-1)k)| \quad |)\frac{N-1}{\lfloor \frac{N-m}{k} \rfloor k}\}}{k} \sim k^{-D}$

   Each subject is represented by a let of HFDs, which describes the temporal characteristics of resting-state fMRI at the voxel level.
3. The data used for this study were from the Parkinson's Progression Markers Initiative (PPMI) database (http://www.ppmi-info.org/data) and OpenNeuro database (https://openneuro.org/).
4. Automatic clustering and classification was obtained for Parkinson's disease. Only fMRI data from slices 41- 47 after images registered to the Montreal Neurological Institute (MNI) common space are used for classification as it is assumed that the signals in motor areas are sensitive for the Parkinson's disease.
5. All images were preprocessed by Data Processing & Analysis for Brain Imaging Toolbox. Preprocessing of data included following procedures, slice timing, realignment, coregitration with T1-weighted data, spatial normalization by DARTEL to Montreal Neurological Institute (MNI) space and smooth. The initial hypothesis is that the motor region of all patients had different topological structure with respect to the healthy controls. Thus, motor region is selected as the first brain region for investigation and several other important regions are also selected for comparison.

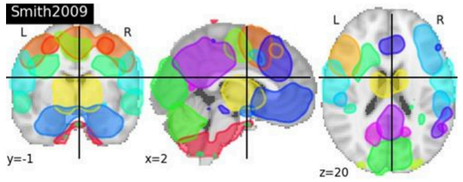
METHOD



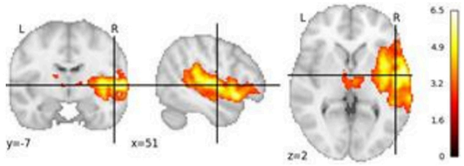
Flowchart of Proposed Methods integrating HFD and UMAP

RESULTS

- The results of using GHEs and UMAP are presented.
- Most of subjects with Parkinson's disease are well separated from the healthy group.
- 5 healthy subjects in the first dataset and 2 healthy subjects in the second datasets are clustered with the Parkinson's group.

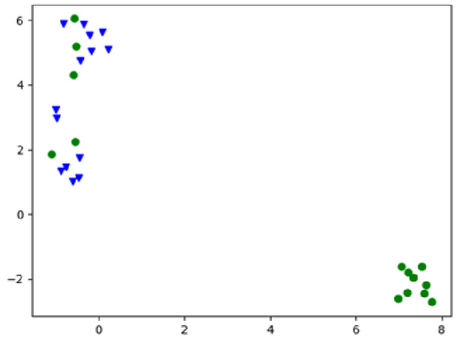


Smith Atlas 2009

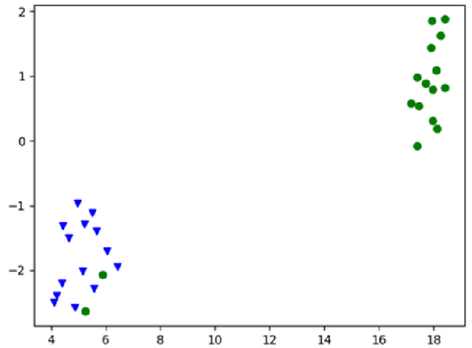


Brain Motor Map used in this Study.

RESULTS



Result of Automatic Clustering Parkinson (Blue) and Health (Green) Subjects – case study 1



Result of Automatic Clustering Parkinson (Blue) and Health (Green) Subjects – case study 2

CONCLUSIONS

Most subjects with Parkinson's disease are well separated from the healthy group. 5 healthy subjects in the first dataset and 2 healthy subjects in the second datasets are clustered with the Parkinson's group and the reason is not clear at this stage. The preliminary results show the great potential using the proposed algorithms to perform neurological disorder diagnosis automatically. Additional datasets with other types neurological disorder are being collected and tested using the proposed method.

ACKNOWLEDGMENT

Thanks OpenNeuro for Sharing the rest state FMRI data.

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