



Multi-View Graph Convolutional Network and Its Applications on Neuroimage Analysis for Parkinson's Disease

Decision and Learning Using Multiple Data Sources

S114

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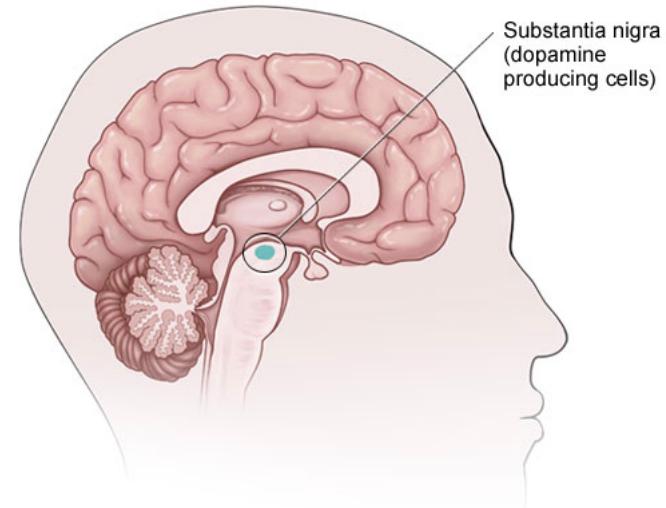
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Motivation

- **What is Parkinson's Disease?**
- **Parkinson's Disease is one of most prevalent neurodegenerative disease.**
- **Why analyze neuroimaging data?**
- **Influence?**

Parkinson's Disease



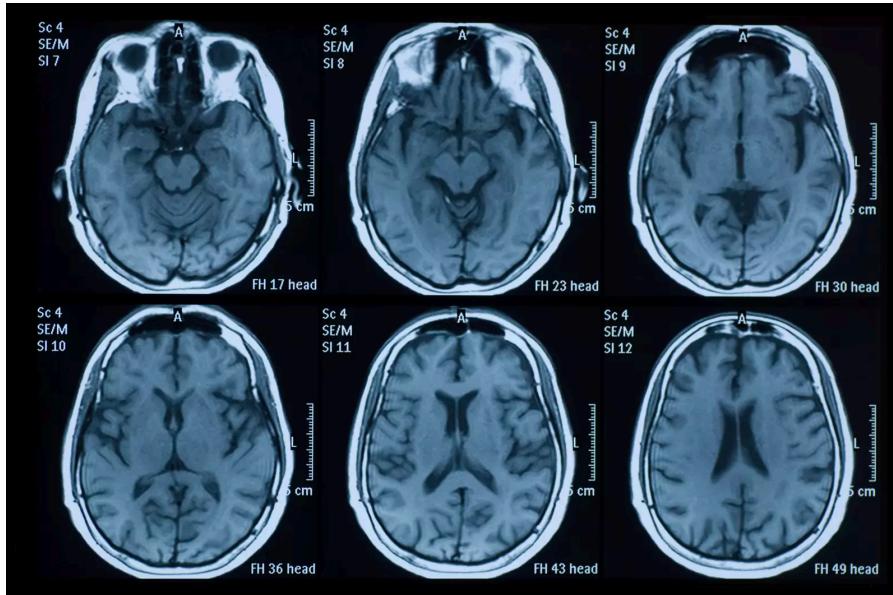
Introduction



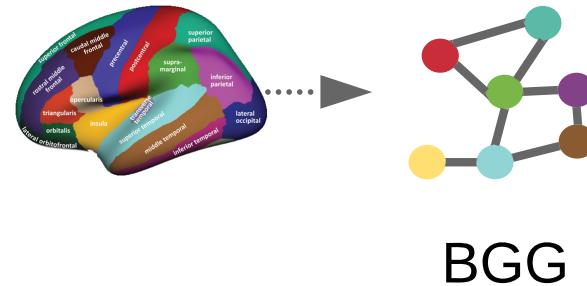
- ❖ Goal: Discriminate early stage Parkinson Cases and Controls.
- ❖ Data: MRI coordinates, DTI image data from PPMI dataset
- ❖ Many computational approaches have been developed for neuroimaging analysis
- ❖ MVGCN, Multi View Graph Convolution Network.
- ❖ What is Multi View?

Problem Setting

❖ Graph Construction: ROI, BGG



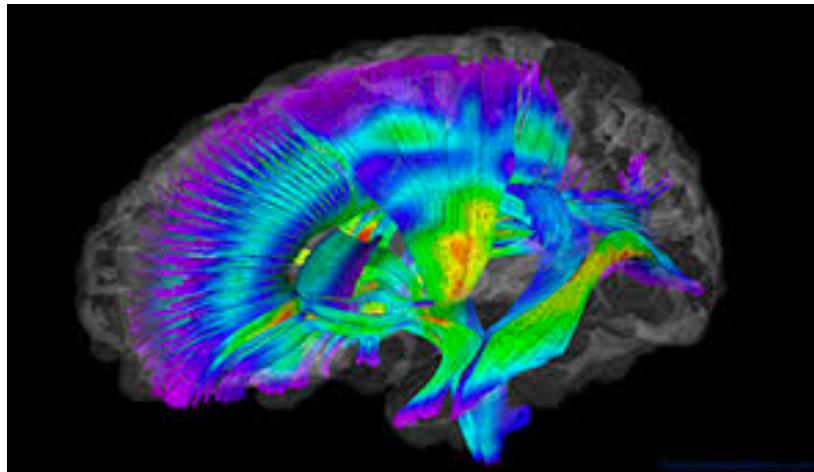
<http://time.com/2860630/mri-scans-can-detect-early-onset-of-parkinsons-study-finds/>



- BGG: Brain Geometry Graph
- ROI: Region of Interest
- Parcel the structural MRI brain image into a set of ROI
- Strategy: Desikan-Killiany 84

Problem Setting

❖ Feature Construction: BCG



- BCG: Brain Connectivity Graph
- tractography is a 3D modeling technique used to visually represent nerve tracts using data collected by diffusion MRI

Credit: <https://neurology.msu.edu/CoGeNT/lab/dti>

Study Overview

❖ Graph Construction: ROI, BGG

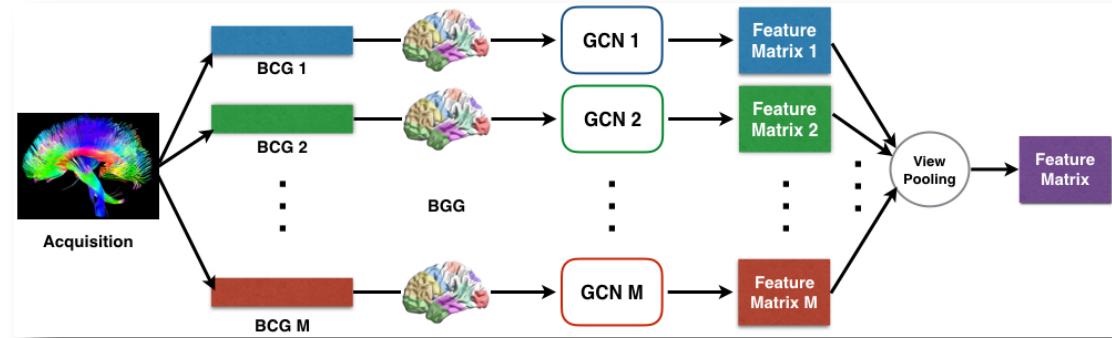
❖ Feature Construction: BCG

❖ Relationship Prediction.

Stark points:

❖ Pairwise Learning.

❖ Multi-Graph Fusion



Methodology: Overview



Basic Components of the Proposed Neural Network

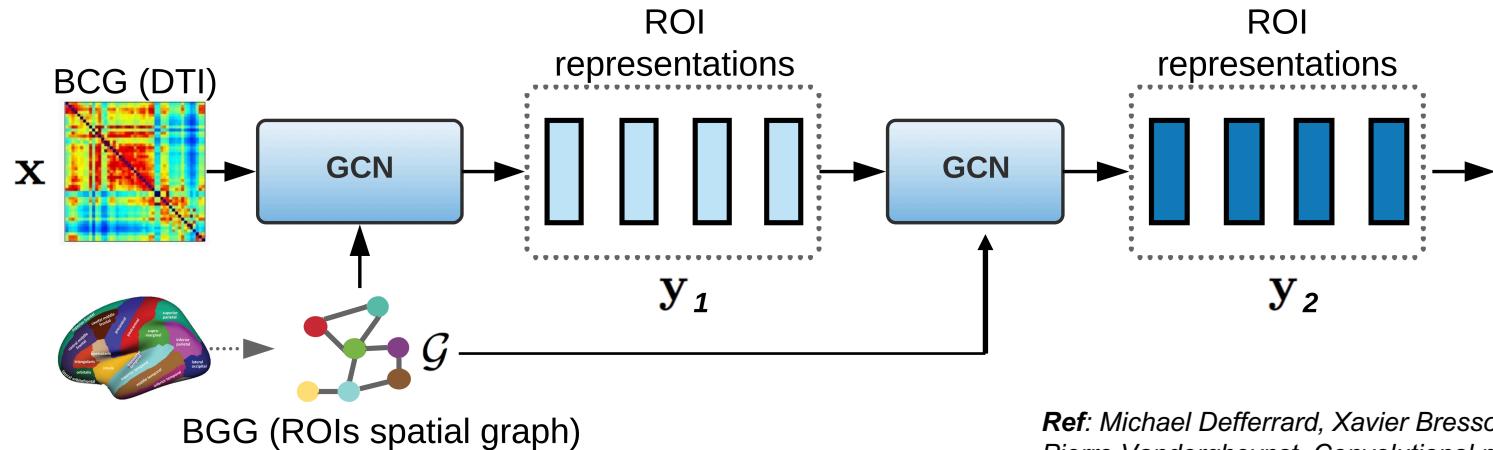
- ❖ C1: Graph Convolutional Network (GCN)
- ❖ C2: View Pooling
- ❖ C3: Pairwise Matching
- ❖ C4: Objective Function

Definition:

- ❖ D1: BCGs -- Brain Connectivity Graphs (DTI data)
- ❖ D2: BGG -- Brain Geometry Graph (ROI coordinates)

Methodology

❖ C1: Graph Convolutional Network



Ref: Michael Defferrard, Xavier Bresson, and Pierre Vandergheynst. Convolutional neural networks on graphs with fast localized spectral filtering. In *Advances in Neural Information Processing Systems*, pages 3844–3852, 2016.

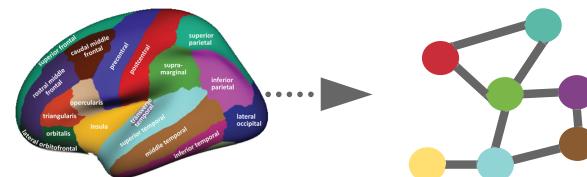
Methodology

✓ Spatial Graph Construction

Suppose we have a population of M acquisitions, coordinates are computed by the global ROI

$$\bar{v}_i = \frac{1}{M}(\Sigma_m^M v_{i,m}^x, \Sigma_m^M v_{i,m}^y, \Sigma_m^M v_{i,m}^z), \forall i \in (1, \dots, n).$$

the edges \mathcal{E} can be constructed by



$$w_{ij} = \begin{cases} \exp(-\frac{\|\bar{v}_i - \bar{v}_j\|^2}{2\sigma^2}), & \text{if } i \in N_j \text{ or } j \in N_i \\ 0, & \text{otherwise.} \end{cases}$$

BGG

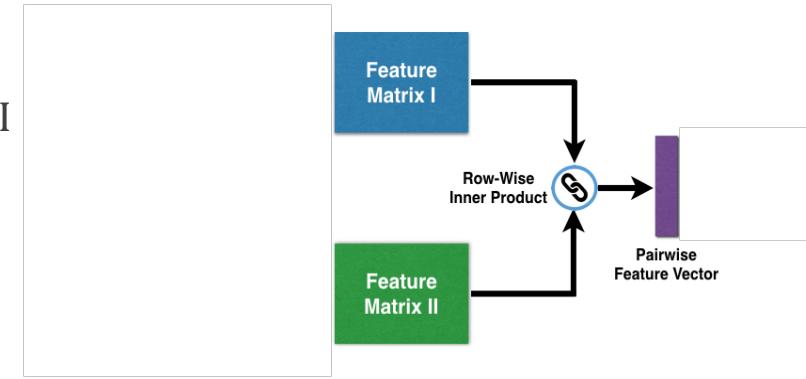
Methodology

❖ C3: Pairwise Matching

- ❖ Each row is a representation of a ROI

row-wise inner product matching

$$\text{sim}(\mathbf{z}_p^i, \mathbf{z}_q^i) = \mathbf{z}_p^i{}^T \mathbf{z}_q^i, \quad i = 1, 2, \dots, n.$$

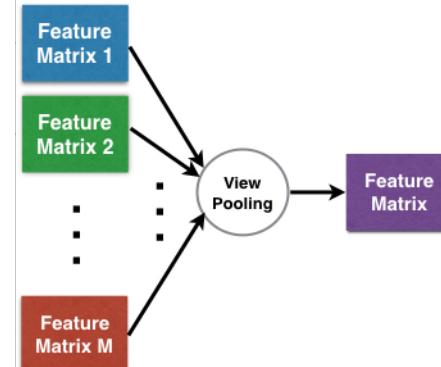
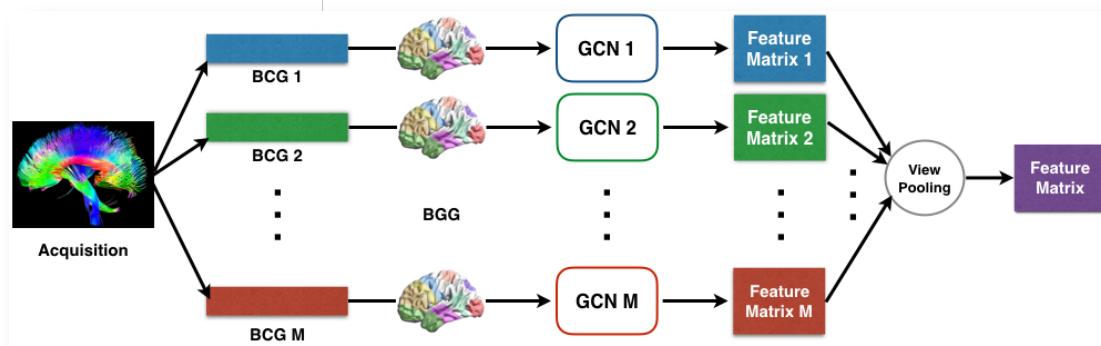


Methodology

❖ C2: View Pooling

Two element-wise pooling methods are explored here:

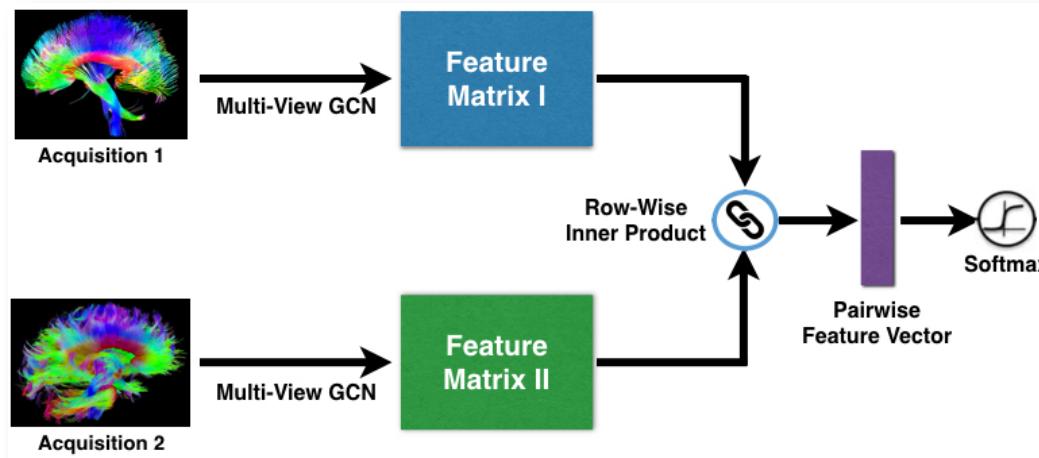
- ✓ max pooling
- ✓ mean pooling



Ref: Hang Su, Subhransu Maji, Evangelos Kalogerakis, and Erik Learned-Miller. Multi-view convolutional neural networks for 3d shape recognition. In Proceedings of the IEEE international conference on computer vision, pages 945–953, 2015.

Methodology

❖ C4: Objective Function



$$\mathcal{L} = \sum_{m, m'}^N \tilde{y}_{m, m'} \log p_{m, m'} + (1 - \tilde{y}_{m, m'}) \log(1 - p_{m, m'}) \\ + \gamma \|\Theta\|_2$$

where $\tilde{y}_{m, m'}$ denotes the label for sample pair $(x_m, x_{m'})$ $p = softmax(w_c^T r)$

Dataset: PPMI



# of Matching Samples	# of Non-Matching Samples	# of PD Subjects	# of HC Subjects
189,713	94,168	596	158

Based on Desikan-Killiany 84 ROIs, we reconstruct six types of BCGs for each subject using six whole brain tractography algorithms, including:

- ✓ Fiber Assignment by Continuous Tracking (FACT);
- ✓ The 2nd-order Runge-Kutta (RK2);
- ✓ Interpolated streamline (SL);
- ✓ The tensorline (TL);
- ✓ Orientation distribution function-based deterministic approach (ODF-RK2) ;
- ✓ Hough voting.



Experimental Results

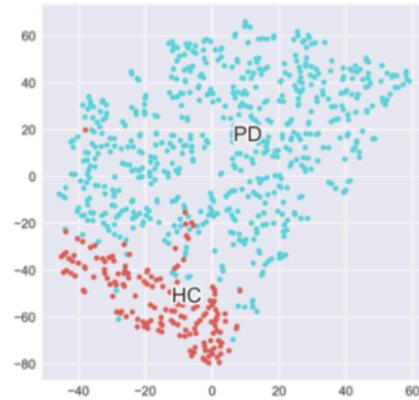
Table 1: Results for classifying matching vs. non-matching brain networks in terms of AUC metric.

Methods	Modals					
	FACT	RK2	SL	TL	ODF-RK2	Hough
Raw Edges	58.47±4.05	62.54±6.88	59.39±5.99	61.94±5.00	60.93±5.60	64.49±3.56
PCA	64.10±2.10	63.40±2.72	64.43±2.23	62.46±1.46	60.93±2.63	63.46±3.52
FCN	66.17±2.00	65.11±2.63	65.00±2.29	64.33±3.34	68.80±2.80	61.91±3.42
FCN _{2l}	82.36±1.87	81.02±4.28	81.68±2.49	81.99±3.44	82.53±4.74	81.77±3.74
GCN	92.67±4.94	92.99±4.95	92.68±5.32	93.75±5.39	93.04±5.26	93.90±5.48

Table 2: Comparison of binary classification (AUC) and acquisition clustering (NMI) results

Architectures	AUC	NMI
PCA100-M-S	64.43±2.23	0.39
FCN1024-M-FCN64-S	82.53±4.74	0.87
GCN128-M-S	93.75±5.39	0.98
MVGCN128-M-S _{mean}	94.74±5.62	1.00
MVGCN128-M-S _{max}	95.37±5.87	1.00

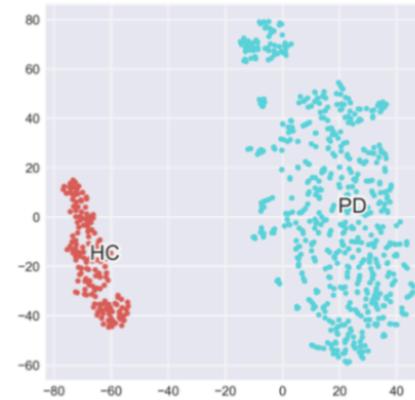
Learned Similarity: Visualization



(a) PCA



(b) FCN_{2l}

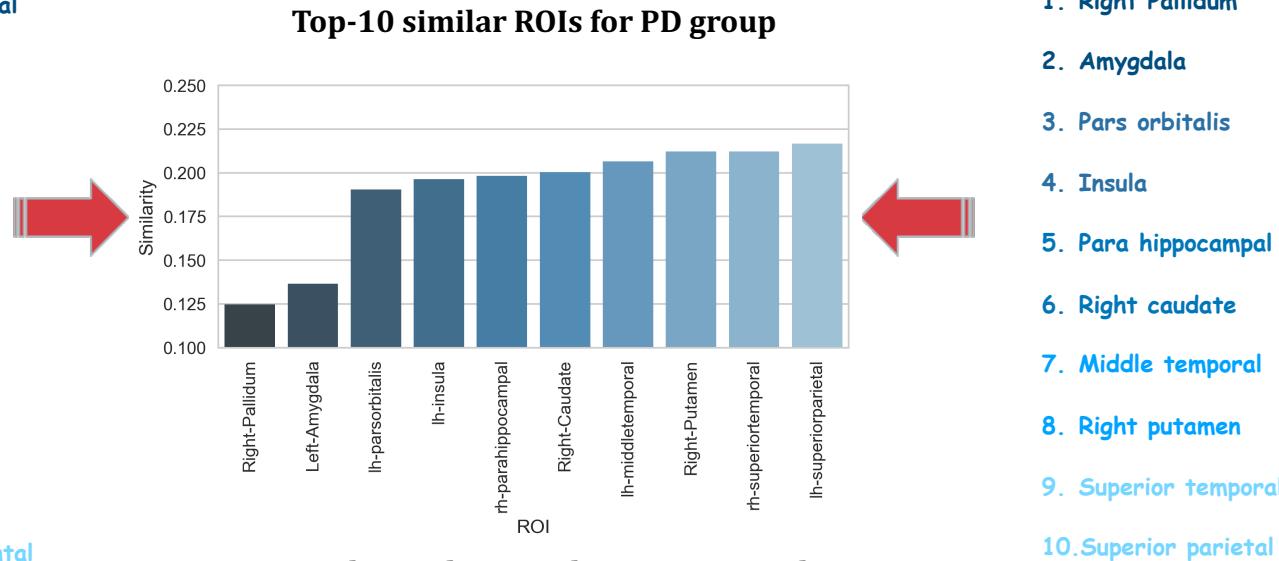


(c) MVGCN

**Visualization of DTI acquisition clusters:
PD versus Healthy Control**

Learned Similarity: Interpretation

1. Lateral orbitofrontal
2. Middle temporal
3. Amygdala
4. Entorhinal
5. Insula
6. Pars triangleularis
7. Paracentral
8. Precentral
9. Superior frontal
10. Rostral middle frontal



Ref: 1. Decision-making performance in Parkinson's disease correlates with lateral orbitofrontal volume.

2. Hypometabolism in Posterior and Temporal Areas of the Brain is Associated with Cognitive Decline in Parkinson's Disease.

Ref: 3. Abnormal amygdala function in Parkinson's disease patients and its relationship to depression.
4. Morphological alterations in the caudate, putamen, pallidum, and thalamus in Parkinson's disease

Conclusion:

- i. Developed a new methodology MVGVN, which can be used to accurately discriminate PD and Healthy subjects.
- ii. Interpretability of the learned high-level representations through MVGCN are explored.

Future Works:

- The clinical data such as MRI feature and CT are not considered in the analysis of the disease, which are important domain knowledge deserved to be analyzed.

Thank you!

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