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Parkinson's Disease Detection from fMRI-derived Brainstem Regional Functional Connectivity Networks

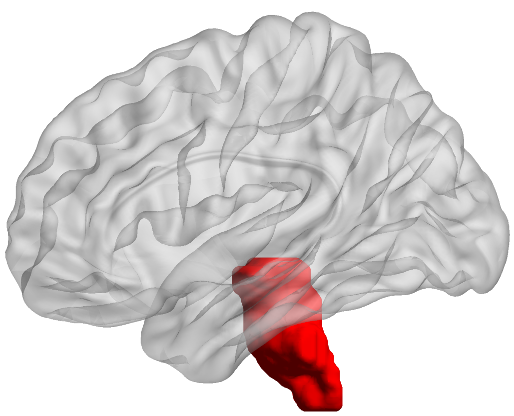
Nandinee F. Haq (*nandinee@ece.ubc.ca*),
J. Cai, T. Yu, M.J. McKeown, & Z. Jane Wang (*zjanew@ece.ubc.ca*)

The University of British Columbia,
Vancouver, Canada.

Motivation

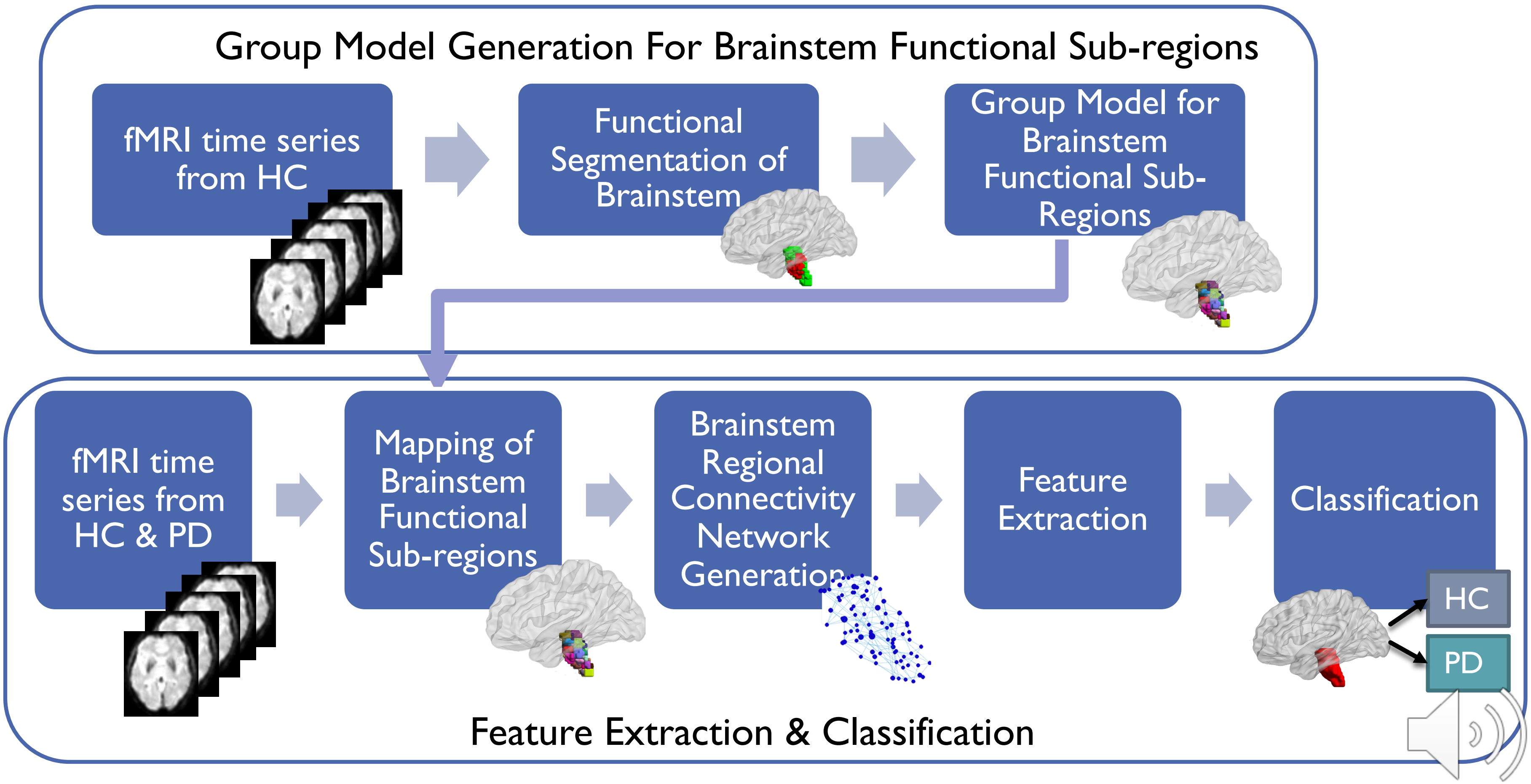
- Parkinson’s disease (PD) is the second most prevalent neurodegenerative disorder
  - largely idiopathic
  - misdiagnosis rate can be very high due to its overlap with other neurological conditions
- Imaging based diagnostic tools can help in characterization of the disease

Motivation

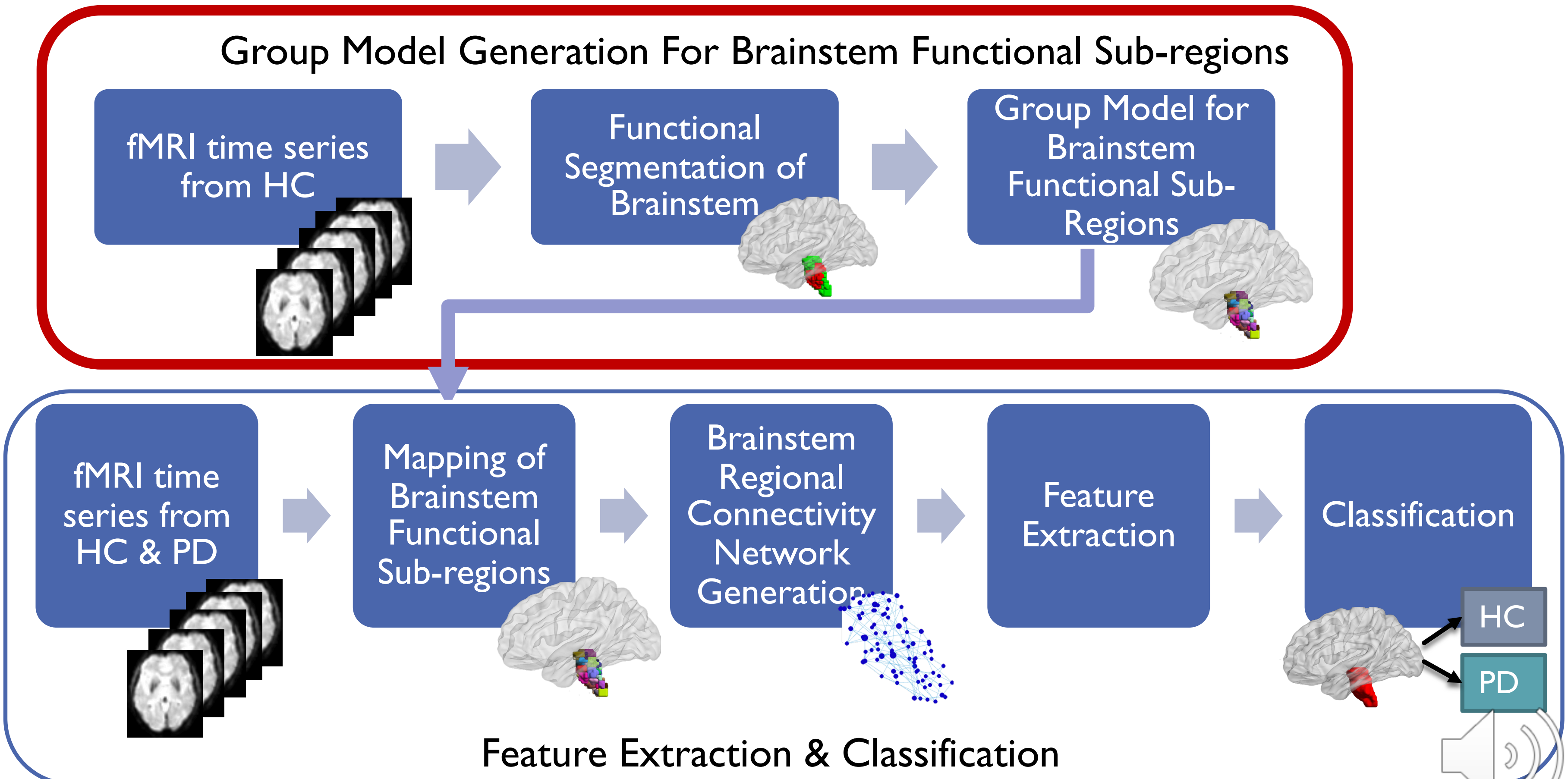


- Motor symptoms associated with PD caused by progressive loss of dopaminergic neurons in the Brainstem (BS)
  - Yet brainstem and its sub-structures are relatively unexplored
- We propose a data-driven, connectivity-pattern based framework to extract functional sub-regions within BS and devise a machine learning based tool that is sensitive to PD changes

Proposed Framework



Group Model Generation For Brainstem Functional Sub-regions



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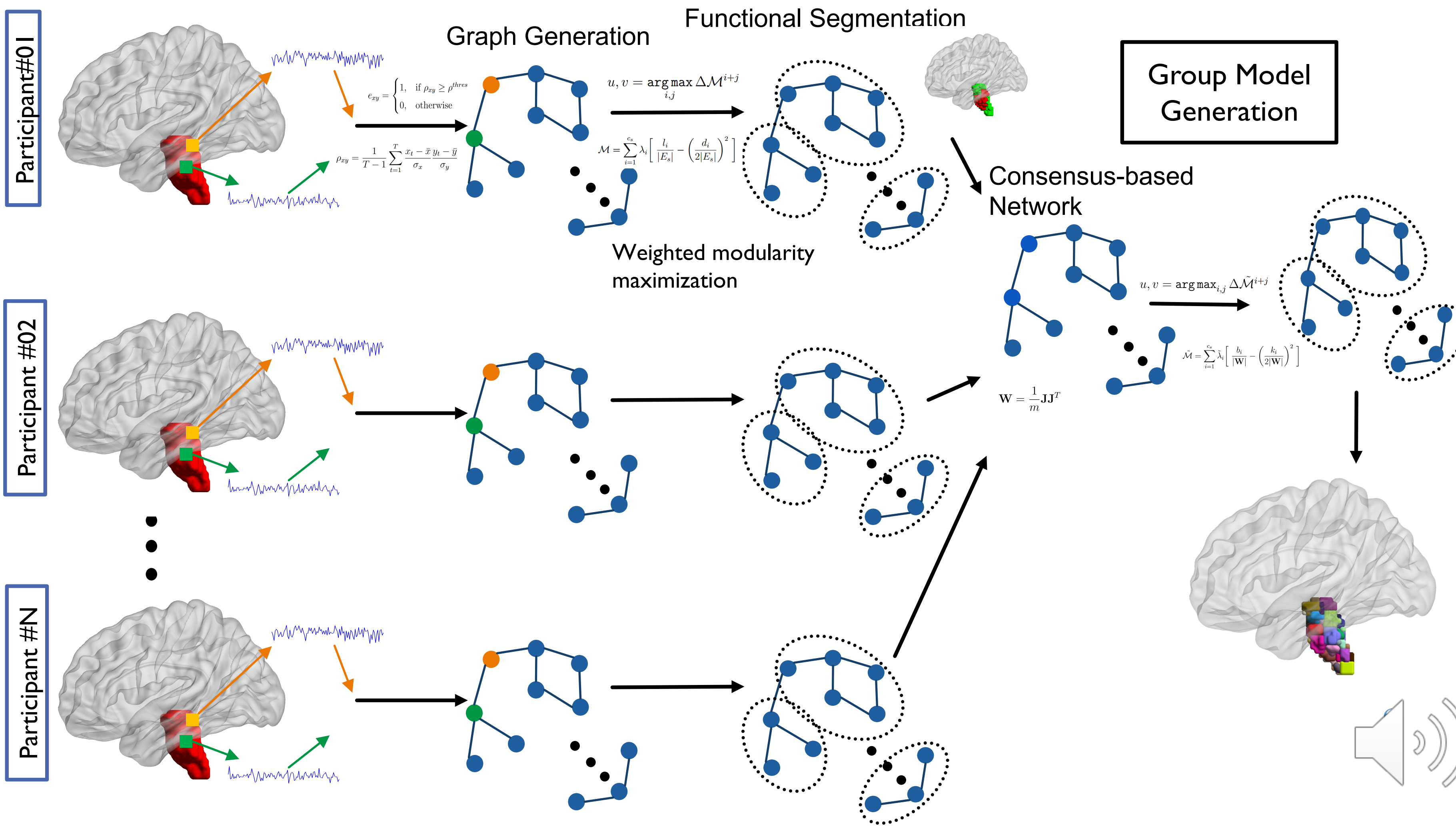
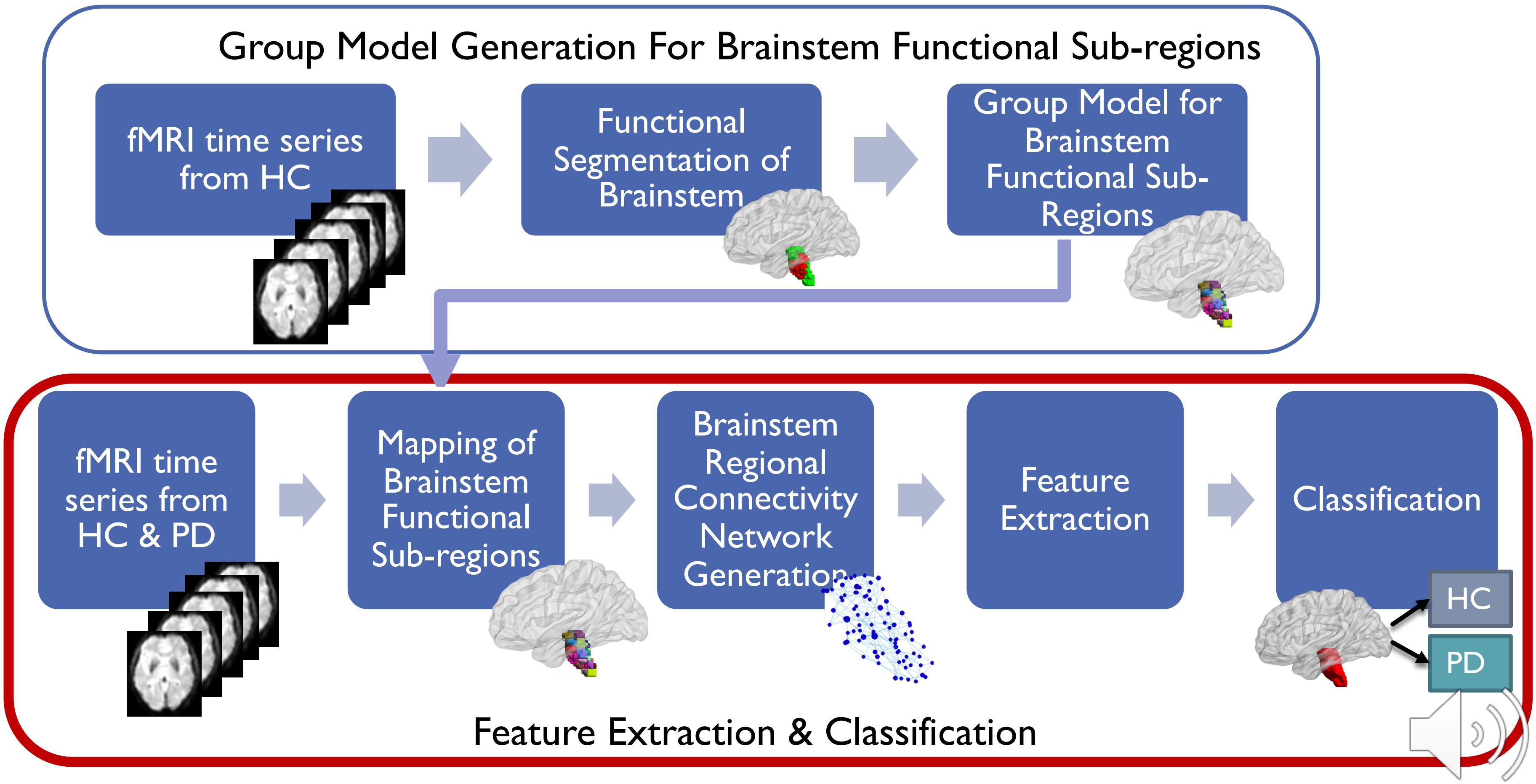


Feature Extraction & Classification



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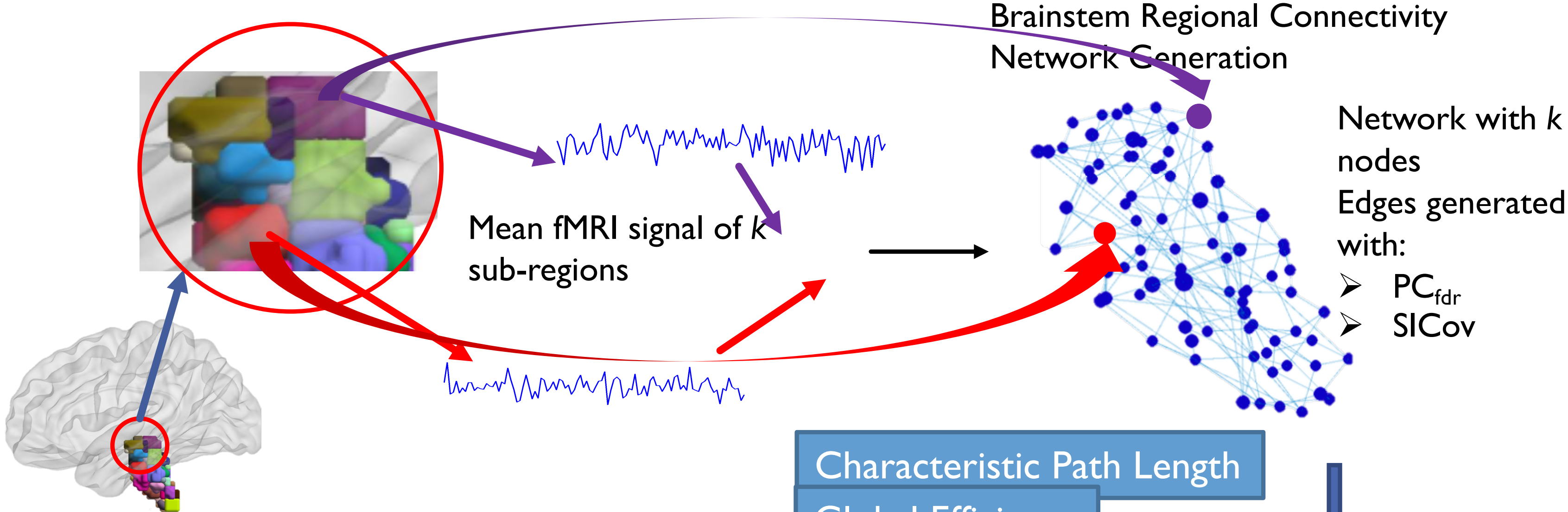


- Characteristic Path Length
- Global Efficiency
- Clustering Coefficient
- Modularity
- Transitivity
- Assortativity Coefficient
- Fiedler Value
- Normalized Fiedler Value
- Sychronizability

Feature Extraction

Classification

HC

PD

PC_{fdr}: Li *et al.* Journal of Machine Learning Research 10(Feb), 475–514 (2009)
SICov: Friedman *et al.* Biostatistics 9(3), 432–441 (2008)

Datasets

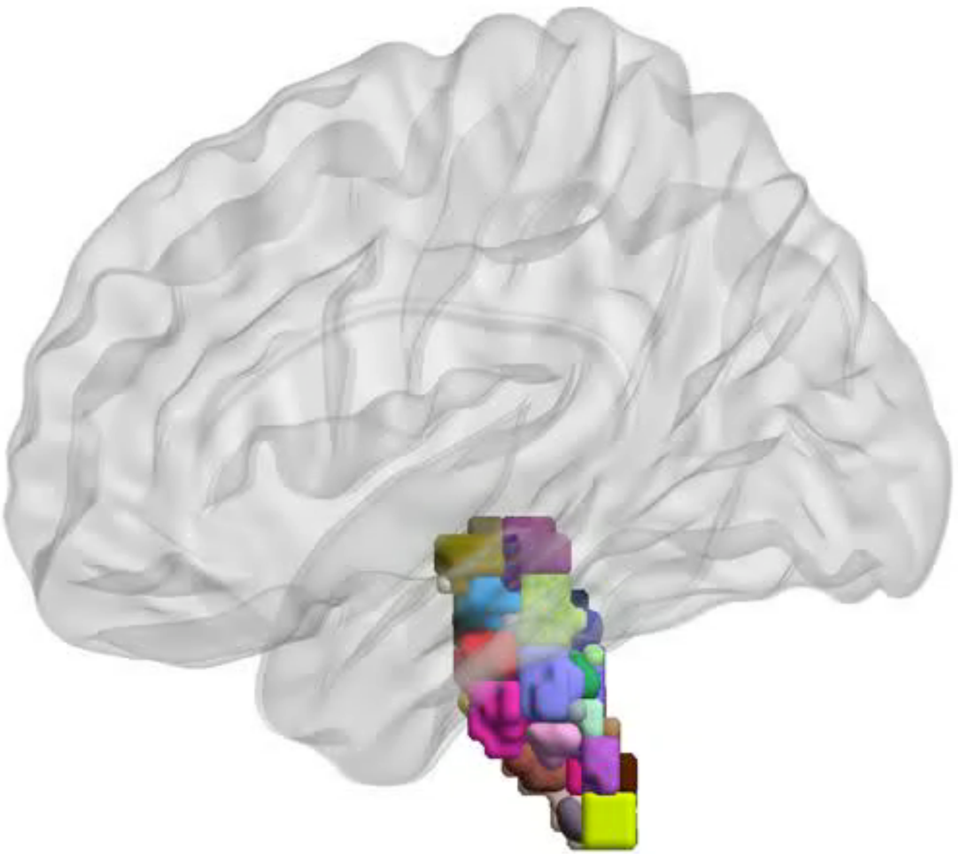
Dataset-I

- 15 Healthy Control (HC)
- 10 male, 5 female
- Average age 69.4 ±4.76 years
- Used to generate the group model for brainstem functional sub-regions

Dataset-II

- 17 HC, 7 male, 10 female, 68.1 ± 5.2 years
- 17 PD, 9 male, 8 female, 67.7 ± 4.7 years
  - H&Y scores 1-3, UPDRS score of 26.7±11.5
  - disease duration of 5.8 ± 3.7 years
  - Levodopa medication
  - scanned exactly one hour after the intake of their medication
- Used for classification

Results : Group Model Generation For Brainstem Functional Sub-regions



- 84 functional sub-regions
  - *spatially contiguous*
- Leave-one-out analysis:
  - Normalized Mutual Information between partitions ~0.9

Results: Classification

	Sensitivity	Specificity	Accuracy	AUC
PC_{fdr} based classifier	**94%**	**71%**	**82%**	**0.81**
SICov based classifier	**82%**	**82%**	**82%**	**0.77**
Chen et al. (2015), 150 features, whole brain	*90.47%*		*93.62%*	--
Cai et al. (2019), whole-brain dynamic connectivities	--	--	*85.7%*	--

Cai *et al.* 2019. IEEE journal of biomedical and health informatics 23(4), 1720– 1729.
Chen *et al.* 2015. Plos one 10(4) (2015)

Conclusions

- The first study that targets the generation of brainstem functional sub-regions and the application of the associated network in PD detection
- Developed a novel data-driven framework for PD detection solely from BS regional functional connectivity networks
  - A novel community detection algorithm on a participant-level and a consensus-clustering based approach to generate group-level BS functional sub-regions
  - Proposed features from BS regional connectivity networks for Parkinson's disease detection.
- Achieved 94% sensitivity with an AUC of 0.81

Future Works

- Large scale study
- Incorporation of the connectivity alterations of BS sub-regions with other cortical/subcortical brain regions
- Investigate both functional connectivity and task-related activation to infer which of the potentially many nuclei are actually being detected

Thank You!