Identifying Alzheimer's Disease Brain Regions from Multi-Modality Neuroimaging Data Using Sparse Composite Linear Discrimination Analysis (SCLDA)

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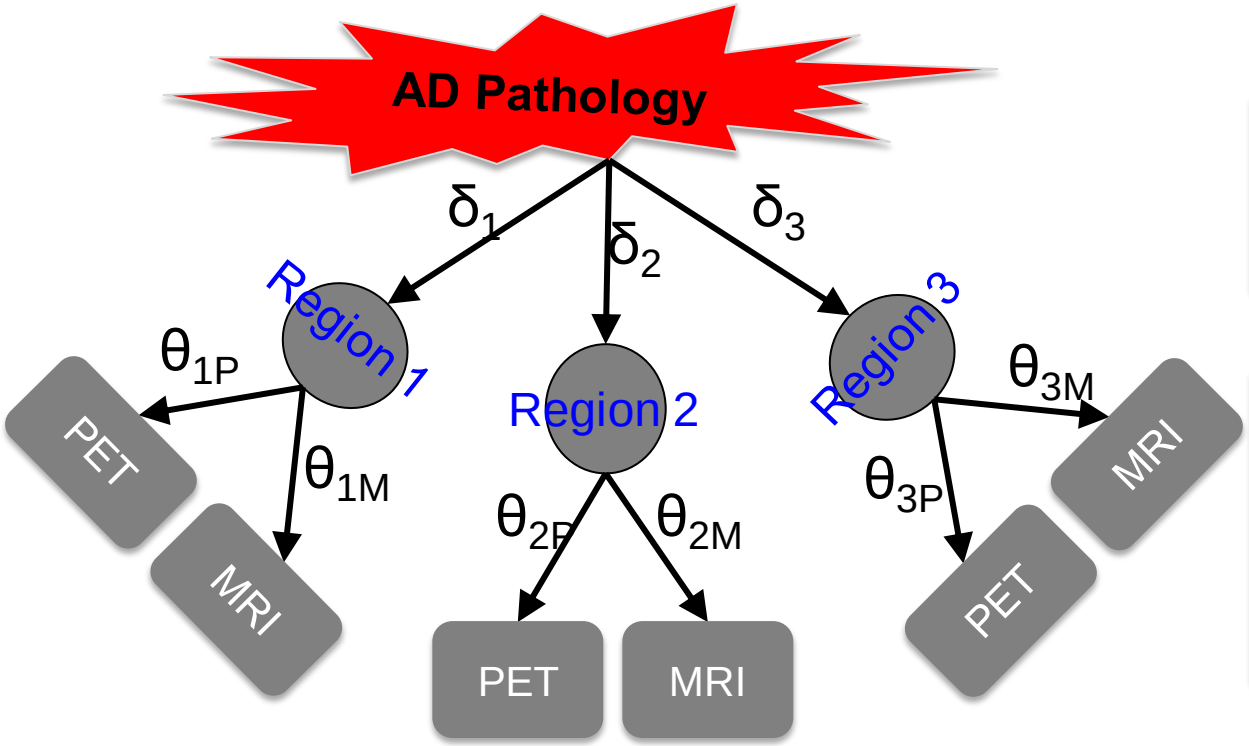
Combine MRI and PET for AD Study

A tree structure which links the AD pathology, brain regions, PET and MRI



MRI and PET measure the same AD pathology, and supplement each other

A joint analysis of MRI and PET imaging data will increase the statistical power to detect AD-related brain regions

- δ_1 : the relatedness of brain region 1 with the AD pathology
- θ_{1P}: the signal strength of θ_1 reflected on PET (i.e., enhanced or reduced)
- θ_{2M}: the signal strength of θ_1 reflected on MRI (i.e., enhanced or reduced)

Formulation of SCLDA

Original formulation – impose penalty on both θ and γ

$$\widehat{\boldsymbol{\Theta}} = \operatorname{argmin}_{\boldsymbol{\Theta}} l_1\left(\boldsymbol{\Theta}|\{\mathbf{Z}^{(1)}, \mathbf{Z}^{(2)}, \dots, \mathbf{Z}^{(M)}\}\right) = \operatorname{argmin}_{\boldsymbol{\Theta}} \left\{-l_0\left(\boldsymbol{\Theta}|\{\mathbf{Z}^{(1)}, \mathbf{Z}^{(2)}, \dots, \mathbf{Z}^{(M)}\}\right) + \lambda_1 \sum_k \delta_k + \lambda_2 \sum_{k,l,m} \gamma_{k,l}^{(m)}\right\}, \text{ subject to}$$

$$\theta_{k,l}^{(m)} = \delta_k \gamma_{k,l}^{(m)}, \delta_k \geq 0, 1 \leq k, l \leq p, 1 \leq m \leq M.$$

Reduced formulation – a non-convex sparse learning model

$$\widetilde{\boldsymbol{\Theta}} = \operatorname{argmin}_{\boldsymbol{\Theta}} l_2\left(\boldsymbol{\Theta}|\{\mathbf{Z}^{(1)}, \mathbf{Z}^{(2)}, \dots, \mathbf{Z}^{(M)}\}\right)$$

$$= \operatorname{argmin}_{\boldsymbol{\Theta}} \left\{-l_0\left(\boldsymbol{\Theta}|\{\mathbf{Z}^{(1)}, \mathbf{Z}^{(2)}, \dots, \mathbf{Z}^{(M)}\}\right) + \lambda \sum_k \sqrt{\sum_{l=1}^{q} \sum_{m=1}^{M} \left|\theta_{k,l}^{(m)}\right|}\right\}$$

Superiority over L1/L2 penalty

Less shrinkage effect – less irrelevant features been selected

No more “all-in-all-out” solution for the parameters under the same square root

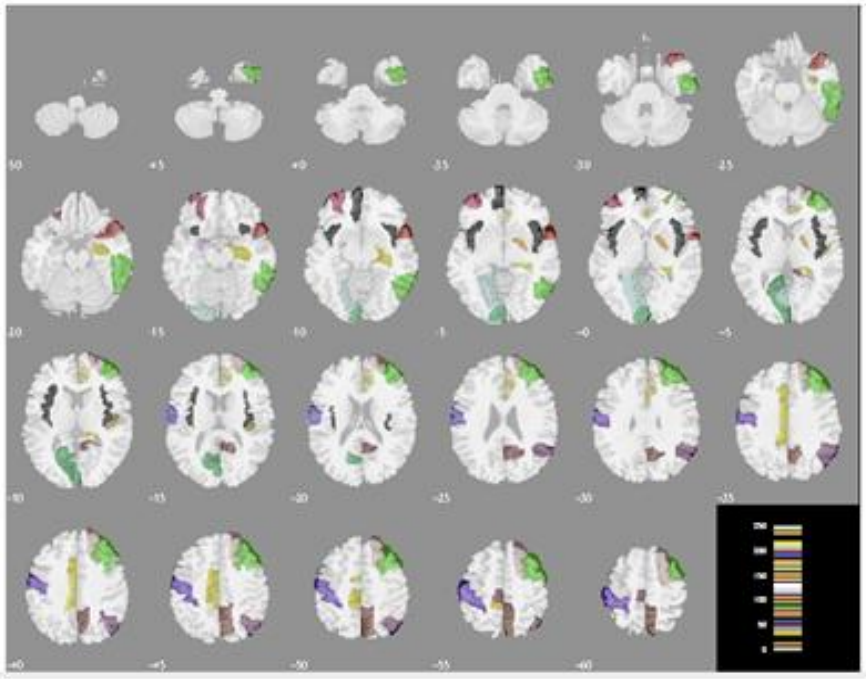
DC (difference of convex functions) programming is used to solve the optimization task

Has a linkage with adaptive LASSO

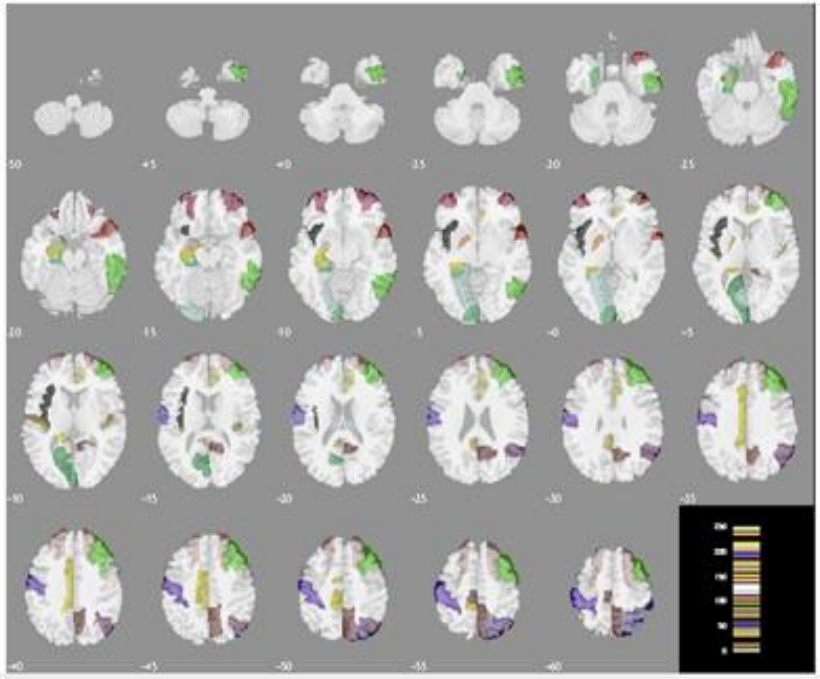
Result – Identified AD-related Brain Regions

Locations of AD-related brain regions

PET



MRI



Most of the AD-related regions are consistent with existing knowledge