Structure-Preserving Graph Kernel For Brain Network Classification

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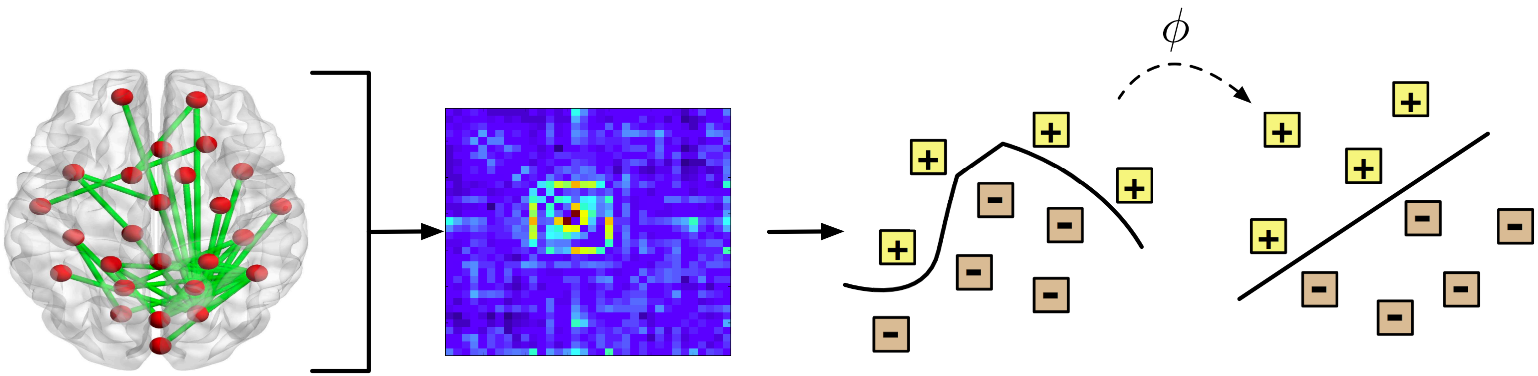
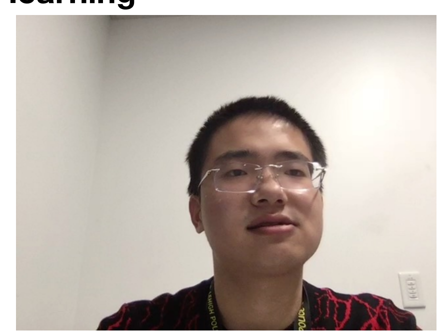
The Proposed Framework



Brain network **Graph modeling** **Graph-based kernel learning**

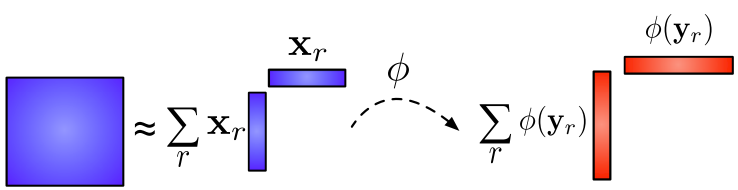


Key Optimization Problem

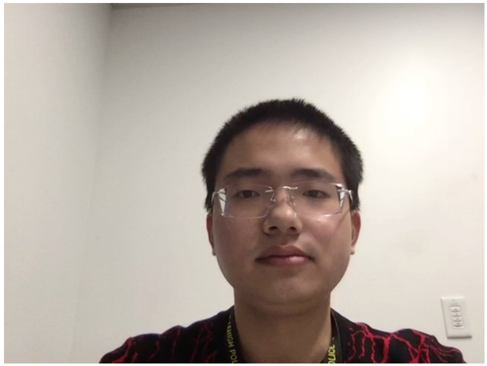
- Graph approximation:

$$\min_{\mathbf{a}_r} \|\mathbf{X} - \sum_{r=1}^{R} \mathbf{a}_r \otimes \mathbf{a}_r\|_F^2 + \lambda \sum_{r=1}^{R} \|\mathbf{a}_r\|_1,$$

- Graph mapping:



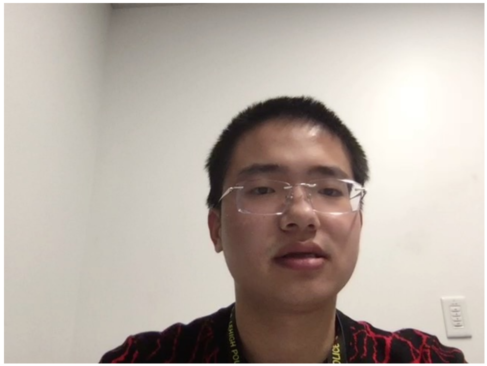
$$\phi : \sum_{r=1}^{R} \mathbf{x}_r \otimes \mathbf{x}_r \rightarrow \sum_{r=1}^{R} \phi(\mathbf{x}_r) \otimes \phi(\mathbf{x}_r).$$



Structure-preserving Symmetric Graph Kernel (SSGK)

- Apply the kernel function on our sparse recovery matrix, we can derive the SSGK model:

$$
\begin{aligned}
\kappa(\mathbf{X},\mathbf{Y}) &= \kappa\Big(\sum_{r=1}^{R}\mathbf{x}_r\otimes\mathbf{x}_r,\sum_{r=1}^{R}\mathbf{y}_r\otimes\mathbf{y}_r\Big)\\
&= \Big\langle\sum_{r=1}^{R}\phi(\mathbf{x}_r)\otimes\phi(\mathbf{x}_r),\sum_{r=1}^{R}\phi(\mathbf{y}_r)\otimes\phi(\mathbf{y}_r)\Big\rangle\\
&= \sum_{p=1}^{R}\sum_{q=1}^{R}\kappa(\mathbf{x}_p,\mathbf{y}_q)\kappa(\mathbf{x}_p,\mathbf{y}_q).
\end{aligned}
$$



Visualization & Experimental Results

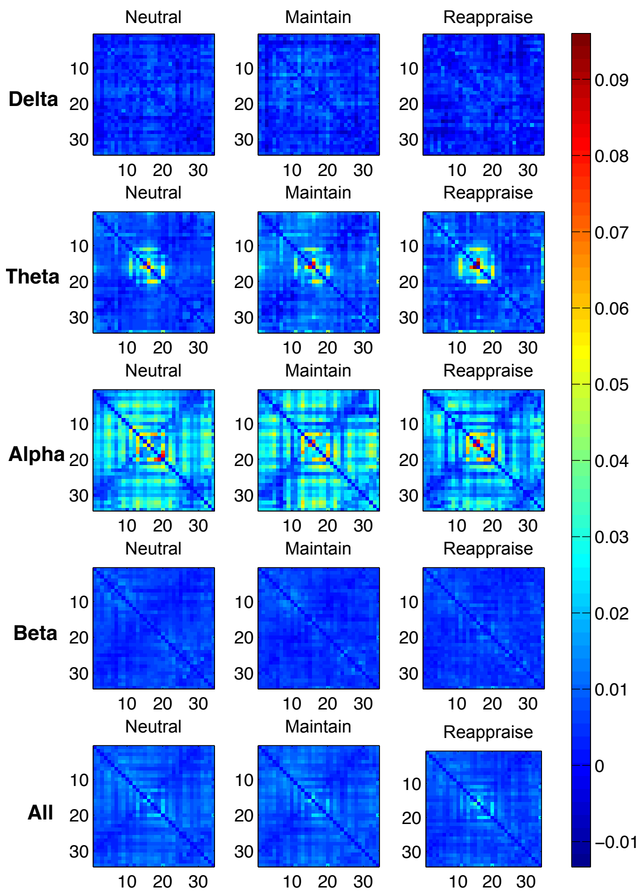


Table 1. The classification accuracy in percentage (%) by competing methods and the proposed method for five tasks. The best results for each task are highlighted in boldfont.

Category	Method	Frequency Band				
		Delta	Theta	Alpha	Beta	All
Traditional	Edge	42.42	54.55	51.52	51.52	45.45
	CC	54.55	54.55	42.42	51.52	42.42
	CPL	48.48	42.42	45.45	48.48	39.39
	gSpan	39.39	51.52	39.39	54.55	48.48
	DuSK–2D	51.52	63.64	51.51	51.52	54.55
	DuSK–3D	57.58	57.58	57.58	54.55	48.48
	DuSK–4D	54.55	54.55	51.52	54.55	57.58
Deep Learning	CNN–2D	51.11	43.71	43.07	42.54	41.48
	CNN–3D	46.67	45.93	41.48	57.04	44.44
	GCN	41.31	48.08	41.01	40.61	37.37
Ours	$\text{SSGK}_{\text{w/o sparse}}$	57.58	66.67	63.64	54.55	57.58
	SSGK	**63.64**	**69.70**	**72.73**	**60.61**	**57.58**