Sleep Stages Prediction via Fusion Signals

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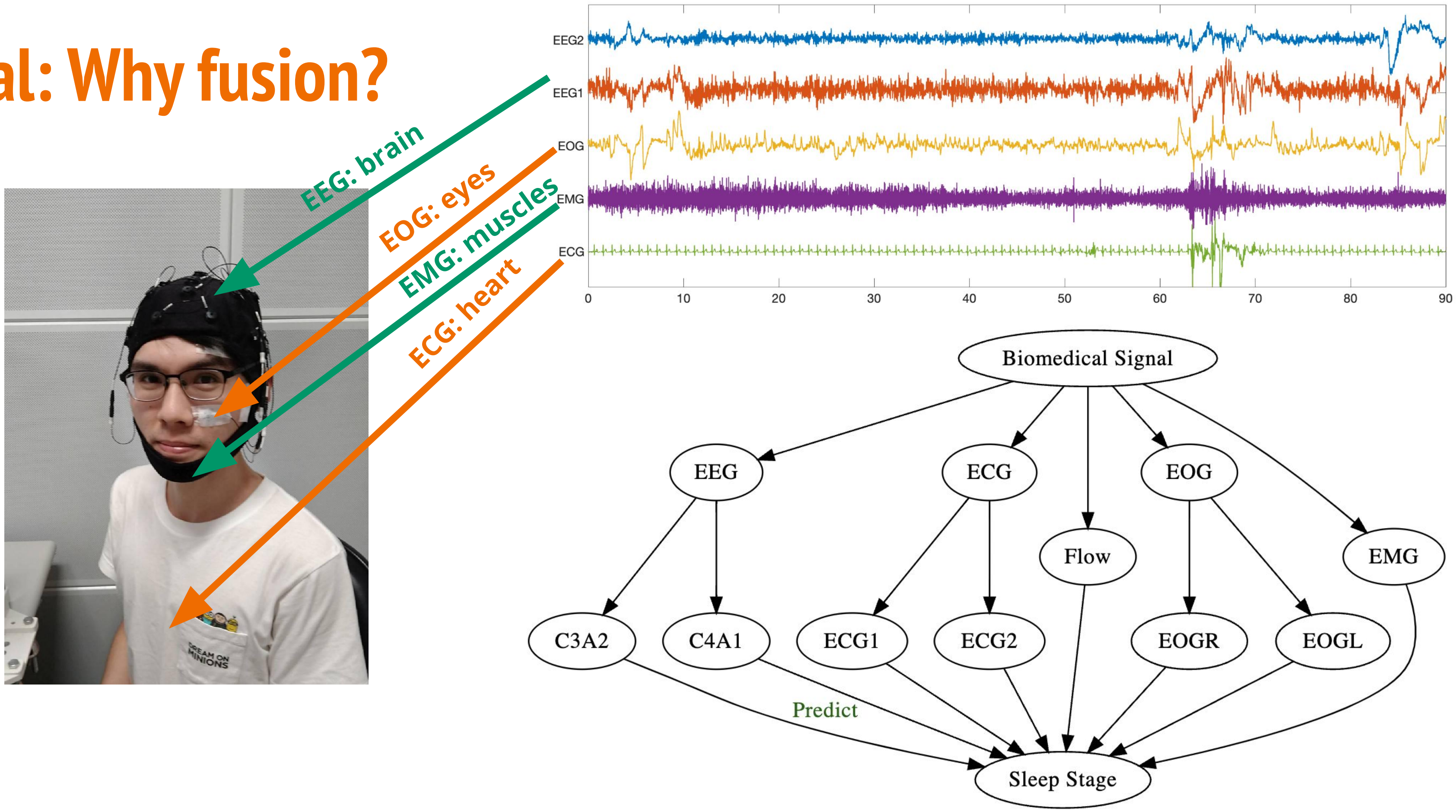
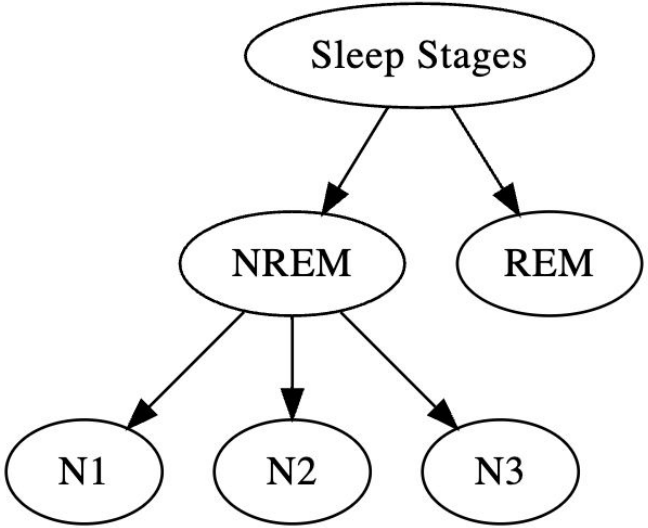
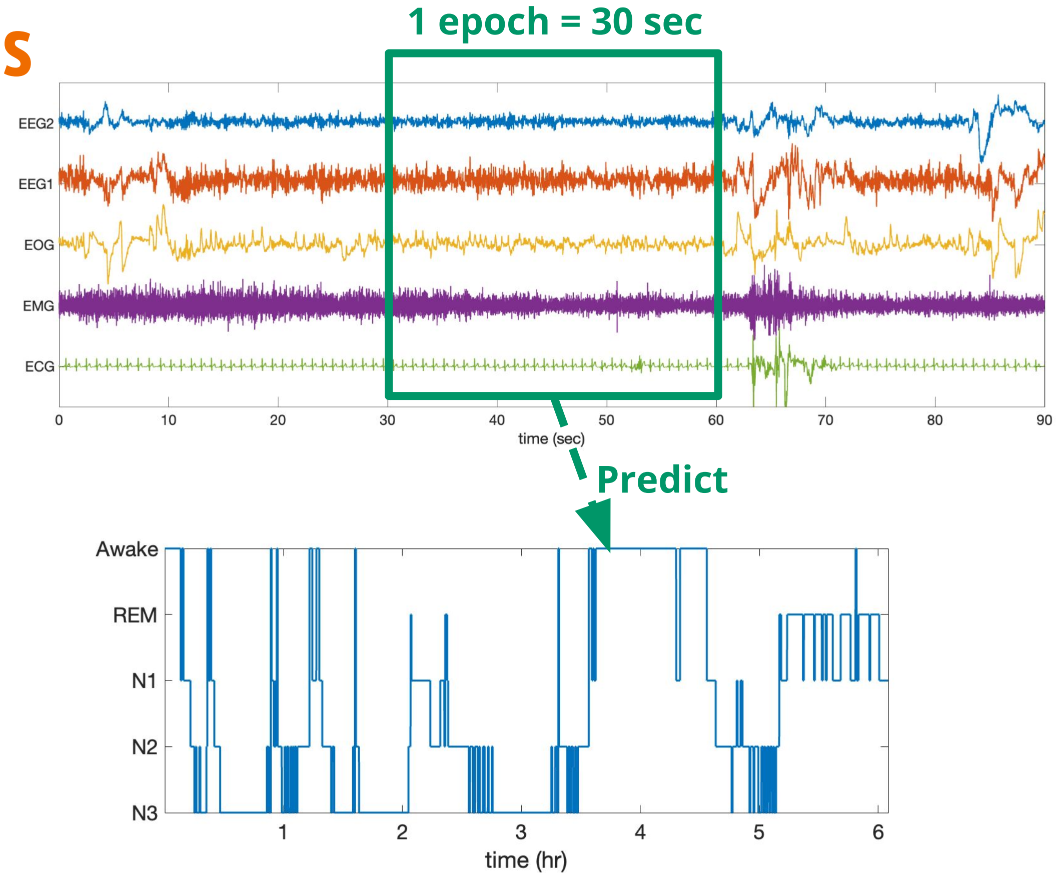
Goal: Why fusion?

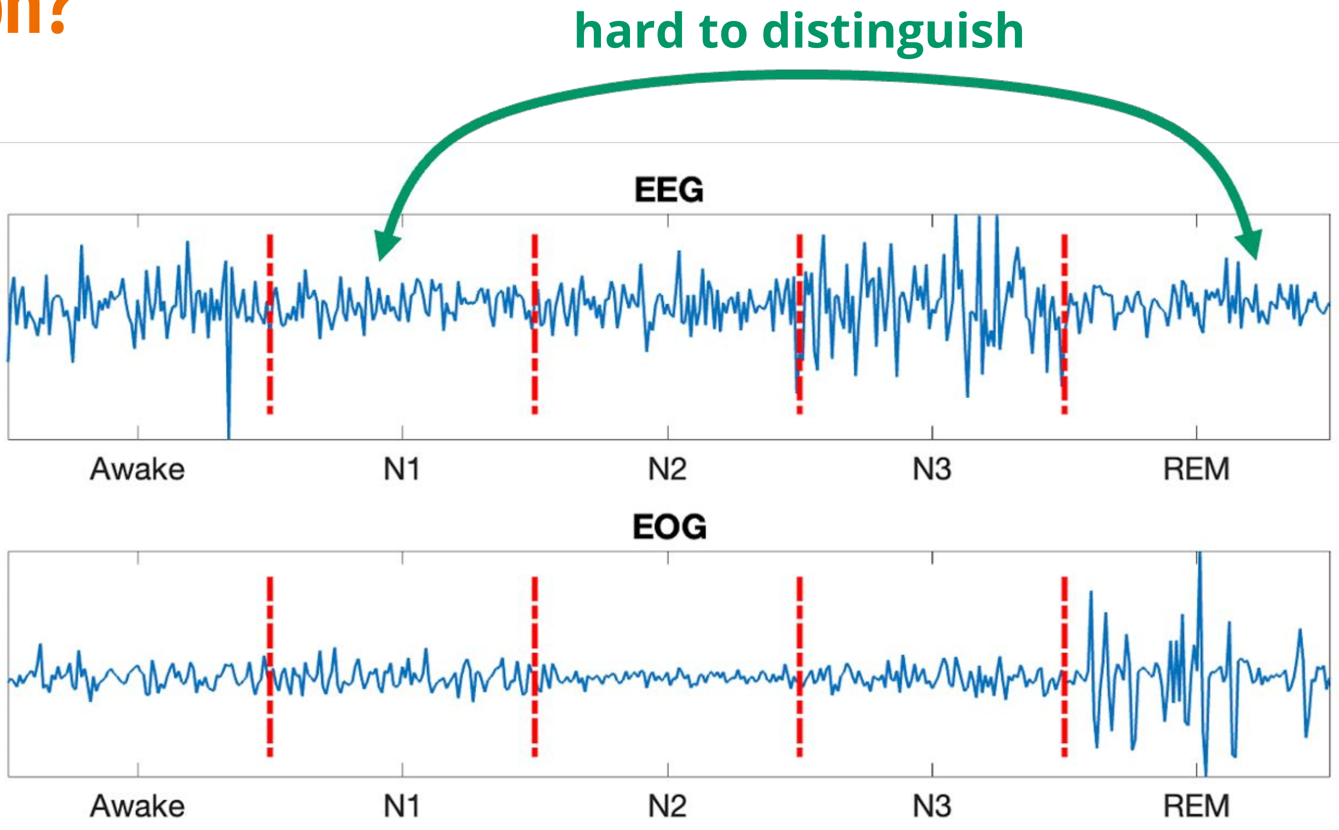


Task: Predict sleep stages

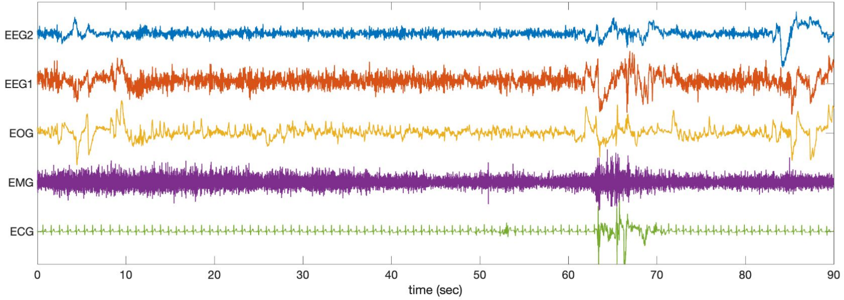




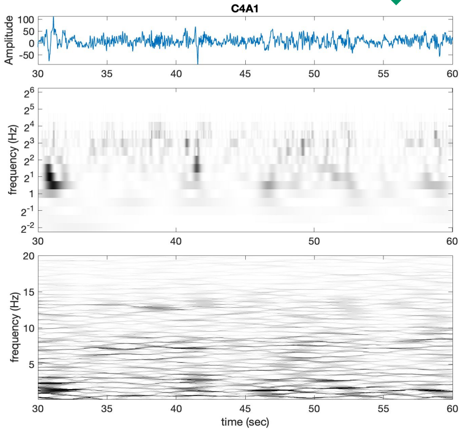
Why fusion?


hard to distinguish
EEG
Awake
N1
N2
N3
REM
EOG
Awake
N1
N2
N3
REM

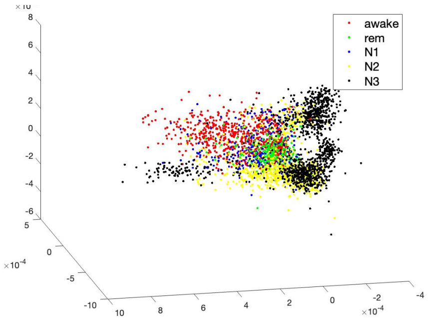
Methodology



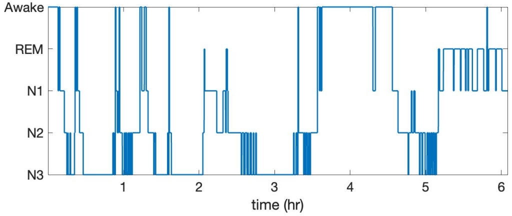
Signal collection: EEG & EOG & EMG



Feature extraction: TFA



Dimension reduction



Predict sleep stages

Please refer to G.-R. Liu, Y.-L. Lo, J Malik, Y.-C. Sheu, H.-T. Wu, Diffuse to fuse EEG spectra -- intrinsic geometry of sleep dynamics for classification, (2018).

Data source

41 patients

29332 epochs

Total: 240+ hours

Mathematics Division
National Center for Theoretical Sciences

Basic diffusion map (DM)

Let $\{x_i\}_{i=1}^n \subset \mathcal{M}^d$ be a dataset, where $\mathcal{M}^d \subset \mathbb{R}^p$. Given a Gaussian kernel k_ϵ with bandwidth ϵ. Let the affinity matrix $W_{ij} = k_\epsilon(x_i, x_j)$. The degree matrix is defined as $D_{ii} = \sum_{j=1}^n W_{ij}$.

Then, the (negative) graph Laplacian operator is defined as

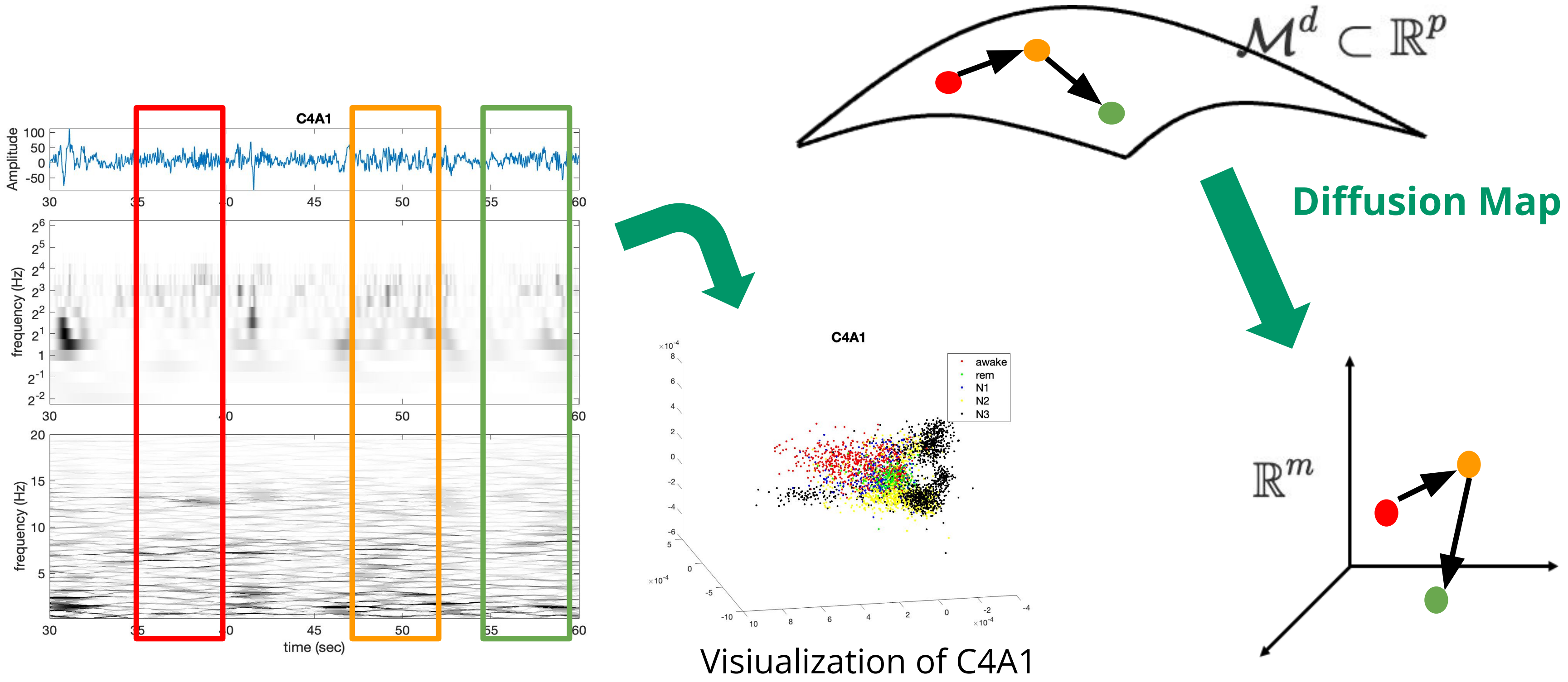
$$L = D^{-1}W - I$$

where $K = D^{-1}W$ is transition matrix

The first m eigenvectors of K are our interests, which embedding the data into lower dimensional space, $\mathbb{R}^m$.

Please refer to R.Coifman & S. Lafon, *Diffusion maps*, (2006).

Recover underlying manifold



Fusion: S+A method

Consider two signals from two sensors. Let degree matrix and affinity matrix $D^{(\ell)}$, $W^{(\ell)}$ define as mentioned where $\ell = 1, 2$ two signals. Define transition matrices $K^{(\ell)} = \left(D^{(\ell)}\right)^{-1} W^{(\ell)}$

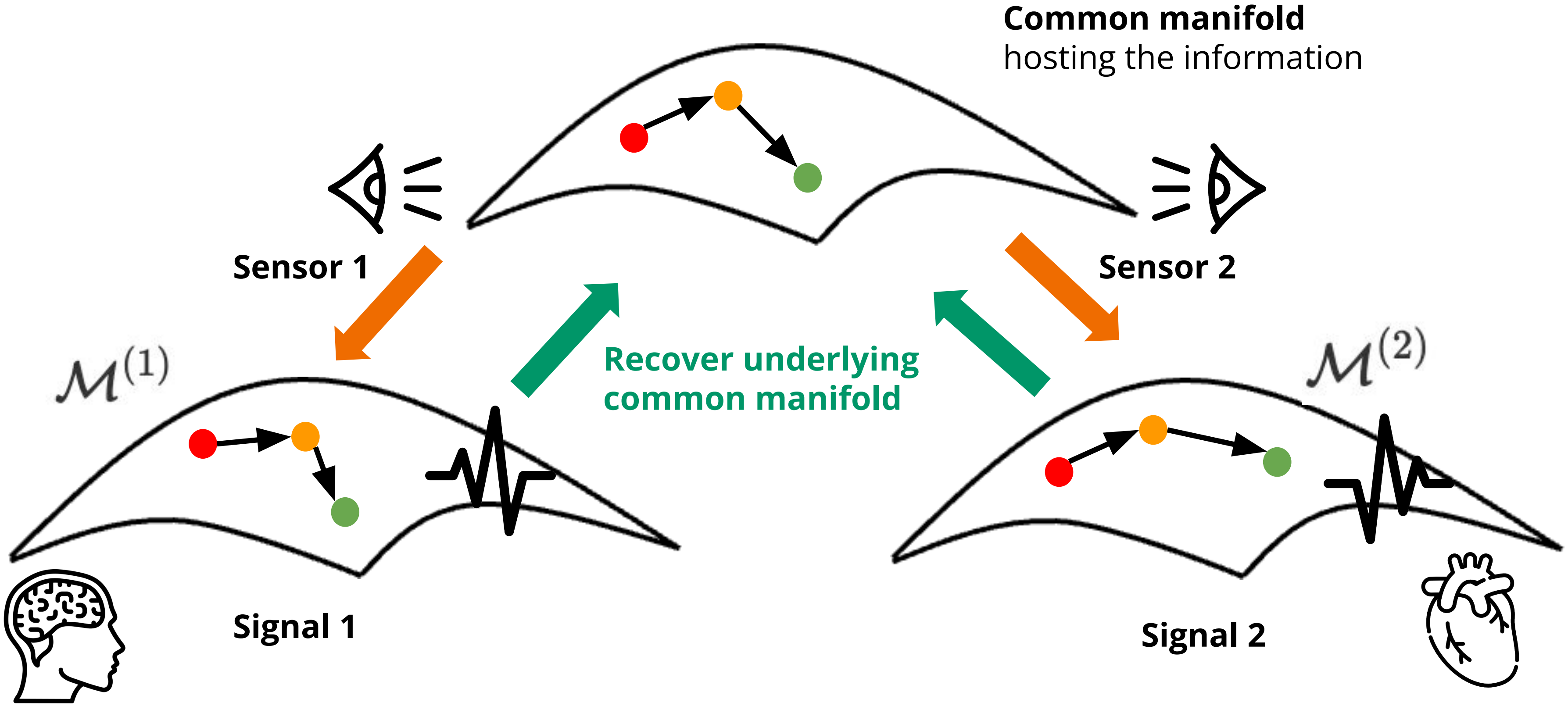
Let $G = K^{(2)} {K^{(1)}}^T$ and $H = K^{(1)} {K^{(2)}}^T$. Define two $n \times n$ matrices

$$\begin{aligned} S &= G + H \\ A &= G - H\,. \end{aligned}$$

In fact, S reveal common structures, and A reveal differences.

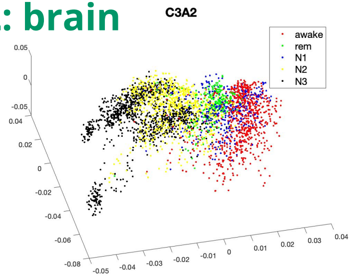
Please refer to T. Shnitzer, M. Ben-Chen, L. Guibas, R. Talmon, H.-T. Wu, *Recovering Hidden Components in Multimodal Data with Composite Diffusion Operators*, (2018).

Interpret S+A method

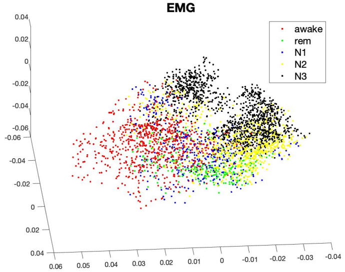


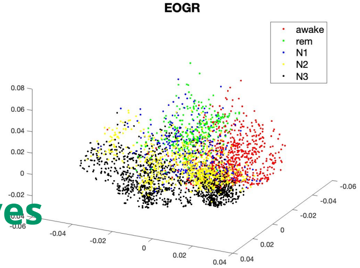
How to fuse 3+ channels

C3A2: brain

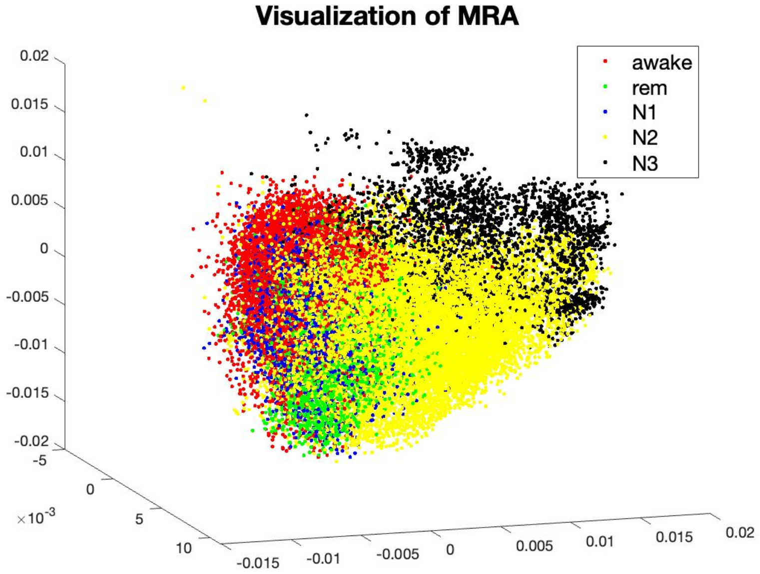


EMG: muscles





EOGR: eyes



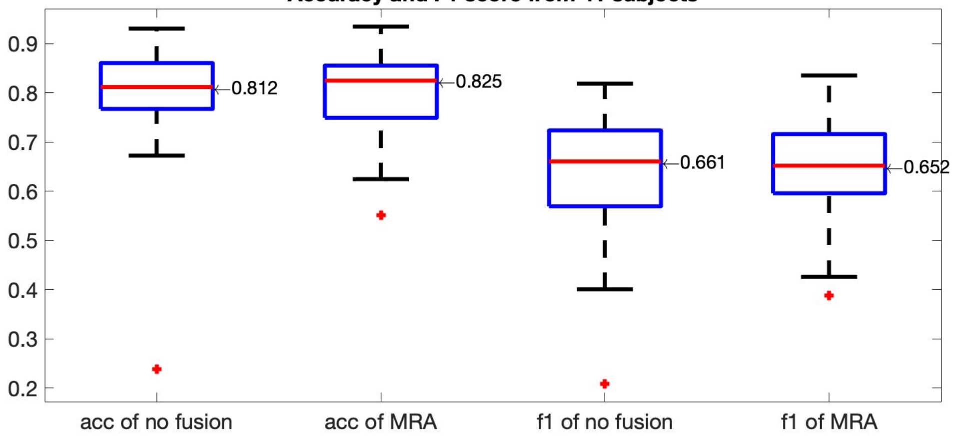
Multi-resolution analysis (MRA)

Please feel free to contact me, if you are interested in this method!

Results

metric: leave one subject out cross validation

	median of acc	median of macro f1	std of acc
No fusion	81.2%	66.1%	0.108
Fusion by MRA	82.5%	65.2%	0.078



No Fusion

		Predict				
		Aw	REM	N1	N2	N3
Target	Aw	82%	4%	9%	5%	1%
	REM	5%	79%	7%	8%	0%
	N1	21%	12%	44%	22%	0%
	N2	4%	2%	4%	86%	4%
	N3	1%	0%	0%	25%	74%

Fusion by MRA

		Predict				
		Aw	REM	N1	N2	N3
Target	Aw	80%	2%	10%	8%	0%
	REM	4%	75%	10%	10%	0%
	N1	20%	9%	49%	22%	0%
	N2	1%	2%	4%	90%	3%
	N3	0%	0%	0%	34%	65%

References

[1] R.Coifman & S. Lafon, *Diffusion maps*, (2006).

[2] G.-R. Liu, Y.-L. Lo, J Malik, Y.-C. Sheu, H.-T. Wu, *Diffuse to fuse EEG spectra -- intrinsic geometry of sleep dynamics for classification*, (2018).

[3] T. Shnitzer, M. Ben-Chen, L. Guibas, R. Talmon, H.-T. Wu, *Recovering Hidden Components in Multimodal Data with Composite Diffusion Operators*, (2018).

[4] A. Singer, H.-T. Wu, *Vector Diffusion Maps and the Connection Laplacian*, (2011).

[5] A. Singer, *From graph to manifold Laplacian: The convergence rate*, (2006).

Thank You