A Unified Model for Structure–function Mapping Based on Eigenmodes

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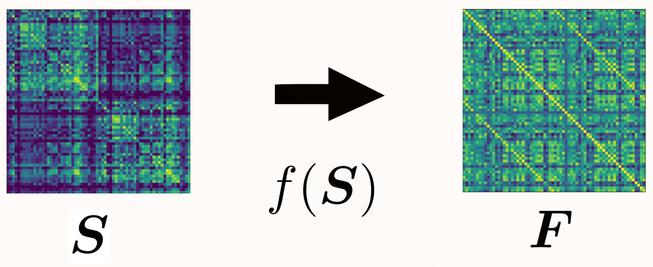
Abstract: Characterizing the connection between brain structure and brain function is essential for understanding how behaviour emerges from the underlying anatomy. A number of studies have shown that the network structure of the white matter shapes functional connectivity, leading to the idea that it should be possible to predict the function given the structure. Here, we show that the mappings based on eigenmodes currently proposed in the literature correspond to particular cases of a more general model that can be used to generate new structure-function mappings.

1 METHODOLOGY

Structure function mapping



$$\underset{f}{\text{minimize}} \sum_{k=1}^{K} \|f(\boldsymbol{S}_k) - \boldsymbol{F}_k\|_{\mathcal{F}}^2$$

Different existing mappings:

Solving the diffusion equation on a graph

$$f(\boldsymbol{L}) = ae^{-\alpha \boldsymbol{L}} + b\boldsymbol{I}$$ [2014a, 2018a]

Graph spectral mapping

$$f(\boldsymbol{S}) = \sum_{m=0}^{M} a_m \boldsymbol{S}^m + \boldsymbol{C}$$ [2016m, 2018b]

Proposed general mapping

$$f(\boldsymbol{A}) = \sum_{n=0}^{N-1} g(\lambda_n) h(\boldsymbol{u}_n) + \boldsymbol{C}$$

$\boldsymbol{A}$ - Transformed structural matrix

$\boldsymbol{A} = \nabla^2 \boldsymbol{S}$	Laplace
$\boldsymbol{A} = \boldsymbol{S}$	Identity

$h(\boldsymbol{u}_n)$ - Mapping on eigenvectors

$h(\boldsymbol{u}_n) = \boldsymbol{R}\boldsymbol{u}_n\boldsymbol{u}_n^T\boldsymbol{R}^T$	Rotation
$h(\boldsymbol{u}_n) = \boldsymbol{u}_n\boldsymbol{u}_n^T$	Identity
$h(\boldsymbol{u}_n) = \boldsymbol{q}_n\boldsymbol{q}_n^T$	Fitted

$g(\lambda_n)$ - Mapping on eigenvalues

$g(\lambda_n) = \sum_{m=0}^{M} a_m \lambda_n^m$	Polynomial
$g(\lambda_n) = e^{-\alpha\lambda}$	Exponential

$\boldsymbol{C}$ - Constant offset

$\boldsymbol{C} = \boldsymbol{I}$	Identity
$\boldsymbol{C} = 0$	Zero
$\boldsymbol{C} = \bar{\boldsymbol{F}}$	Mean

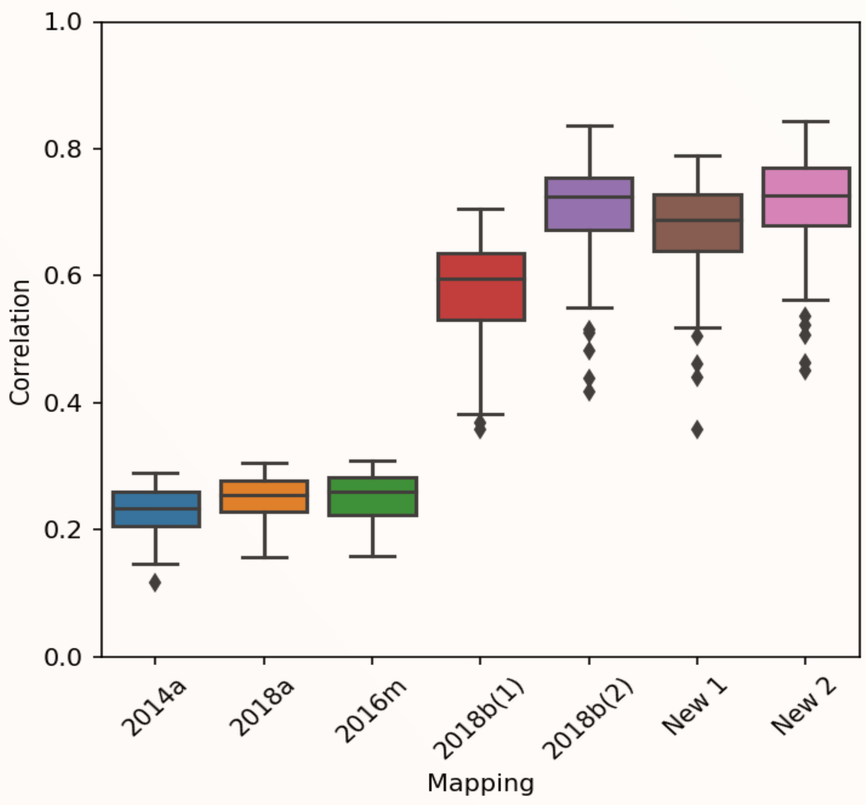
2 RESULTS

By selecting the transform, eigenvalue mapping, eigenvector mapping, and the constant our model can correspond to previously proposed mappings.

It can also generate new mappings by combining features of previous mappings.

Mapping	Transform	Eigenvalues	Eigenvectors	Constant
2014a	Laplacian	Exponential	Identity	Zero
2018a	Laplacian	Exponential	Identity	Identity
2016m	Identity	Polynomial	Identity	Zero
2018b (1)	Identity	Polynomial	Fitted	Zero
2018b (2)	Identity	Polynomial	Rotation	Zero
New 1	Laplacian	Polynomial	Fitted	Zero
New 2	Identity	Polynomial	Fitted	Mean

Correlation between predicted and true functional connectome on 40 subjects of the Human Connectome Project



3 CONCLUSIONS

For specific choices of parameters, our model reduces to previously proposed models and yields comparable results.

By allowing to choose the eigenvalue and eigenvector mapping independently, our models can also produce novel mapping.

References

[2014a] F. Abdelnour, H. U. Voss, and A. Raj. Network diffusion accurately models the relationship between structural and functional brain connectivity networks. NeuroImage, 90:335–347, 2014.
[2016m] J. Meier, P. Tewarie, A. Hillebrand, L. Douw, B. W. van Dijsk, S. M. Stufflebeam, and P. Van Mieghem. A mapping between structural and functional brain networks. Brain Connectivity, 6(4):298–311, 2016.
[2018a] F. Abdelnour, M. Dayan, O. Devinsky, T. Thesen, and A. Raj. Functional brain connectivity is predictable from anatomic network's Laplacian eigen-structure. NeuroImage, 172:728–739, 2018.
[2018b] C. O. Becker, S. Pequito, G. J. Pappas, M. B. Miller, S. T. Grafton, D. S. Bassett, and V. M. Preciado. Spectral mapping of brain functional connectivity from diffusion imaging. Scientific Reports, 8(1411), 2018.

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