Data-Driven Reconstruction of Brain Network Dynamics from Short and Noisy Observations

Deniz Eroglu[1,2]

[1]Kadir Has University, Istanbul, Turkey, [2]Imperial College London, London, United Kingdom

Reconstructing network dynamics from data is fundamentally challenging in regimes characterized by short observations, noise, and weakly coupled chaotic behavior. In such settings, correlation-based methods fail due to the rapid decay of dynamical information. We present a data-driven framework that exploits stochastic fluctuations as signal and combines sparse model recovery with dynamical systems insights to infer both interaction topology and effective dynamics without prior knowledge of the system. Using reduced representations, particularly phase-based descriptions, we render the inverse problem tractable while preserving the mechanisms underlying critical transitions. We demonstrate accurate reconstruction in synthetic neuronal networks and applicability to experimental neocortex recordings. The resulting models enable prediction of critical transitions beyond the training regime, offering a principled approach to analyzing high-dimensional biological systems.