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Going Beyond the Mean Connectivity: How Much Do We Lose by Ignoring Local Motifs?

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A key concern in both neuroscience and machine learning is how the connectivity features of networks drive dynamics and computation in biological and artificial neural networks. Previous research has followed two complementary approaches to quantify the structure in connectivity: either from the perspective of biological experiments by characterizing the local statistics of connectivity motifs between small groups of neurons [1-5]; or from the perspective of artificial neural networks by leveraging the network-wide low-rank patterns of connectivity that influence the resulting low-dimensional dynamics [6-9].

Both approaches point to mechanisms by means of which the network connectivity offers a degree of control over the space of activity patterns and the network dynamics. However, there has not been much exploration done on the direct relationships between these two, thus it is still not apparent how local connectivity statistics relate to the global connectivity structure and affect the network dynamics.

To bridge this gap, here we develop an analytical method for mapping locally-defined biological connectivity statistics onto an approximate global low-rank structure [10]. Our method rests on approximating the global connectivity matrix using dominant eigenvectors, which we compute using perturbation theory for random matrices. This approach demonstrates that multi-population networks defined from local connectivity statistics for which the central limit theorem holds can be approximated by low-rank connectivity with Gaussian-mixture statistics. We specifically apply this method to excitatory-inhibitory networks consisting of multiple interneuron populations. Furthermore, we demonstrate that it produces accurate predictions for low-dimensional dynamics, the balancing and competing between network excitation and inhibition, and statistics of population activity.

All in all, our approach allows us to disentangle the effects of mean connectivity and multiple types of second-order motifs on global recurrent feedback and feedforward propagation, providing an intuitive picture of how local connectivity shapes global network dynamics.

References:

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