Nonlinear control of biological dynamical systems

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Abstract

Networks in nature regularly exhibit dynamics that are difficult to characterize and control due to their nonlinear nature, stochasticity, and use of obscure control signals. These systems are often marked by low-dimensional dynamics, multiple stable fixed points or attractors, and outputs that are generated from nonlocalized network activity. We develop a procedure for characterizing high-dimensional network systems with transparent, low-dimensional models and controlling them with nonlinear control signals. After using the SINDy algorithm to fit a low-dimensional model to our data, we use bifurcation theory to find collections of constant control signals that will produce the desired objective path and then project the control signals back to the original network space. We first illustrate our nonlinear control procedure on established bistable, low-dimensional biological systems, showing how control signals are found that generate switches between the fixed points. We demonstrate our control procedure for high-dimensional systems on random high-dimensional networks and Hopfield networks — a model for memory in humans.