Trajectory Piecewise-Linear Model Order Reduction for Neural Mass Modeling

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ABSTRACT

Model order reduction (MOR) methods approximate the input-output relationship of high-dimensional dynamical systems using less complex systems. MOR works best with linear systems but a method for reducing weakly nonlinear systems also exists. The established approaches of using linear algebraic methods for linear systems and Taylor series expansions spanning higher order derivatives for weakly nonlinear systems do not work well for strongly nonlinear systems.

The trajectory piecewise-linear (TPWL) method reduces the computational costs of the dynamics of a nonlinear system. It does this by partitioning the state space into discrete regions of reduced linear models. The reduced linear models are generated along a trajectory through the state space of the full nonlinear system. TPWL simulates the full system's nonlinear output using the weighted sum of nearby reduced models.

Recently, neural mass models have grown in popularity as a means of simulating neural firing rates. Neural mass models represent the activation dynamics of small brain regions that can be connected together in order to simulate large networks of brain regions. The dynamics of these models are chaotic, highly nonlinear, and strongly coupled making them a challenge for MOR.

This thesis details an implementation of TPWL for simple neural mass models at small time scales that yields reductions in simulation time and state space dimensionality. In particular it is noted that the full nonlinear system is more efficient to compute at small simulation times but by approximately 0.11 seconds and longer of simulation time, the TPWL method overtakes it in computational speed. Outstanding challenges to MOR for neural mass models and future work are also discussed.