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Interacting Particle Systems on Networks: joint inference of the network and the interaction kernel

Modeling multi-agent systems on networks is a fundamental challenge in a wide variety of disciplines. We jointly infer the weight matrix of the network and the interaction kernel, which determine respectively which agents interact with which others and the rules of such interactions from data consisting of multiple trajectories. The estimator we propose leads naturally to a non-convex optimization problem, and we investigate two approaches for its solution: one is based on the alternating least squares (ALS) algorithm; another is based on a new algorithm named operator regression with alternating least squares (ORALS). Both algorithms are scalable to large ensembles of data trajectories. We establish coercivity conditions guaranteeing identifiability and well-posedness. The ALS algorithm appears statistically efficient and robust even in the small data regime but lacks performance and convergence guarantees. The ORALS estimator is consistent and asymptotically normal under a coercivity condition. We conduct several numerical experiments ranging from Kuramoto particle systems on networks to opinion dynamics in leader-follower models.