High-dimensional Stochastic Dynamics on Diverse Network Topologies

Project Abstract

The overall goal of the proposed research program is to develop foundational theory for a general class of interacting particle systems and multi-agent (cooperative and non-cooperative) games on realistic but tractable network topologies, including those with heterogeneous (dense and sparse) connectivity structures, with possibly non-Markovian dynamics that may be either diffusive or of jump type. The project aims to forge a new field of inquiry into a systematic study of the effect of network topology on not only equilibrium behavior and phase transitions and large deviations behavior, but also transient phenomena such as oscillatory behavior, which although of great importance in applications, are currently poorly understood at a rigorous mathematical level. The project will also entail the analysis and development of neuromorphic learning algorithms, which are special examples of processes with local interactions. A third thrust of the program includes the development of rough paths analysis for both interacting diffusions on graphs and constrained diffusions, and the use of the signature from rough paths analysis to study stochastic optimization and prediction under model uncertainty. Throughout the course of the project, specific applications of the general theory will be investigated. Interacting stochastic processes arise as models in a variety of applications including distributed computing, opinion dynamics, neuronal spiking, neural network dynamics, epidemiological models of the spread of diseases. Further, the understanding and prediction of the behavior of strategic multi-agent systems such as sensor networks, robotic systems, etc., is of critical interest to DoD. Thus, the theoretical and computational frameworks developed could have far-reaching consequences, both leading to the development of fundamental new mathematical techniques that would be more broadly applicable in other contexts, as well as having the potential to transform our understanding of fundamental phenomena in several scientific and engineering domains. The proposal will also result in the rigorous mathematical training of several post-doctoral scientists and graduate students, as well as supervision of undergraduate student projects. The project will also involve collaborations with scientists that have synergistic research interests at the Flatiron Institute and IBM's Thomas J. Watson Research Center.

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