Toward Theory-Grounded AI Solvers and Controllers with Stable, Robust, and Accurate Approximations

Hossein Matin

Amherst College, USA

As dynamical systems governed by ODEs and PDEs grow increasingly complex-especially in high-dimensional settings, AI-based solvers have emerged as powerful tools to address these challenges. In this talk, I will first present the Neural Finite Volume Method, comparing its solution accuracy against traditional finite volume schemes. I will also introduce a refined variant of this method, demonstrating that its performance is competitive with the Discontinuous Galerkin (DG) formulation of the Finite Element Method (FEM). Furthermore, I will discuss some of the theoretical results on the approximation error of the proposed methods. If time permits, I will also explore a novel mathematical model for the control of conservation laws, with a particular focus on applications in traffic flow theory. I will show how reinforcement learning (RL)-based optimal control can effectively capture complex wave interactions and learn sophisticated control behaviors. Importantly, I will present a theoretical framework that significantly narrows the feasible control space, thereby reducing the exploration required for finding optimal solutions. Several numerical studies will be provided to illustrate the efficiency and performance of the learned control strategies

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