COMPUTATIONAL RESEARCH in BOSTON and BEYOND SEMINAR

Physics-assisted machine-learning models in fluid mechanics and agent-based systems

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ABSTRACT:

The heart of research in engineering entails developing predictive dynamical equations from observations. For instance, traditional modelling approaches involve developing constitutive equations from experiments in material science or developing subgrid scale models for coarse-grained equations in fluid dynamics, as these systems require detailed simulations that can be computationally expensive. Modern data-driven and ML techniques can also be used to discover these equations and deduce reduced order models for nominally infinite dimensional dynamical systems (PDEs) or stochastic (SDEs), which capture the physics well. We can even bypass these equations and instead, predict the desired dynamics in a fully data-driven manner.

In this talk, I will focus first on a fluid system with PDE dynamics, namely thin films flowing down an inclined plane and exhibiting spatio-temporal wave patterns. And second, on SDEs arising in agent-based models of a population of interacting agents in a stock market, with behaviors similar to disease transmission in the field of epidemics. In the first topic, I will show how to develop reduced order models and learn PDEs to predict the amplitude of the wave directly from data, as well as a new approach to recover the full velocity field from partial observations of the amplitude of the wave. For the second problem, I will show how we can use these techniques to learn the effective Langevin-type SDE that governs the behavior of the distribution of agents close to a tipping point where the distributions becomes unstable. The developed models are more accurate and have wider range of applicability than traditional analytically derived models.

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