Graduate Student Research Seminar

Fall 2023

Controlled density transport in nonlinear systems with applications in Stokes flows and uncertain control systems

Jake Buzhardt (PhD student)

Advisor: Dr. Phanindra Tallapragada

Monday, September 18th

3:00 pm (EST) – 132 Fluor Daniel Building

Abstract

The controlled transport of groups or ensembles of states of a dynamical system has many engineering applications, including motion planning and robot navigation in uncertain environments, mixing and manipulation of fluid particles, control of multi-agent systems, and uncertainty quantification in complex systems. We consider the problem of transporting a density of states from an initial state distribution to a desired final distribution through a dynamical system with actuation. We consider two models of the density transport dynamics: (1) a data-driven method based on finite-dimensional approximations of the Perron-Frobenius operators associated with the drift and control vector fields of the system and (2) a model-based method based on polynomial chaos expansions, where the system dynamics are expanded in orthogonal polynomials of the uncertain quantities. Using these approximations, the density transport problem can be expressed as an optimal control problem in a higher dimensional, lifted state, which we solve using differential dynamic programming, an iterative trajectory optimization scheme. As a test-case, we apply these methods to the problem of steering distributions of fluid particles in a Stokes flow to a desired final distribution in a fixed, finite time by controlling the torques of a group of micro-rotors in the flow. We study cases of fixed rotors, where only the rotor strengths are controlled, as well as cases where both the strengths and translational velocities of the rotors are controlled. We analyze the benefits of using multiple rotors as well as the flow structures associated with the flow field generated by the optimal control.

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