

UNIVERSITY of HOUSTON

Department of Mathematics

Scientific Computing Seminar

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Fast Algorithms for Inverse Transport Problems

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1 PM- 2 PM
Room 646 PGH

Abstract: We explore work on efficient numerical methods for large-scale PDE-constrained optimization problems governed by transport equations. Our focus is on designing high-performance algorithms and computational kernels that enable fast solution of challenging inverse transport problems.

Our recent work centers on the computation of diffeomorphic transport maps that match image intensities or densities across datasets. We consider several model formulations that impose PDE constraints of varying complexity, including incompressible and near-incompressible flows, mass- and intensity-preserving transport, and geodesic equations on the diffeomorphism group under right-invariant metrics. These models lead to nonlinear, nonconvex optimization problems with high-dimensional and often ill-conditioned optimality systems.

To address these challenges, we employ adjoint-based first- and second-order optimization algorithms coupled with advanced preconditioning strategies to achieve rapid and robust convergence. Our solvers are implemented in a GPU-accelerated software framework optimized for real-world problem sizes and capable of scaling to hundreds of GPUs on modern heterogeneous architectures. We also explore how to use approximate curvature information of the negative log posterior to efficiently generate estimate how uncertainty propagates through our problem.

We present experiments on synthetic and real datasets to evaluate convergence behavior, accuracy, scalability, and time-to-solution. We also compare different formulations and preconditioners, demonstrating their impact on efficiency, numerical stability, approximation properties, and overall computational throughput.