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FLOW RECONSTRUCTION BY MULTIRESOLUTION OPTIMIZATION OF A DISCRETE LOSS WITH AUTOMATIC DIFFERENTIATION

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ABSTRACT

We present a potent computational method for the solution of inverse problems in fluid mechanics. We consider inverse problems formulated in terms of a deterministic loss function that can accommodate data and regularization terms. We introduce a multigrid decomposition technique that accelerates the convergence of gradient-based methods for optimization problems with parameters on a grid. We incorporate this multigrid technique to the ODIL (Optimizing a DIscrete Loss) framework. The multiresolution ODIL (mODIL) accelerates by an order of magnitude the original formalism and improves the avoidance of local minima. Moreover, mODIL accommodates the use of automatic differentiation for calculating the gradients of the loss function, thus facilitating the implementation of the framework. We demonstrate the capabilities of mODIL on a variety of inverse and flow reconstruction problems: solution reconstruction for the Burgers equation, inferring conductivity from temperature measurements, and inferring the body shape from wake velocity measurements in three dimensions. We also provide a comparative study with the related, popular Physics-Informed Neural Networks (PINN) method. We demonstrate that mODIL provides 200x speedup in terms of iteration number on the lid-driven cavity problem and has orders of magnitude lower computational cost. Our results suggest that mODIL is the fastest and most accurate method for solving 2D and 3D inverse problems in fluid mechanics.