



SISMA

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Toward generative surrogate models of hydrodynamic instabilities and turbulent mixing

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Multi-fluid turbulent flows are very challenging due to their chaotic and transient behaviors, the wide range of spatio-temporal structures they exhibit, and complex mixing effects. Among these flows, those induced by hydrodynamic instabilities such as Rayleigh-Taylor or Richtmyer-Meshkov are of great interest in the study of astrophysical objects and the development of inertial confinement fusion experiments. These systems are determined by a large number of parameters that may be only partially known, and whose influence can be crucial for their understanding and optimization. To help in these two tasks, our work focuses on building modeling and design assistants by leveraging artificial intelligence tools. A key component of this project is the development of effective surrogates with conditional score-based diffusion models. The aim is to faithfully reproduce features and statistics of complex, possibly turbulent flows. In addition, given the nature of modeling and design tasks, the surrogates must be capable of generalizing well. In pursuit of this goal, our mid-term focus is on exploring the benefits of incorporating gradient information and physical constraints into the learning process, drawing on the differentiable codes and adjoint methods developed within our team.