Modeling and Simulations in Fluids
Poster Session Abstracts
Saturday, September 7, 2024

Application of adaptive mesh refinement in the front-tracking method for Rayleigh Taylor fluid instability simulations
James Burton, University of Arkansas

Front-tracking is an adaptive numerical approach that explicitly tracks the interface between distinct mediums as a hypersurface moving through a rectangular grid, providing sharp resolution of the wavefront and preventing unwanted mixing between neighboring cells of different materials. The increased accuracy of front-tracking comes at a computational cost, which can be mitigated through adaptive mesh refinement by refining in areas of complex structures and vorticities, and coarsening in smoother areas. The front-tracking based software library FronTier has been used in validation and verification of turbulence mixing due to hydrodynamic instabilities. A Rayleigh Taylor instability simulation is used as a test-case in implementing the block-structured, adaptive mesh refinement library AMReX to reduce computational costs and increase accuracy in regions with complex mixing structure.

Flow Control Through Shape Optimization of Lagrangian Coherent Structures
Derek Drumm, Worcester Polytechnic Institute

Shape optimization problems arise in fluid dynamics through the need to control internal and external flow properties. We are interested in a problem of passive flow control, where we would like to determine optimal flow obstacles which generate pre-specified Lagrangian Coherent Structures. Utilizing techniques from abstract shape optimization, we show that such optimal obstacles exist, and provide a framework to apply numerical techniques to locate these obstacles. We use a derivative free optimization algorithm to locate these optimal structures in a Navier-Stokes channel flow.

Simulation of RMI using Front Tracking and high order WENO
Ryan Holley, University of Arkansas

We present an increasingly accurate and robust front tracking method for simulating shock-induced turbulent mixing. The two-dimensional shock-driven Richtmyer–Meshkov Instability (RMI) of an air/SF$_6$ interface is studied to understand the dynamics of interface growth. The verification and validation studies help identify discrepancies between single-mode RMI simulations and Collins and Jacobs 2002 shock tube experiments for Mach $M=1.21$. This paper highlights advances in RMI simulations and improvements in small-scale structures within vortex roll-ups using the ninth-order weighted essentially non-oscillatory scheme.

Front Tracking and Its Applications
Xiaolin Li, Stony Brook University

Started by Jim Glimm at Courant Institute of Mathematical Sciences, front tracking method was originally designed to study the fluid interface instabilities such as the Rayleigh-Taylor and Richtmyer Mushkov instabilites. But we have go far and beyond of this agenda. I will show the application of front tracking code to phase transition, fluid structure interaction, parachute simulation, particle tracking in climate and weather study, and even the Black-Schoes equation for American option pricing.

Optimal Sensor Placement for Dynamic Thermal Modelling Using Physics-Informed Neural Networks
Kateryna Morozovska, KTH Royal Institute of Technology

Our work aims at simulating and predicting the temperature conditions inside power components, specifically a power transformer filled with mineral oil using Physics-Informed Neural Networks (PINNs). The predictions obtained are then used to determine the optimal placement for temperature sensors inside the transformer, under the constraint of a limited number of sensors, enabling efficient performance monitoring. The method consists of combining PINNs with Mixed Integer Optimization Programming to obtain the optimal temperature reconstruction inside the transformer. First, we introduce a novel approach for the regularization of the PINN model through physical unit scaling. Then, we extend our PINN model for thermal modelling of power transformers to solve the heat diffusion equation from 1D to 2D space. Finally, we construct an optimal sensor placement model inside the transformer that can be applied to problems in 1d and 2D.

Are the Physics Informed Neural Networks robust enough for data modeling of the breast cancer cell growth?
Widodo Samyono, Jarvis Christian University

Physics Informed Neural Networks (PINNs) present a promising approach for modeling complex biological systems like breast cancer cell growth. Their ability to integrate physical laws and handle limited data makes them particularly appealing in this domain. However, their robustness in accurately predicting tumor behavior remains a subject of ongoing research. This poster will explore the potential and challenges of applying PINNs to breast cancer cell growth modeling. It will discuss the advantages of PINNs, such as incorporating prior knowledge and generalizing well, as well as the challenges associated with modeling tumor complexity and selecting appropriate governing equations. Additionally, it will highlight the importance of data quality and computational considerations in developing robust PINN models for breast cancer research. By presenting current findings and ongoing research directions, this poster will shed light on the potential of PINNs to revolutionize our understanding of tumor growth and contribute to the development of more effective cancer treatments.

Keywords: Physics Informed Neural Networks (PINNs), breast cancer, tumor growth modeling, machine learning, data-driven modeling, physical constraints.