PHYSICAL MATH SEMINAR

A unified constraint formulation of immersed body techniques for coupled fluid-solid motion

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ABSTRACT:

Numerical simulation of moving immersed solid (rigid or deforming) bodies in fluids is now practiced routinely following techniques based on the immersed boundary method, the fictitious domain method, and other related methods. These methods rely on using a background mesh for the fluid equations and tracking the solid body using Lagrangian points. The key idea is to assume that the entire fluid-solid domain is a fluid and then to constrain the fluid within the solid domain to move in accordance with the solid governing equations. *However, what is the strong form of the governing equations that these methods are solving wherein the fluid is extended into the solid domain?* In this talk an extended domain strong form of the governing equations will be presented. The resulting constrained fluid-solid governing equations provide a unified framework for various immersed techniques and are independent of the nature of temporal or spatial discretization schemes. It will be shown that specific choices of time stepping and spatial discretization lead to different techniques reported in literature ranging from specified velocities to freely moving rigid bodies to elastic self-propelling bodies. An extension to simulate Brownian systems by adding thermal fluctuations in the fluid equations via random stress terms (fluctuating hydrodynamics) will be presented. Resolution of long-standing challenges in immersed techniques pertaining to high solid-to-fluid density ratio, leakage through the interface, and internal boundary conditions will be discussed. These techniques have been used in wide ranging applications including aquatic locomotion, underwater vehicles, car aerodynamics, organ physiology (e.g. cardiac flow, esophageal transport, respiratory flows), wave energy convertors, among others.

Bio: Neelesh Patankar received his BS (B.Tech.) in Mechanical Engineering from the Indian Institute of Technology, Bombay (1993) and his doctorate in Mechanical Engineering from the University of Pennsylvania (1997). Following his Ph.D., he was a post-doctoral associate with Prof. Daniel D. Joseph at the University of Minnesota until 2000. He joined the Department of Mechanical Engineering at Northwestern University in 2000 where he is currently a Professor. Neelesh is a Fellow of the American Physical Society. He has received the NSF CAREER award, the International Conference on Multiphase Flow's Junior Award, the Prominent Researcher Award from mFIP, and has been selected to the Defense Science Study Group. Neelesh has been on the Editorial Boards of the Journal of Computational Physics, ASME Journal of Fluids Engineering, and Scientific Reports. He has also received several university-wide teaching awards at Northwestern University including Charles Deering McCormick Teaching Professorship.

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