ME Seminar

From Beating Hearts to Flapping Fins: Insights into Biological Flows Empowered by High-Fidelity Immersed Boundary Methods

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ABSTRACT

The unceasing growth in computational power coupled with the development of new software tools and numerical algorithms is opening up exciting areas for research, discovery and translation at the intersection of computational fluid dynamics and biology. Consider the mammalian heart, which has been sculpted by millions of years of evolution into a flow pump par excellence. During the typical lifetime of a human, the heart will beat over three billion times and pump enough blood to fill sixty Olympic-sized swimming pools. Each of these billions of cardiac cycles is itself a manifestation of a complex and elegant interplay between several distinct physical domains including hemodynamics, electrophysiology, muscle mechanics, flow-induced valves dynamics, acoustics, and biochemistry. In the arena of biolocomotion, fish are known to employ their highly flexible bodies and fins to extract energy from vortices and propel themselves in water with grace and efficiency that is the envy of all engineers. Previous investigations of such problems were often limited by the tools at hand, but modern computational tools are enabling exploration of such multi-physics problems with an unprecedented level of fidelity, precision and realism. In my talk, I will describe projects that exploit the power of high-fidelity sharp-interface immersed boundary methods to address problems ranging from the chemo-fluidics of clot formation in the heart and aeroacoustic sound generation by flying insects, to the hydrodynamic mechanisms that schooling fish may exploit to increase thrust and efficiency.

ABOUT THE SPEAKER

Rajat Mittal is Professor of Mechanical Engineering at the Johns Hopkins University with a secondary appointment in the School of Medicine. Prior to that, he held faculty appointments at the University of Florida and George Washington University. He received his B. Tech. degree from the Indian Institute of Technology at Kanpur in 1989, his M.S degree in Aerospace Engineering from the University of Florida, and his Ph.D. degree in Applied Mechanics from The University of Illinois at Urbana-Champaign, in 1995. From 1995 to 1996, he was a postdoctoral scholar at the Center for Turbulence Research at Stanford University, where is worked on large-eddy simulation and bluff-body wakes. His research interests include computational fluid dynamics, vortex dominated flows, biological fluid dynamics, fluid-structure interaction, and flow control. Rajat is the recipient of the 1996 Francois Frenkiel Award and the 2022 Stanley Corrsin Award from the Division of Fluid Dynamics of the American Physical Society (APS), and the 2006 Lewis Moody as well as 2021 Freeman Scholar Awards from the American Society of Mechanical Engineers (ASME). He is a Fellow of ASME and APS, and an Associate Fellow of the American Institute of Aeronautics and Astronautics. He is an associate editor for the Journal of Computational Physics, Frontiers of Computational Physiology and Medicine, the Journal of Experimental Biology, and the International Journal for Numerical Methods in Biomedical Engineering. Rajat's research on COVID 19, cardiac hemodynamics, competitive swimming and golf, and computational algorithms has also been featured extensively in the public media.

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