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From Wave-Powered Propulsion to Flight with Membrane Wings: Insights Powered by High-Fidelity Immersed Boundary Methods based FSI Simulations

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Abstract : The perpetual advancement in computational capabilities, coupled with the continuous evolution of software tools and numerical algorithms, is creating novel avenues for research, exploration, and application at the nexus of computational fluid and structural mechanics. Fish leverage their remarkably flexible bodies and fins to harness energy from vortices, propelling themselves with an elegance and efficiency that captivates engineers. Bats fly with unparalleled agility and speed by using their flexible membrane wings. Wave-assisted propulsion (WAP) systems, utilizing elastically mounted hydrofoils, convert wave energy into thrust. Each of these problems involves a complex and elegant interplay between fluid dynamics and structural mechanics. Historically, investigations into such phenomena were constrained by available tools, but modern computational advancements now facilitate exploration of these multi-physics challenges with an unprecedented level of fidelity, precision, and realism. In this work, the author will discuss projects that harness the capabilities of high-fidelity sharp-interface immersed boundary methods to address a spectrum of engineering and biological challenges involving fluid-structure interaction.

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