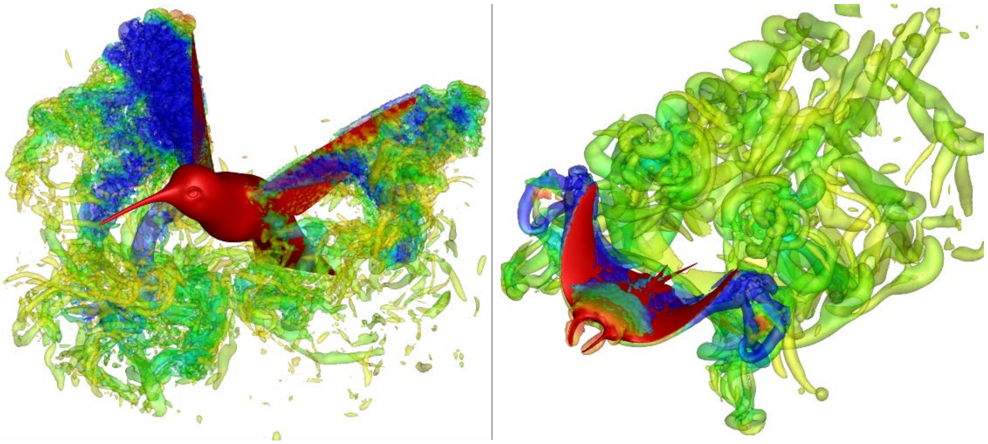

Flow Simulation Research Group

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"Studying the physics and mechanics that underlie the flight and swimming in nature."

The Flow Simulation Research Group focuses on understanding the physics of complex flows of flying and swimming in nature by combining state-of-the-art computational methods, experimental tools, and theoretical fluid dynamics research. Research is driven by the quests to answer questions both from fundamental fluid dynamics problems and from practical applications. Current research in our group involves biological fluid dynamics, insect flights, fish swimming, design of Micro-size UAVs and bio-inspired propulsors, fluid-structure interactions, reduce order modeling, high performance computing, high-speed photogrammetry, direct injection and simulation of small engines, and computational methods for bio-medical applications.

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Bio-Inspired Flight and Micro-size UAVs

We are investigating the underlying principles of aerial locomotion and maneuverability in insects, using both high-speed photogrammetry and flow simulations. This work involves measurement of the free flight of animals and analysis of the obtained flight data using physics-based modeling and different data-mining techniques. The measurement tools quantify the wing flexion and body kinematics of animals in free flight with extraordinary details. A series of analytical and computational methods including quasi-steady modeling of the unsteady flow phenomena, 3D computational flow simulation and analysis, flexible body dynamics and modeling of the coupled dynamics of wings and the body in flapping flight, are employed to provide an integrated approach to understanding the biological fluid dynamics in animal flight. In addition to advancing our knowledge of the fundamentals of flapping flight in nature, the results of our study are applied to analyze, design, measure and optimize the bio-inspired UAV design. Advanced manufacturing technologies are utilized to achieve high aerodynamic performance for remotely piloted aircrafts at tiny size.

Physics of Non-Traditional Propulsion in Water

We are investigating the underlying principles of high-speed and high-efficiency in fish swimming. This work involves quantification of the body/fin flexibility and kinematics in animal swimming, flow simulations, and exploration of hydrodynamic mechanisms. Teaming with specialists in biology, structure and design, experimental fluid dynamics, we aim to develop significant advances in the basic understanding of fast, efficient propulsion inspired by biology by coupling fluid dynamics with structural dynamics in an integrated platform of experiment, computation and analysis.

Small Engine-Direct Injection Engine Technologies

Direct injection engines are internal combustion engines with spark ignition of fuel directly in to the chamber. They are a new trend of engines, in which the amount of fuel injected in to the combustion chamber can be moderated according to the power requirement. The fuel and air mixture is controlled in the direct injection engine as per the requirement. The mixture can be a rich mixture with more fuel than the available oxygen or lean with more oxygen than required to burn the injected fuel for high and low power output requirements. We are working on computational modeling of direct injection on various engines such as Solstice, Rotax, and Wankel rotary engines.

RECENT RESEARCH DEVELOPMENTS

- Highly efficient high-fidelity 3-D immersed boundary Navier-Stokes DNS/LES solver for studying flows with multiple moving bodies.
- Proper Orthogonal Decomposition based tools for analyzing kinematics, flexibility and morphometrics of deformable structures.
- Visualization tools for understanding 3D unsteady flows and vortex dynamics in bio-inspired locomotion.

RECENT GRANTS

- ONR-MURI: Bio-Inspired Flexible Propulsors for Fast, Efficient Swimming: What Physics Are We Missing?
- NSF - CAREER: An Integrated Study of Biological Fluid Dynamics in Nature
- AFOSR - Physics-based Morphology Analysis and Optimization of Flexible Flapping Wings

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