PROGRESS TOWARD THE NON-INVASIVE DETERMINATION OF ANIMAL SWIMMING AND FEEDING DYNAMICS

John O. Dabiri

Graduate Aeronautical Laboratories and Bioengineering
California Institute of Technology
Pasadena, CA 91125, USA
jodabiri@caltech.edu

The design of next-generation propulsion systems is being aided by the recent increase in translational research related to the mechanophysiology of animal swimming and flying. However, progress has been limited by our inability to quantitatively study animal locomotion non-invasively. Such capabilities will not only support basic research in the field, but will also facilitate real-time, field performance evaluations of the resulting bio-inspired vehicle designs.

Despite the increasing popularity of laser velocimetry techniques such as DPIV for the non-invasive quantification of fluid flows created by biological propulsion systems, a complementary analytical framework in which to interpret those results is currently lacking. We describe recent efforts toward the establishment of such a methodology, demonstrating the results in experimental studies of jellyfish swimming and feeding. The incorporation of feeding dynamics in bio-inspired propulsion studies is introduced here, and allows for the extraction of design principles related to both traditional thrust goals as well as fluid-based sensing capabilities.

The foundation of the present thrust and sensing studies is the transition to a Lagrangian analysis of the measured fluid flows. While this perspective is not directly compatible with prevalent Eulerian measurement techniques such as DPIV, recent work by the author and coworkers has demonstrated the utility of Lagrangian methods from dynamical systems for the quantitative visualization and interpretation of data obtained from DPIV measurements [1]. Concurrently, the concept of wake vortex added-mass has been refined and shown to be useful for determining the contribution of the unsteady fluid pressure field to the resulting locomotive dynamics, an effect neglected in traditional DPIV analyses [2, 3]. Together these tools provide a general framework for the empirical evaluation of animal locomotion and also portend the possibility of refining bio-inspired propulsion designs according to quantitative comparisons with animal systems.

As an example, we describe measurements of fast escape-swimming in *Aglantha digitale* jellyfish and flow sampling behaviors of *Aurelia aurita* jellyfish, in order to highlight discovered design principles that can be applied in engineered systems. It is shown that a Lagrangian perspective is not only more efficient than traditional Eulerian approaches in the extraction of important fluid dynamics, but in some cases it is successful where Eulerian approaches fail altogether.

References

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Keywords: swimming, flying, vortex