PHYSICAL MATHEMATICS SEMINAR

Low-dimensional coherent structures in unsteady fluids: dynamical systems, model-reduction, and closed-loop feedback control

STEVEN BRUNTON

University of Washington

ABSTRACT:

Unsteady fluid flows are ubiquitous in modern engineering and in the life sciences. These flows are modeled by an infinite-dimensional, nonlinear dynamical system, resulting in discretized equations with millions or billions of degrees of freedom. However, many complex flows exhibit low-dimensional behavior that is mediated by coherent structures (for instance, the laminar vortex shedding past a wing). We address two challenging and exciting problems: 1) controlling the unsteady aerodynamic forces and moments on a small-scale wing, and 2) predicting the transport of particles through the velocity field induced by an unsteady fluid (e.g., mixing, combustion, pollution, etc.).

The first part of this work focuses on obtaining reduced-order unsteady aerodynamic models of a pitching and plunging wing at low Reynolds number (Re=100 and Re=65,000). In particular, balanced input/output models are constructed based on numerical simulations and wind-tunnel measurements. Control laws are then developed to robustly track an aggressive reference lift trajectory despite noisy sensor measurements and gust disturbances.

The second part of this work investigates reduced-order models of the flow map for particles advected through an unsteady fluid velocity field. By composing multiple short-time flow maps, we are able to construct accurate long-time flow maps in a computationally flexible and efficient way, despite significant chaotic stretching and folding of trajectories. This method has implications for the propagation of uncertainty using generalized polynomial chaos (gPC), the computation of Lagrangian coherent structures (LCS), and the Perron-Frobenius operator. These ideas are illustrated on numerical examples.

TUESDAY, APRIL 2, 2013
2:30 PM
Building 56, Room 180

Reception following in Building 2, Room 290
(Math Dept. Common Room)

http://math.mit.edu/pms

Massachusetts Institute of Technology