Dynamics of Insect Flight and Maple Seeds

Z. Jane Wang
Sibley School of Mechanical and Aerospace Engineering and Department of Physics, Cornell University, Ithaca, NY 14853
(Dated: January 9, 2012)

Animals, small and large, must solve the problem of locomotion in order to survive. Insects offer some of the most ingenious solutions to locomotion. To understand its flight, our approach is to 'take an insect apart' and then put different pieces back together. We start from the outer scale, where insect wings are immersed in fluids, and gradually work toward inner scale, where the wings are driven by the muscles, and the muscles are controlled by insect's brain.

In this talk, I will describe two of our recent work focusing on the analyses of 3D flight dynamics.

The Timing in the Control of Flapping Flight

Song Chang and Z. Jane Wang (manuscript in preparation)

Flapping flight of insects is intrinsically unstable. Insects actively control their wings to maintain the stability in steady flight as well as to execute maneuvers. Using 3D dynamic simulation of flapping flight, we analyze the stability of periodic states associated with the limit cycles of the dynamical system. We construct a discrete time-delayed linear controller and examine the controllability condition. We show that the controller's effectiveness depends in a subtle manner on the timing of the sensory measurement combined with the delay time in actuation. The control strategies depend on the coupling of sensory feedback loops of insects and the underlying dynamics of the 3D flapping flight.

The kinematics of falling maple seeds and the initial transition to a helical motion

Song Chang and Z. Jane Wang (Nonlinearity 2012, Cover Article)

A maple seed falls in a characteristic helical motion. A crude analogy with auto-rotation of a wind-turbine suggests that the torque due to the aerodynamic force would initiate the gyration of the wing. We were therefore surprised that a seed with torn wings gyrate in a similar manner as a full-winged seed. In fact, a seed with only a sliver of leading edge can still gyrate. The gyrating motion appears not to depend on the aerodynamic force. If, on the other hand, the aerodynamic force is completely absent, a seed would fall like a rock in a vaccum.

To investigate how the seed reaches its steady helical motion, we use a high speed digital camera to film the intact and cut seeds at 1000Hz. With a mirror, the camera records two views simultaneously so that we can extract the 3D kinematics of the wing. We tracked the center of mass and quantified the descending speed, the azimuthal rotation, and the cone angle for seeds with different shapes of the wing. We found that the initial transition from rest to a steady gyration occurs in three steps: a tumble about the span wise direction, followed by a tilt toward the vertical axis, and an opening of the cone angle before settling into a steady state. We offer a new explanation for the cause of the auto-gyration that accounts for these three stages.