Towards Virtual Testing of Flapping Flight

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Abstract

Flapping flight has undoubtedly played a significant role in many of the aeronautical engineering achievements in the past several centuries. Flapping motions of wings/fins are used by animals (such as birds, insects and bats) to generate lift or thrust to keep them aloft in the surrounding fluid. Researches in this area are not only motivated by the fundamental interest of understanding the mechanism of flapping flight, but also the development of Micro Air Vehicles (MAVs) based on biomimetics.

In this lecture, we will address our efforts towards both experimental studies and virtual testing of flapping flight with our High End Digital Prototyping (HEDP) system. The aim of our research is to use physical and biological models to drive the engineering design of these vehicles.

Firstly, two types of flapping-wing Unmanned Air Vehicles (UAVs) with spatial four-bar drive mechanism will be presented, including the wind tunnel experiment and prototype flight test results. Secondly, various computation approaches have been adopted to simulate the flapping motions, including traditional moving mesh techniques based on Arbitrary Lagrangian Eulerian (ALE) formulation, and Lattice Boltzmann method with immersed boundary methods. For a single wing-system, we have investigated the influences of various parameters on both the symmetric flapping and asymmetric flapping with bird-like or turtle-like flapping mode. For a tandem wing system, we have investigated the interaction between the hind wing and the vortex shedding off the fore wing and learned how to utilize the flow mechanism to achieve better aerodynamic performances. Moreover, Dynamic Mode Decomposition (DMD) algorithm has been adopted to reveal the underlying physics due to its capability and accuracy in analyzing the complex transient systems. Finally, the flight control design of a dragonfly-like Flapping Wing Micro Aerial Vehicle (FWMAV) is presented, which has incorporated a Linear-Quadratic Regulator (LQR) method and an Iterative Learning Tuning (ILT).

In general, we expect that these virtual testing by computational simulations and flight control can drive the design of our next generation flapping-wing UAVs in the future.

Keywords: virtual flight test, flapping flight, computational simulations, flight control.