Micro Flapping-Wing Flyer (MFWF)

An Introduction

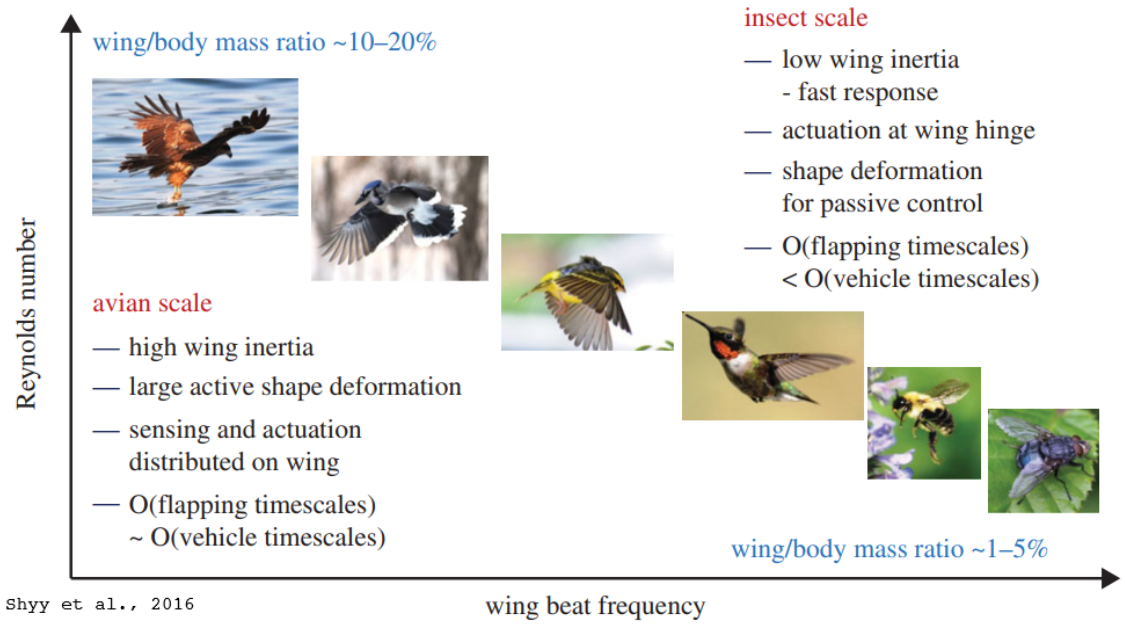
Prof. Fidel Khouli [1], Prof. Jason Etele[1], Prof. Andrei Artemev[1]

[1]Department of Mechanical and Aerospace Engineering, Carleton University

March , 2021

Why Flapping-Wing Flight ?

Motivational Examples from Nature



Arranged Examples of Biological Flapping-Wing Flyers

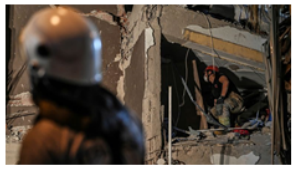
- In nature, there are $\sim$ million species of flying insects and $\sim$ 13,000 warm blooded vertebrates (including mammals and birds) that rely on flapping-wings for flight.
- Natural convergence towards flapping-wing flight! Scientist realized there must be advantages to this mode of flight compared to fixed-wing and rotary ones.

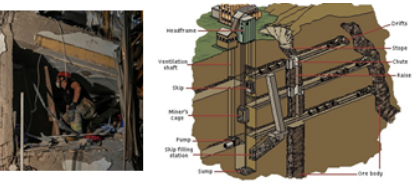
Why Flapping-Wing Flight ?

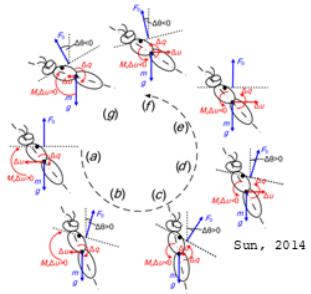
Advantages and Potential Applications

MFWF
(Micro Flapping-Wing Flyer)

1. Given their potential for subcompact sizes, they can navigate in environments that are inaccessible to other Unmanned Aerial Systems (UASs), such as in dense foliage, small shafts and debris-blocked passageways.
2. They can perform complex manoeuvres that are not possible with other aerial platforms.
3. They are environmentally friendly due to their lightweight, the high efficiency afforded by flapping-wing flight and the amenability of some of their components to be manufactured from bio-degradable materials.
4. They possess the element of the stealth for surveillance and monitoring.
5. New potential advantages are still being identified such as the recently found gust-mitigating potential of flapping-wing flight.







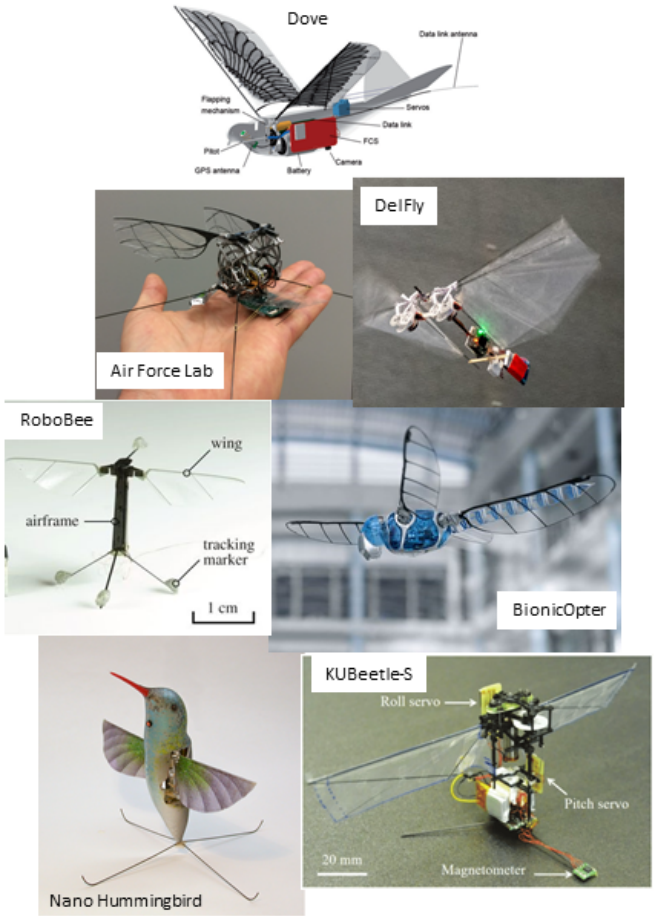
MFWF Carleton UNIVERSITY

Research and Development in MFWF

MFWF
(Micro Flapping-Wing Flyer)

Select Examples

- Over the past two decades there were numerous attempts to develop and deploy tailed and tailless MFWF with the latter being more challenging.
- Efforts are continuing but engineering challenges and open research questions remain: wing aeroelasticity, nonlinear aerodynamics, stability and control, weight constraints, flapping mechanism, power management, etc.



Project Principal Goal & Challenges

MFWF
(Micro Flapping-Wing Flyer)

Principal Goal

The *principal goal* of this newly introduced Capstone Project is to design, build and test a bioinspired micro flapping-wing flyer that is capable of vertically taking-off then hover over a small area for a period of at least one-minute while being subjected to occasional lateral disturbances.

Technical & Engineering Challenges

The challenge of designing a light airframe, power-efficient avionics and an efficient flapping mechanism to achieve the goal of the project will be tackled. Innovative flapping-mechanism and wing designs, which include smart materials; 3D-printing; micromachining; ultra-lightweight controllers and biologically-inspired flight dynamics will be utilized to arrive at the optimal design and achieve the project principal goal.

Breakdown of Technical Goals

MFWF
(Micro Flapping-Wing Flyer)

Major Project Technical Goals Leading to The Principal Goal

1. Develop a flight dynamics model of a bioinspired two-winged MFWF.
2. Develop a control law to stabilize the attitude of the MFWF in hover over a small area.
3. Design and manufacture an efficient lightweight flapping mechanism. Investigate the utilization of smart materials to induce the flapping motion.
4. Design and manufacture a set of wings.
5. Design the avionics, select and program the microcontroller and design the power electronics to fulfill the MFWF mission goal.
6. Design the airframe that will house the flapping mechanism, the avionics and the battery.
7. Fabricate and assemble the MFWF. Test the performance of the MFWF against the stated principal goal of the project.

Major Skills You Will Acquire

MFWF
(Micro Flapping-Wing Flyer)

Learning Objectives

1. Develop an understanding of the flight physics and control of flapping-wing flyers and appreciate the intricacies of this mode of flight.
2. Develop skills in micromachining, 3D-printing, mechanism design and smart materials through the development of an efficient flapping mechanism for the MFWF.
3. Develop skills in avionics design, microcontrollers programming, efficient power management and ultralight electronics and batteries.
4. Recognize and appreciate the complexities associated with designing an autonomous micro air vehicle in general and an MFWF in particular.
5. Communication skills that include presentations, progress reports, technical drawings in addition to team work.

Team Structure

Streams Within The Team (Preliminary)

- Project Management
  - Flight Dynamics & Control
  - Wing Design & Aerodynamics
  - Flapping Mechanism Design & Actuation
  - Mechanical Design & Fabrication
  - Avionics

Questions

?

For Further Reading

A. Thomas A. Ward and M. Rezadad and Christopher J. Fearday and Rubentheren Viyapuri
Review of Biomimetic Air Vehicle Research: 1984-2014
International Journal of Micro Air Vehicles, **3**, 375–394 (2015).