FIRE: THE FIRST-YEAR INNOVATION & RESEARCH EXPERIENCE

BIOINSPIRED ROBOTICS

RoboRaptor: Articulated Wing Glider

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Goal

This project aims to create a bird-inspired, tethered gliding robot (kite) with articulating flapping wings capable of measuring and characterizing the effects of atmospheric behavior and wind on mechanical flapping and gliding robots.

Background

Unlike traditional drones which require a constant external power source for propulsion, gliding robots leverage aerodynamic efficiency to sustain flight by using the gliding and soaring behavior of birds. [1] This enables them to fly without requiring continuous power input, making them especially valuable for environmental monitoring and data collection. [2]

Governing Principles

Aspect Ratio: The ratio of the length of the wings to their width. It is calculated by dividing the square of the wingspan by the area of the wing. [3] Our kite has a high aspect ratio, which enables it to glide without relying exclusively on flapping to generate lift.

Aspect Ratio: $AR = \frac{b^2}{A}$

Wind Data:

Prototype 1: *Sparrow & Falcon*

- Large wings made with plastic film and a lightweight frame made up of wooden dowels
- Failure: Unable to fly due to unstable joints and fragile plastic body

Prototype 2: *Sparrow & Falcon with Actuating Wings*

- Improved design with 3D printed servo mounts, end connectors, servo wing spars, and a middle hinge connector
- Used flexible black film, which was more resistant to wind
- Incorporated electronics and servos into the kite
- Failure: Wooden dowels were too stiff and broke during flight test

Prototype 3: *Eagle*

- Transitioned the frame from wooden dowels to carbon fiber and aluminum
- Adjusted the wing shape based on dimensions of an eagle
- Success: Was able to take flight with winds above 7 mph

Prototype 4: *Eagle with Actuating Wings*

- Added servos and actuating wings with 3D printed wing arms and mounts
- Used a white film as it is lighter and better suited for hotter climates
- Used a 3D printed plate to incorporate all electronics, including wind sensor
- Success: Was able to fly with the ability to flap and turn

House Sparrow [4,5]

Scientific Name: *Passer domesticus*
Wing Shape: Elliptical Wing
Wingspan: 25.4 cm
Sparrow Aspect Ratio: 5.5
Model's Aspect Ratio: 2.92

- Sparrows have wide, rounded wings, which allow for greater control
- The larger wing width allows for the model to generate greater lift
- The wider wings also tend to increase the drag force on the kite

Peregrine Falcon [4,6]

Scientific Name: *Falco peregrinus*
Wing Shape: High Speed Wing
Wingspan: 81.8 cm
Falcon Aspect Ratio: 7.9
Model's Aspect Ratio: 4.29

- Falcons have a keeled sternum and powerful wing muscles
- They have adaptive wings that can adjust shape for various flight conditions
- The model's curved wing shape aids in reducing drag

Golden Eagle [4,7]

Scientific Name: *Aquila chrysaetos*
Wing Shape: Slotted High Lift Wing
Wingspan: 194 cm
Eagle Aspect Ratio: 7.4
Model's Aspect Ratio: 6.24

- Their wings are more rounded than a falcon's but are narrower than a sparrow's
- Allows for reduced drag, increased lift, and cutting through the air
- The model's wing contains an inward curve despite its narrower wings

References

[1] A. Mohamed, G. K. Taylor, S. Watkins, and S. P. Windsor, "Opportunistic soaring by birds suggests new opportunities for atmospheric energy harvesting by Flying Robots," *Journal of The Royal Society Interface*, vol. 19, no. 196, Nov. 2022. doi:10.1098/rsif.2022.0671

[2] A. Khaheshi, H. T. Tramsen, S. N. Gorb, and H. Rajabi, "Against the wind: A load-bearing, yet durable, kite inspired by insect wings," *Materials & Design*, vol. 198, p. 109354, Jan. 2021. doi:10.1016/j.matdes.2020.109354

[3] "Aircraft Wing area and aspect ratio," AeroToolbox, https://aerotoolbox.com/intro-wing-design/ (accessed Jul. 17, 2024).

[4] D. B. Savile, "Adaptive evolution in the avian wing," *Evolution*, vol. 11, no. 2, p. 212, Jun. 1957. doi:10.2307/2406051

[5] "House Sparrow Overview, all about birds, Cornell Lab of Ornithology," Overview, All About Birds, Cornell Lab of Ornithology, https://www.allaboutbirds.org/guide/House_Sparrow/overview (accessed Jul. 17, 2024).

[6] "Peregrine Falcon Overview, all about birds, Cornell Lab of Ornithology," Overview, All About Birds, Cornell Lab of Ornithology, https://www.allaboutbirds.org/guide/Peregrine_Falcon/ (accessed Jul. 17, 2024).

[7] "Golden Eagle Overview, all about birds, Cornell Lab of Ornithology," Overview, All About Birds, Cornell Lab of Ornithology, https://www.allaboutbirds.org/guide/Golden_Eagle/ (accessed Jul. 17, 2024).