Darwinian MAVs

The Biomimicry of a Hybridization of Small Birds' Flight Patterns in the UAV Context

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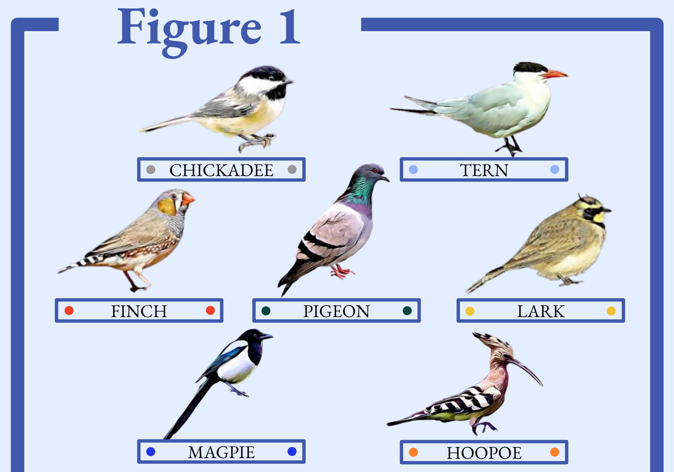
Abstract

Darwinian evolution has yielded adaptations of small birds to their environments. Leveraging these abstractions to create Biomimetic MAVs can significantly improve UAV technology. Hybridizations of flight patterns of several small birds are isolated for a selection of use cases, including environment, load and manoeuvrability. The MAV status of the birds is affirmed by calculating their Reynolds numbers. The ensuing discussion applies the hybridizations to the UAV context. Future research should construct and simulate models under varying conditions.

Introduction

Micro-aerial vehicles (MAVs) are very small, remotely piloted vehicles. The wing design of MAVs varies widely as fixed wings, rotary wings, and flapping wings have been researched.[1-3] MAVs commonly have a wingspan of less than 15 cm and weigh under 1 kg.[4,5] Due to the size and weight constraints of MAVs, biomimicry of insects and small birds can be used in developing MAV wing designs.[5] A class of MAVs called small ornithopter-type MAVs have flapping wings and were inspired by small bird flight.[6] The study of small bird flight characteristics is important because natural flier performance shows better manoeuvrability, drift compensation and flight efficiency than modern aircraft.[5,7,8] The birds focused on herein include the lark and finch.

Figure 1



Sketches of each of the birds to be studied, not to scale. Colour indicator markers defined here will be used throughout this research as a legend.

Methods

A prospective MAV should have *Re < 15000*,[9] and is thus restrained in size and weight. Hence, a series of small birds were analyzed, including the chickadee (*Poecile atricapillus*),[10] the hoopoe (*Upupa epops*),[11] the tern (*Sterna paradisaea*),[12] the pigeon (*Columba livia*),[13] the lark (*Eremophila alpestris*),[14] the finch (*Taeniopygia guttata*),[15] and the magpie (*Pica pica*).[16] Birds have evolved to adapt to varying environmental and mechanical requirements. Hence, several hybridizations of bird flights – adapted to serve varying purposes and needs – can be abstracted and applied to the MAV context.

Discussion

Reynolds Number

To fall under the MAV classification, ornithopters should have a Reynolds number less than 15000.[9] Wingtip velocity,[17] and chord value[18] could be obtained by experimentation, but this was out of the scope of this study. Hence, as an alternative, a linear interpolant drawing a relationship between wing length (R) and Reynolds number (Re) was used – $Re \approx 30.24R - 2.833$.[19] Finding Re was considered important because it can later be useful in deriving the values of wingbeat frequency and wingbeat amplitude of the MAVs.

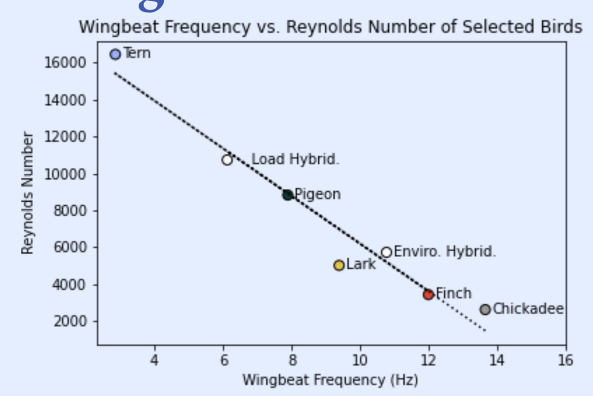
Sources of Error

For any calculation, the air density was taken as 1.21 kgm^{-3} which is mean value within 100 m (concentrated within 20 m of sea level).[20] Here, wing length of the selected birds was assumed to be half of the wingspan, where wingspan value was retrieved from the literature.[11,21] Ideal conditions were assumed for the fluid.

Application to the UAV Context

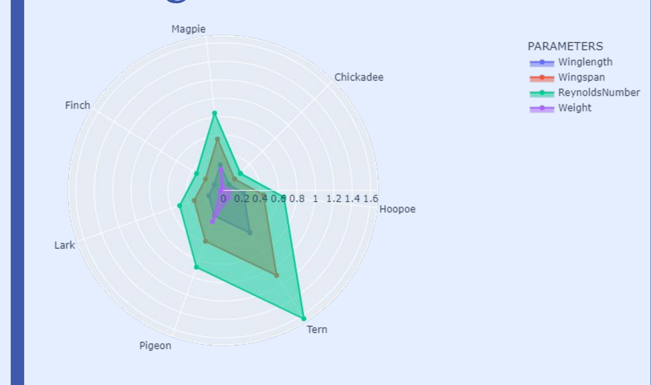
Now, hybridizations created in the Results sections will be applied to the UAV context. UAVs must ensure that they can operate in harsh environments, including high wind speeds. Combining the ascent/descent patterns of a lark,[14] with the landmark perception of a tern will yield an optimal UAV for flight in harsh environments.[12] Another UAV might be required to carry a load; for these cases, it should opting for improved aerodynamics like a finch.[15] Finally, a UAV might require optimal manoeuvrability. A UAV should use the largest gap for vertical obstacles [13] and the nearest for horizontal obstacles.[13] Additionally, it should point its sensors in the direction of travel.[10]

Figure 3



Scatter plot of wingbeat frequency of selected birds against Reynolds number, with linear interpolant plotted.

Figure 4



Radar chart of wing length (m), wingspan (m), Reynolds number (10^4) and weight (kg) of the 7 birds chosen.

Universal Patterns

Some flight patterns should be applied to all MAVs. The magpie presents a possibility to communicate through variations in wingbeat frequency, and the hoopoe presents a transitory state from entomopters to ornithopters.

Results

Use Cases

Hybridizations for several use cases were considered in the analysis. Flight through several environments was considered, including under variations in weather condition, wind speed, temperature, gravitational field strength and medium. The transportation/load use case was also considered. Finally, the use case of flight with optimal manoeuvrability was considered.

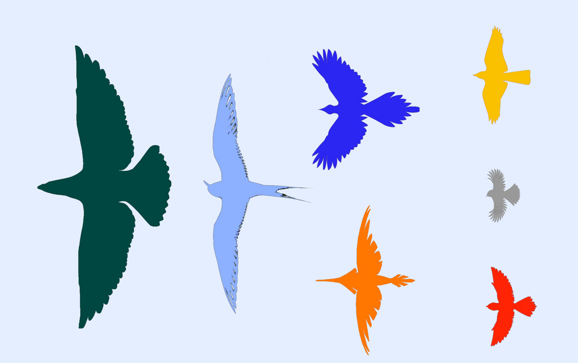
Environment

The tern has adapted by varying its flight pattern to a crosswind or tailwind.[12] While flying, anisotropic perception is hindered, so a visual landmark system must be employed.[12] The lark has adapted by varying ascent/descent speeds to wind conditions.[14] It uses a strong headwind to ascend on steeper subintervals.[14]

Load

Adding a load to a finch results in drastically varied flight kinematics.[15] When carrying a load, the finch decreased its average wingbeat amplitude and angular velocity, and increased time flapping.[15] It is assumed herein that the finch opts to increase aerodynamic efficiency due to the cost of muscle activation.

Figure 2



A silhouetted depiction of the shapes of the selected birds, approximately to scale.

Manoeuvrability

The pigeon steers towards the largest gap between vertical obstacles, and aims for the nearest gap in horizontal obstacles, regardless of size.[13] The chickadee is able to rotate its body to manoeuvre around object, while preserving direction by orienting its head in the direction of travel.[10]

Future Research

This study provides an abstracted analysis of the use of small birds' flight patterns in an MAV context. Thus, there are several suggested topics of further research, including:

- the construction and testing of prototypes of biomimetic MAVs for particular use cases;
- the inclusion of other small birds in the abstract analysis;
- the further physical study of the mechanics behind each of the small bird flight pattern hybridizations proposed; and,
- the examination of other bird characteristics, including dimensions, weight, and unique physical attributes.

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