4. Semi-annual report

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Ph.D. Thesis title: Designing and Creating a Proto-type Semi-Autonomous Bird Inspired UAV for Bird Tracking and Filming

Description of research work

Non-flapping flight of soaring birds can be considered in two flight phases: gliding and thermal circling. The gliding can be explained by loss in altitude or airspeed or both, relative to a moving atmosphere, but these losses can be balanced by soaring behaviour, in which the bird takes advantage of updraft motions in the atmosphere usually referred to as thermals. Soaring flight is dependent on various parameters, relating to bird morphology, meteorological conditions, and the behavioural response of birds to their environment. Bird morphology, especially relating to its wings (e.g., size or shape) and body weight, has been used to comprehend differences in thermal soaring traits between species. Conventional methods of measuring the gliding performance of birds rely on wind tunnel experiments. However, wind tunnels are not particularly feasible for large bird species, despite their sensitive measuring ability. Moreover, the soaring flight cannot be studied in a laboratory and needs to be observed in the field with freely flying birds. Thanks to the recent progress in satellite telemetry (and particularly in Global Positioning System technology), birds' positions can be precisely obtained in three dimensions.

My research aims at quantifying the effects of morphology (wingspan, wing loading and aspect ratio) on soaring and gliding performances of different bird species. I collected an extensive data set from research groups around the world studying thermalling birds in the wild (previously published and unpublished data sets) and carried out a comparative analysis on flight performances of 14 bird species: *Falco naumanni* (lesser kestrel), *Falco peregrinus* (peregrine falcon), *Milvus migrans* (black kite), *Haliaeetus leucocephalus* (bald eagle), *Haliaeetus vocifer* (African fish eagle), *Aquila verreauxii* (Verreaux's eagle), *Aquila rapax* (Tawny eagle), *Aquila nipalensis* (Steppe Eagle), *Gyps fulvus* (Griffon vulture), *Gyps himalayensis* (Himalayan vulture), *Gyps Rüppellii* (Rüppell's Vulture), *Vultur gryphus*(Andean condor), *Ciconia ciconia* (Stork), *Geronticus eremita* (Northern bald ibis). All these species rely heavily on the soaring flight for their daily life and have broad and elongated wings that display different aspect-ratio (between 6.1 and 10). Some species have larger body mass, wingspan and wing loading when compared to other species. These different species would present morphological differences, which are certainly related to different ecological niches, that are likely to generate intra- and interspecific variations in flight behaviour. For this reason, different species were pooled into groups for comparison. To figure out genetically close species, I retrieved cytochrome b sequences of the species from the NCBI website [1] and created a phylogenetic tree with bootstrap by using Molecular Evolutionary Genetics Analysis software [2]. Biometry of birds was taken from the measurements of our collaborators who collected the dataset. If there is no measurement for a species, I used information from the literature. Creating groups according to their genetic relativeness would not simply explain the variation in morphology, as closely genetically related species can have different morphology or the other way around, similar morphology could be achieved by species that are phylogenetically more distant. For example, although the black kite belongs to the order

Accipitriformes, it is more suitable to evaluate this bird in the group of small raptors with the other falcon species due to similar morphological features. Eagles are well-known and common creatures worldwide, but their classification is not easy. In our evaluations, five different species belonging to two distinct genera (*Aquila and Haliaeetus*) are classified in this group. The vulture group includes the *Gyps*, a genus of Old World vultures, and the New World vultures, *Cathartidae*. White stork and Northern bald ibis are shown in another group called migratory birds (Figure 1).

Using data recorded via animal-attached high-resolution GPS loggers, the positions were recorded and the flight parameters such as vertical and horizontal speed, radius of circles, glide ratio were calculated. In order to compare flight performances measured in this study with onboard data loggers, the polar glide curves were examined. Glide polars show the relationship between gliding airspeed (on X-axis) and sink rate (on Y-axis). However, the glide polar curves in this study still have the effect of environmental factors such as wind. So we needed to find ways to compensate for that.

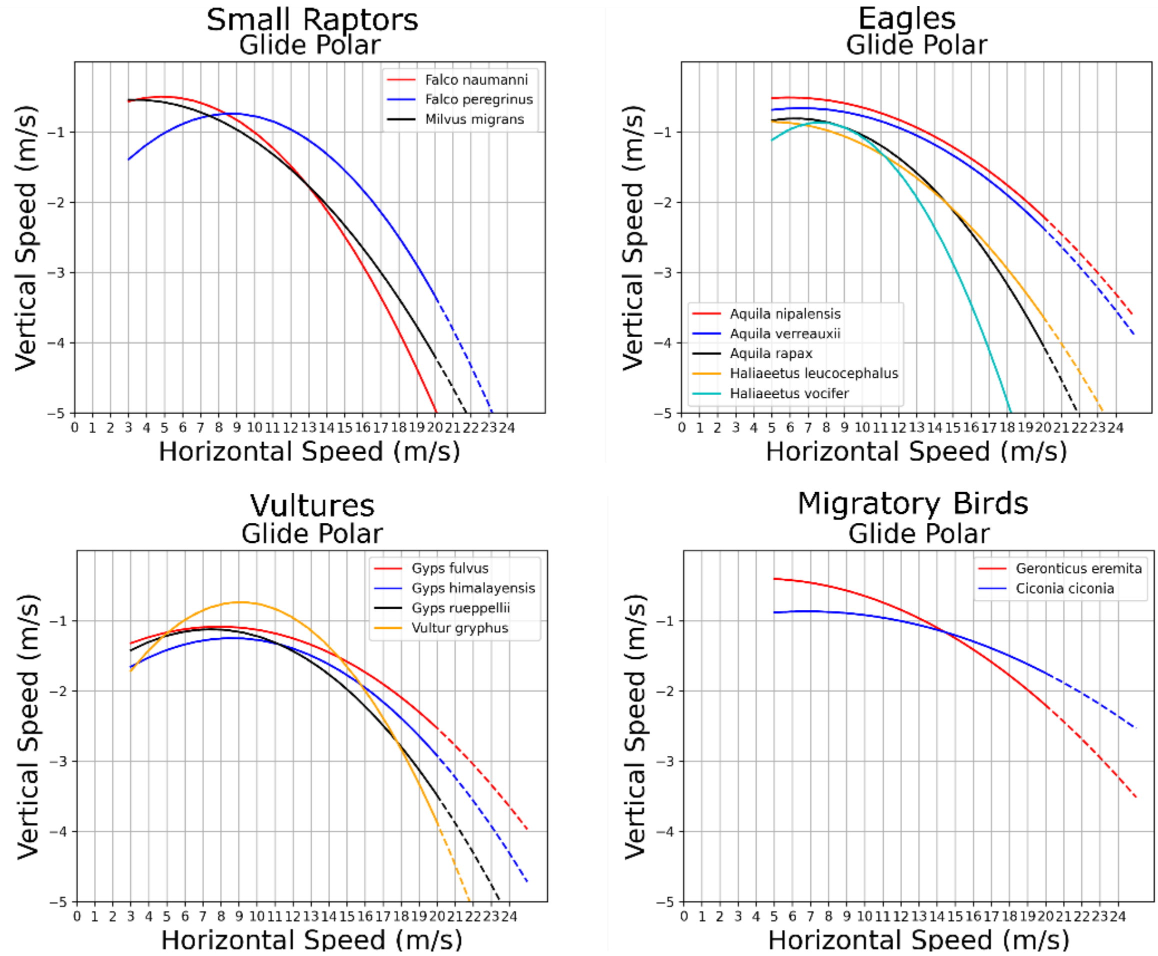

Figure 1: For all species, the effective polar curve as fitted to the measured average sinking and horizontal velocities (range between 5 m/s and 20 m/s) of the gliding parts of the flights.

Another purpose of using logged data is to investigate the thermalling performance of the birds. It was necessary to remove the wind effect here as well to find out the circling radius during thermalling [3]. Equation 1 shows that for a particular lift coefficient (C_L) and angle of the bank (φ), the turn radius is directly proportional to the mass (m) to wing area (S) ratio. The wing loading is usually defined as the ratio of the weight rather than the mass to the wing area, but either way, it determines the minimum circling radius [4]. The result revealed from the thermalling part of the data confirms that the circling radius increased with wing loading assuming that centrifugal force is exactly compensated by the horizontal component of the lift (Figure 2).

$$r = \frac{2mg}{C_L \rho S sin\varphi} \tag{1}$$

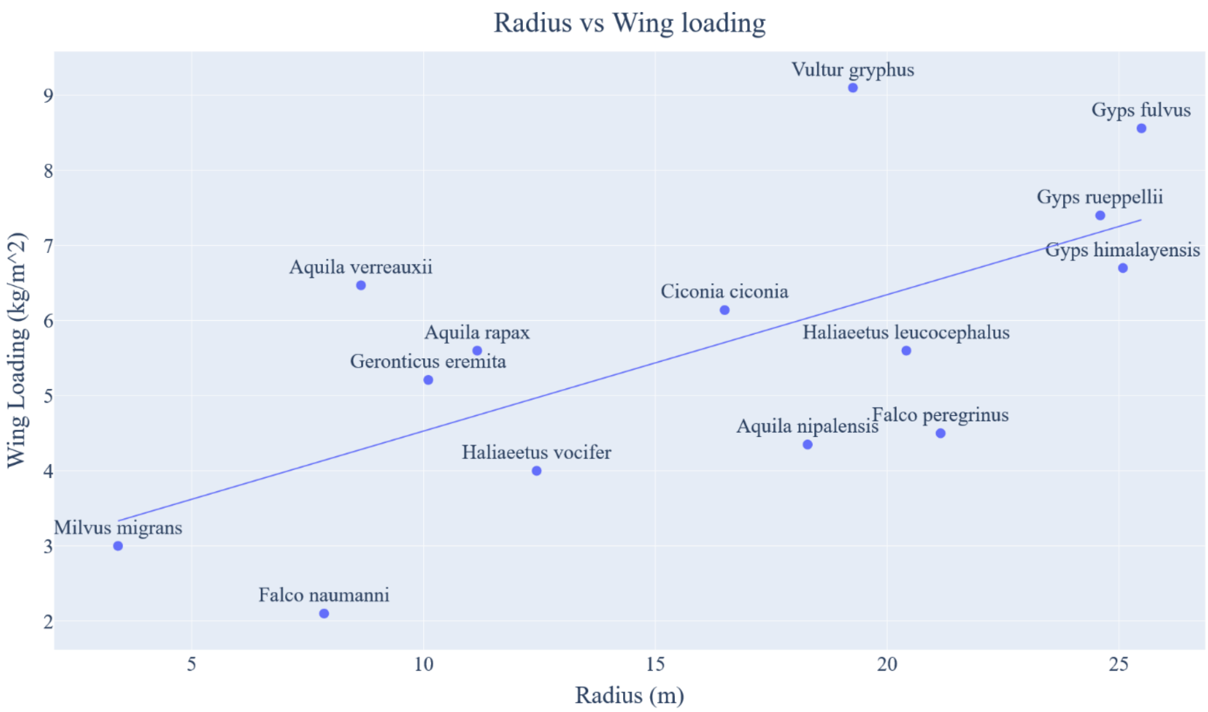

Figure 2: Median radius (m) of turns in relation to wing loading (kg/m^2) in 14 species of soaring birds ($R^2 = 0.43$, N=14, p = 0.0114).

Besides species based analysis, another focus of this research is to analyse how the individuals compare against the species average. The morphology of the individuals in the same species is closer to each other, which helps us to understand the effects of strategy, and decisions making on the soaring flight. All results from this study are currently in drafting for submission as a manuscript. The final results of this study, in addition to their biological relevance, will be used to design a robotic drone glider.

In the experimental line of my research, I made ready a prototype glider drone to measure the flight of birds. I carried out several successful test flights with this glider and analysed the flight performance of the drone to match it with the free-flying birds. The plan for the future of this experiment is to bring an autonomous soaring ability to my own design glider drone.

A manuscript titled "What are birds looking at? A large-scale motion-capture system revealed the visual attention of freely-behaving pigeons" is in preparation that I contributed as co-author. This manuscript will be submitted soon to Scientific Reports with the following author list: Fumihiro Kano, Hemal Naik, Göksel Keskin, Iain Couzin, and Mate Nagy.

Description of educational activities carried out in the current semester

Environmental fluid hydrodynamics II. EA (FIZ/3/037E)

I attended this course to deepen my knowledge of Earth's conventions and the effects of the planet's rotation on horizontal flows. The course was beneficial for me to understand the physics behind convection which is a crucial phenomenon in my research topic.

Certificate of Drone Operator

I took an online course and exam from Austro Control to have an official drone certificate valid in European Countries for the sake of future flight experiments. The relevant certificate was issued according to the rules of the European Union Aviation Safety Agency (EASA).

Teaching/Mentoring

I supported the Erasmus internship application of Melike Dogru who will do her internship in our research group this summer. I'm going to be her mentor during her internship under the supervision of Dr Mate Nagy.

Conference participations during the doctoral studies

"Differences in flight performance and their connections to morphological traits of 14 different bird species". *2022 Ornithological Conference*, 27 June-2 July 2022, American Ornithological Society and Birds Caribbean. (*Accepted*)

"Who is a curious pig? Individual variation in family pigs' response to novelty". Paula Perez Fraga, Bence Ferdinady, Máté Nagy, Göksel Keskin, Linda Gerencsér, Attila Andics, 7th European Student Conference on Behaviour & Cognition. (*Presented by Ms. Fraga*)

I am planning to participate in a conference related to the experimental part of my research. 17^{th} International Conference on Biomimetics and Bioinspired Robotics could be a beneficial conference to attend for my topic.

I presented my progress in my research regularly at the group meetings.

Awards

Stipendium Hungaricum

References

1 https://www.ncbi.nlm.nih.gov/

2 https://www.megasoftware.net/

3 Ákos Z, Nagy M, Vicsek T. 2008 Comparing bird and human soaring strategies. Proceedings of the National Academy of Sciences, 105 (11) 4139-4143. Doi: 10.1073/pnas.0707711105

4 Pennycuick, C. J. (2008). Modelling the flying bird. Elsevier.