Seabird's morphing wings inspire design for robots that can both fly and swim

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The common guillemot flies with straight wings and swims with bent wings, which reduces profile drag by up to 50%. This strategy is providing inspiration for the design of aerial/aquatic robotic vehicles. Image credit: Lock, et al. Adapted from unpublished BBC footage.)

(PhysOrg.com) -- There are robots that can fly, and there are robots that can swim, but so far a robot that can both fly and swim does not exist. With the goal to design an aerial/aquatic robotic vehicle, a team of researchers is investigating how nature achieves both aerial and aquatic motion in a single entity, particularly in a seabird called the common guillemot. They plan to use their calculations, models, and simulations to design a robotic vehicle with a morphing wing similar to the one used by the seabird.

Researchers Richard Lock, who is working under the supervision of Dr.

Ravi Vaidyanathan at the Bristol Robotics Laboratory, University of Bristol, and coauthors, have published their investigation of the common guillemot's locomotive abilities in a recent issue of *Bioinspiration & Biomimetics*.

“The capacity to mathematically model the morphological shifts the bird makes from aerial to aquatic media is our first step in being able to reproduce the process,” Lock told *PhysOrg.com*. “Understanding locomotion in a single medium is already a complex problem to solve; therefore, attempting to further our understanding of systems with a multi-modal capability, i.e., operations in two different media, provides many challenges. Our work focuses on trying to understand this balance between the different media, focusing on how different mission requirements present different compromises in performance.”

As the researchers explained, a variety of birds and insects are capable of locomotion in both air and water. However, these animals are confronted with numerous physiological challenges, due primarily to the fact that water is some 800 times denser than air. The animals' locomotive strategies that solve this problem can generally be divided into two categories: two different mechanisms for the two different media, or a single mechanism adapted for both media.

The common guillemot falls into the second category, as it flaps its wings for locomotion in both media. However, the bird modifies its wing shape when swimming by folding part of its wing. This simple change results in a reduction of surface area, which, as the researchers calculated, reduces profile drag by as much as 50% and significantly reduces the overall power requirements. This ability enables the common guillemot to nest on land along the coast, fly up to 30 km out to sea, dive underwater, and flap its wings to swim and hunt for marine food.

After developing a model of the common guillemot's wing size, shape, and flapping behavior, the researchers validated the model with simulations. Their goal was to find the values of key variables that achieve the highest performance (i.e., the lowest energy requirements) for a robotic vehicle that could fly with a range of 2 km at a velocity of 20 m/s and swim with a range of 500 m at a velocity of 1.5 m/s. These values are similar to that of the typical feeding habits of the common guillemot. The model's suggested values for key geometric and kinematic parameters were in close agreement to those exhibited by the guillemot, providing the researchers with preliminary validation of their numerical model. The model can also be used for additional missions based on projected uses of the concept vehicle.

A robotic vehicle with the ability to fly and swim could have a variety of applications. For example, the vehicle could be used to inspect underwater oil pipes while flying to and from remote oil rigs. It could also be used for aerial and aquatic surveillance for counter-terrorism purposes. Variations in the missions could require very different operating speeds in each medium. The numerical model developed by the researchers takes these issues into consideration and can provide mission-specific optimal values to use in future concept vehicle designs. Currently, the researchers are developing an experimental platform from which they can investigate various parameters associated with flapping propulsion during aquatic locomotion.

As Lock noted, there are still several challenges that need to be addressed, starting with the need to better understand the performance compromise between operations in the air and water due to the fact that robots of this type have not yet reached a level of maturity within the research community.

"The second biggest challenge that we face is one that everybody within the robotics community has to deal with, and that is the problem of a suitable power source," he said. "There is of course a finite payload which any robotic vehicle can carry, of which the power source invariably contributes a significant proportion of the overall mass. Implementing a power source that is light enough to allow aerial operations but provides sufficient power to enable the use of the locomotion mechanisms for any feasible length of time is a huge problem that we face. Luckily this is a common problem faced by many robots whereby the ultimate aim is for the untethered operations and as such many research groups are striving towards new power sources with greater power-to-weight ratios and lifespans. Although not currently available, we believe that in time a suitable power source will be developed that allows aerial/aquatic vehicles to be developed.

“Finally, the third challenge we face comes from developing a vehicle of this scale capable of aerial operations utilizing beating wing flight. Very few mature examples exist that achieve this mode of locomotion through a flapping locomotion strategy, and they are not attempting operations in water as well. Solutions to this problem do exist, such as the inclusion of an additional propulsion source for use whilst in air such as a propeller, but this then moves away from the biological example from which the work drew inspiration. However, we are not ruling this out as a stepping stone whilst addressing other elements of the complex task that we face.”

More information: Richard J. Lock, et al. “Development of a biologically inspired multi-modal wing model for aerial-aquatic robotic vehicles through empirical and numerical modelling of the common guillemot, Uria aalge.” *Bioinsp. Biomim.* 5 (2010) 046001 (15pp). DOI:10.1088/1748-3182/5/4/046001

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