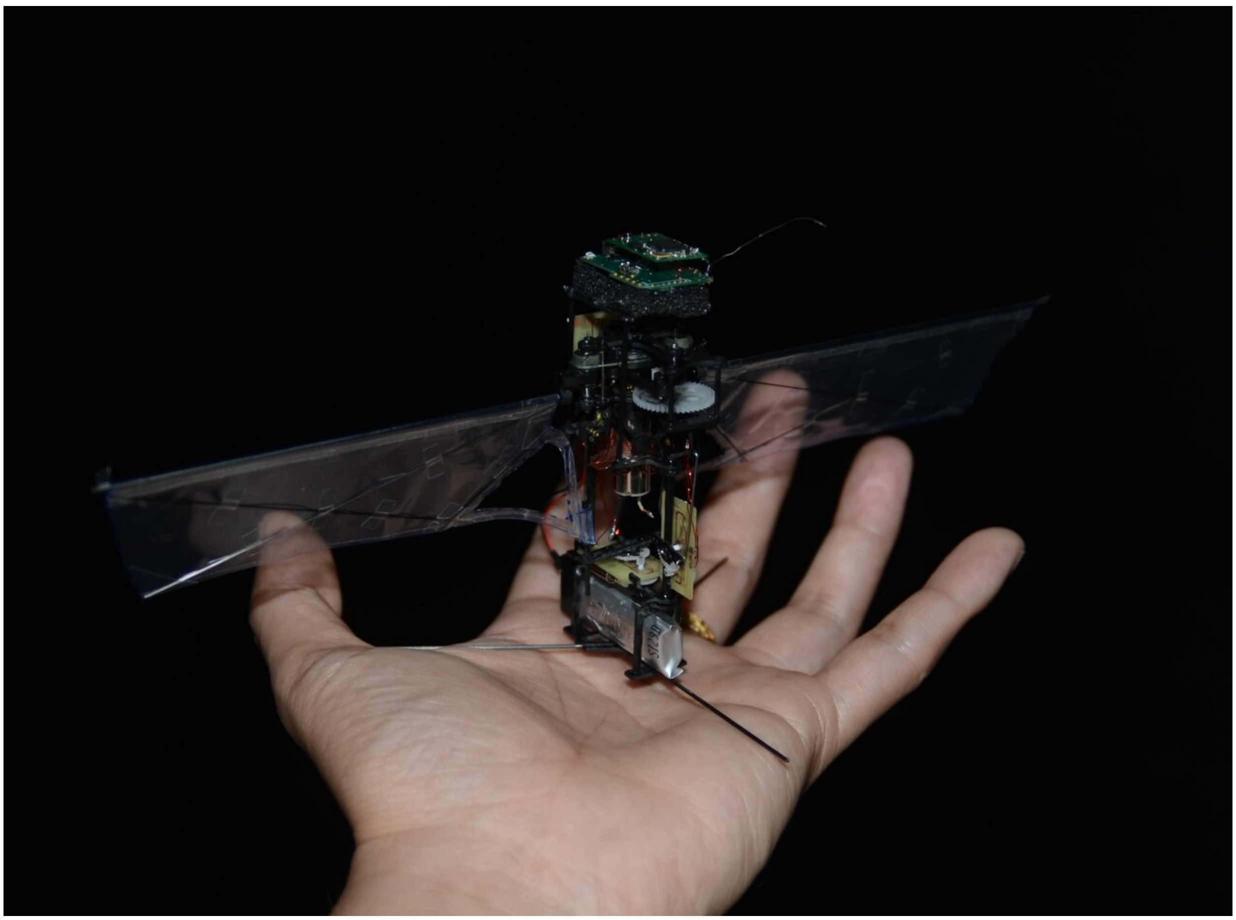
KUBeetle-S: An insect-inspired robot that can fly for up to 9 minutes

June 8 2020, by Ingrid Fadelli



The KUBeetle-S robot. Credit: Hoang Vu Phan et al

Researchers at Konkuk University in South Korea recently created KUBeetle-S, a flying robot inspired by a species of horned beetle called

Allomyrina dichotoma, which is among the largest insects on the planet. Allomyrina dichtoma weighs approximately 5 to 10 g and has a wing loading of 40 N/m^2, which is remarkably high when compared to average insect wing loadings (typically around 8 N/m^2).

"To mimic the beetle's flight, we first developed a flapping-wing mechanism that can create a large flapping angle and produce lift to compensate weight of the KUBeetle-S, just like the horned beetle it draws inspiration from," Prof. Hoon Cheol Park, one of the researchers who carried out the recent study, told TechXplore. "Since the KUBeetle-S is not equipped with control surfaces at the tail, unlike a conventional flyer, its flapping wings must be able to produce control moments only by changing their wing kinematics in the middle of the flapping motion."

The control moment generator that Prof. Park and his colleagues installed within KUBeetle-S can change the robot's wing stroke plane to the right, left, front and back, ultimately enabling the redirection of its vertical lift as desired and simultaneously generating control moment. This generator is mechanically integrated with lightweight servo motors and can also be electronically controlled via a control board and a feedback control system based on an algorithm developed by the researchers.

Just like the horned beetle it draws inspiration from, KUBeetle-S, first presented in the *International Journal of Micro Air Vehicles*, can switch between a variety of locomotion styles, including hovering flight, with an impressive high stroke amplitude of over 180 degrees. In a recent paper pre-published on arXiv, the researchers were also able to improve its flight endurance significantly using a low-voltage power source.

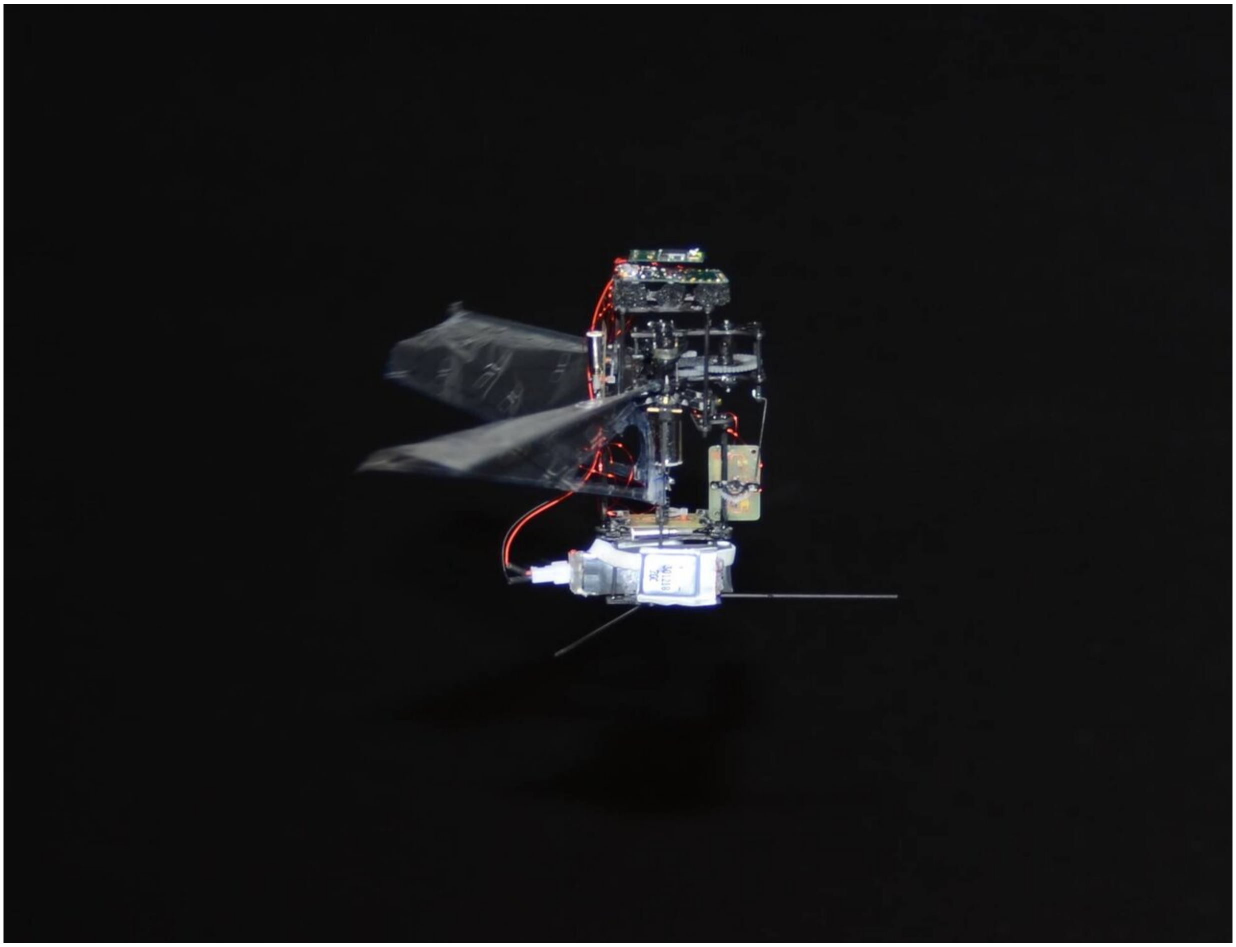
"The main objective of our recent paper pre-published on arXiv was to prolong the KUBeetle-S robot's flight time or endurance," Prof. Park explained. "We were able to extend the robot's endurance by choosing an aerodynamically efficient wing and enlarging the wing area to match the wing loading with that of the real beetle. In particular, the inboard wing area was cut out."

In addition to enhancing the robot wings' lift and lift-to-power ratio, the design strategies employed by Prof. Park and his colleagues reduce the overall input voltage. Moreover, they allow researchers to operate KUBeetle-S with a low voltage power source, using a single LiPo battery within the operating range of the robot's motor.

The researchers carried out a series of tests to evaluate the performance and endurance of KUBeetle-S when employing these new design strategies. They found that low voltage operation prevented the driving motor from being overheated, enhancing the robot's endurance.

"Another key advantage of our robot is that it is light weight," Hoang Vu Phan, another researcher involved in the study, told TechXplore. "Thanks to the simple but effective control mechanism that we reported in our previous work, we could use tiny servos to save weight. The 15.8 g KUBeetle-S is the lightest two-winged robot so far that can sustain free controlled flight with all onboard components."

The first version of KUBeetle-S, introduced in the researchers' previous paper, weighed 16.4g and was powered by a two-cell LiPo 7.4 V battery. By changing and enlarging the robot's wings, the researchers were able to bring its weight down to 15.8 g, improving its total flight time from three minutes to almost nine minutes.



The KUBeetle-S robot. Credit: Hoang Vu Phan et al

"Our results suggest that finding an aerodynamically efficient wing is crucial for extending a flying robot's endurance," Prof. Park said. "We also found that the KUBeetle-S can fly longer when its wing loading is close to that of the real beetle, which indicates that wing loading is an important parameter, even when we mimic nature's flyers."

In addition to improving the robot's endurance and increasing its flight time, the new strategies introduced by Dr. Park, Phan and their colleagues allow it to move in any direction, fly outdoors, and carry extra payloads. These qualities make the robot better suited for a number of real-world applications, such as moving objects from one place to another.

In the future, KUBeetle-S could also be used to study insects and better understand the mechanisms behind their movements, such as the quick banked turns often observed in flies. Due to its small size, it could potentially even be deployed in natural habitats to collect footage of insects and other wildlife or used to conduct secret military missions.

"In our next studies, we will focus on further extending the robot's flight time and installing an onboard vision system for navigation flight," Phan said. "We also plan to see if we can improve the stability during flight transition, for instance, taking it from quick forward flight to hover, and in the presence of wind disturbance for better flight agility of the robot. The final goal will be autonomous flight of the KUBeetle-S."

More information: Hoang Vu Phan et al. Towards long-endurance flight of an insect-inspired, tailless, two-winged, flapping-wing flying robot. arXiv:2005.06715 [cs.RO]. arxiv.org/abs/2005.06715

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