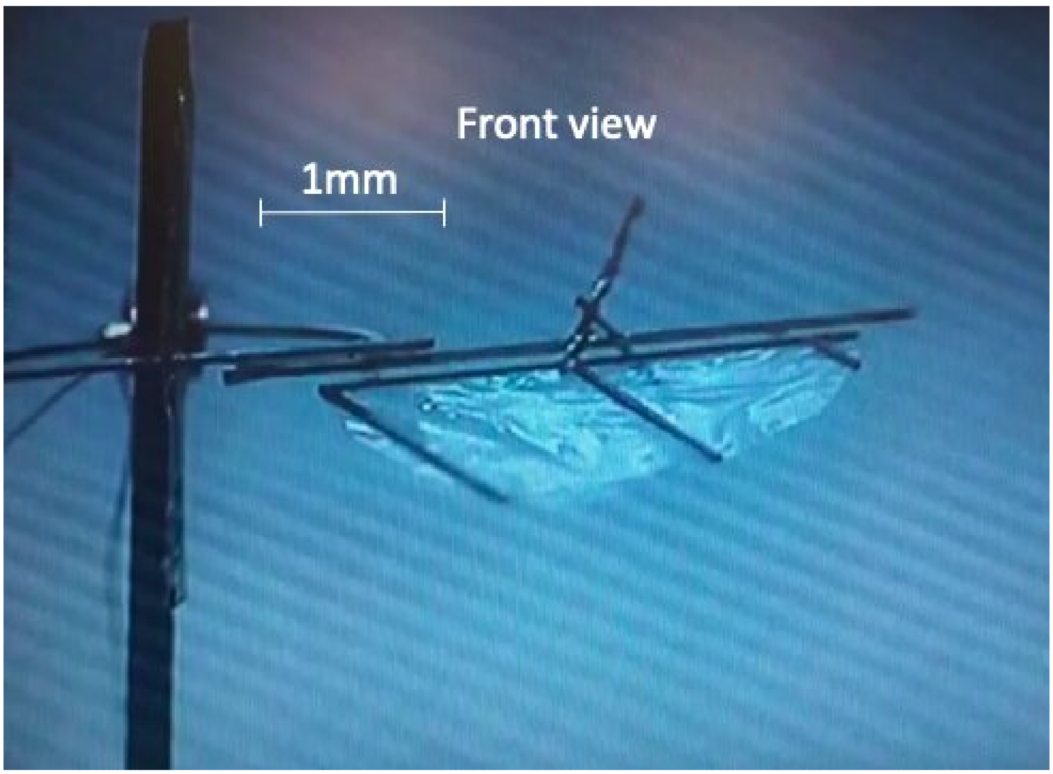
New designs for jumping and wing-flapping microrobots

August 28 2019, by Ingrid Fadelli



The fruit fly bot's wing. Credit: Bhushan & Tomlin.

Researchers at the University of California (UC) Berkeley have recently designed two insect-scale microbots, one that jumps and another that flaps its artificial wings. These robot designs, presented in two papers pre-published on arXiv, mimic real biological behaviors observed in insects. The two microbots, referred to as the fruit fly bot and jumping μbot, were developed by Ph.D. student Palak Bhushan as part of his thesis under the supervision of his professor, Claire Tomlin.

In the future, tiny robots could have numerous important applications, assisting humans in tasks such as remote sensing, searching for survivors after natural disasters, and space exploration. In fact, microbots have several favorable characteristics, including their small size, insect-like maneuverability and easier navigation in challenging terrains.

"Robustness to tough terrains generally increases the less a bot interacts with the environment," Bhushan and Tomlin told *TechXplore*. "Fliers and jumpers (e.g. flies, grasshoppers, etc.) minimize this interaction by flying/jumping over the obstacles and to their next destination, in contrast with ants which have to walk over each little bump. Fliers are more relevant to Earth and other planets with dense atmosphere, whereas jumpers are more relevant for places with negligible to no atmosphere and lower gravity."

The first robot developed by the researchers, which they refer to as the fruit fly bot, is the first sub-milligram wing vehicle ever developed that effectively mimics insect wing kinematics. Most small flapping wing microbots to date are at the 100 mg mass scale. In nature, however, tiny flying insects (e.g. fruit flies) are at a 1 mg mass scale, and some can be even smaller.

The 'fruit fly bot' wing pitch, top view. Credit: Bhushan & Tomlin.

"The motivation behind the development of this particular microbot was to bridge the size gap between what has been made and what is possible," the researchers explained. "Our main objective was to demonstrate flapping wing motion at this size scale using onboard motors and mechanisms, but with external electrical power."

Small flying insects typically generate lift by performing large wing strokes. One of the key challenges for Bhushan and Tomlin while developing this robot was to create small actuators than are able to generate large enough rotations to drive the artificial wings.

"Prior works use small-rotation motors and then amplify this motion to large rotations using an amplifying mechanism," Bhushan and Tomlin explain. "The feature sizes in these amplifying mechanisms go down to 70um, even for 100 mg-scale bots. Simply scaling down the design by 100x would lead to an even smaller motor motion which in turn would demand even lower feature sizes in the amplifying mechanism which isn't feasible."

To tackle issues associated with scaling down the design of the microbot, the researchers created a large-rotation motor that doesn't require any amplifying mechanisms to work. They achieved this by developing a torsion spring in which small-rotations of individual cantilevers add up to produce a large rotation when driven at resonance.

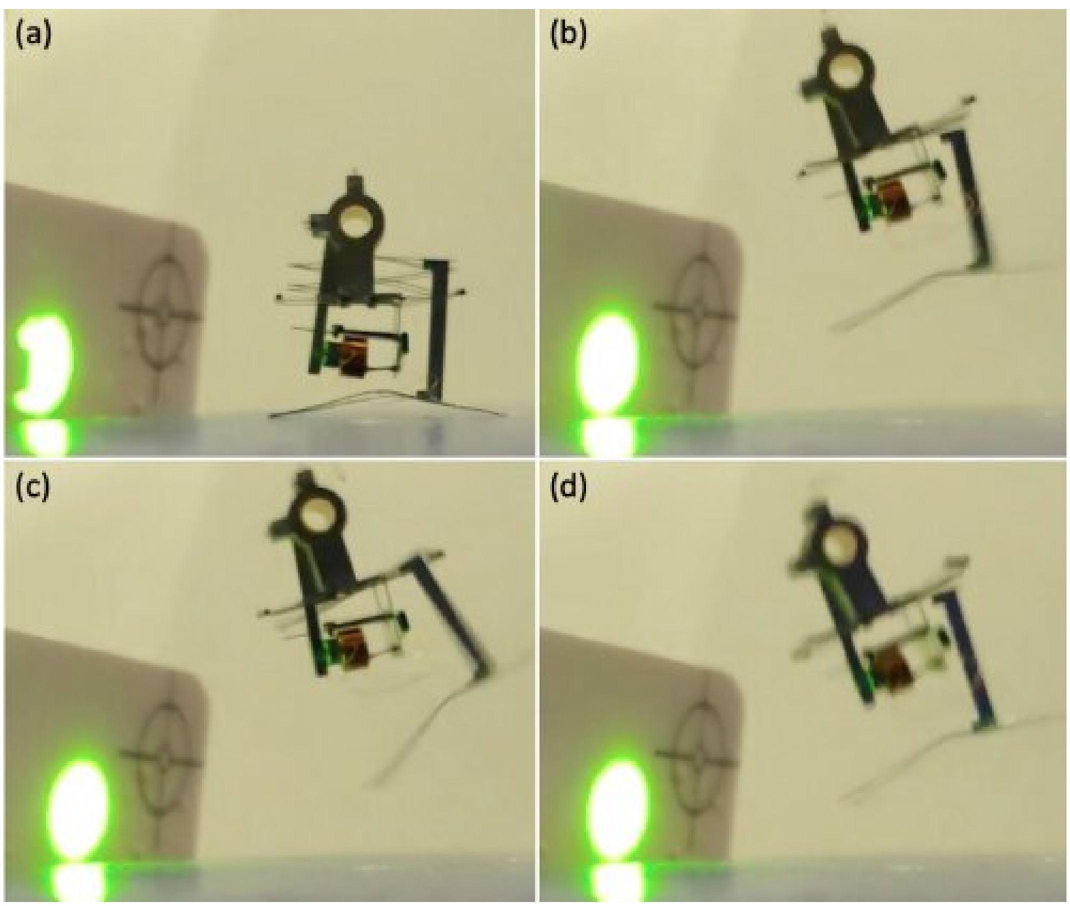
The 'fruit fly bot' wing pitch, front view. Credit: Bhushan & Tomlin.

With the reseachers' design, the flying robot's feature sizes can go down to only 100um, even at the 1 mg-scale. Remarkably, their fruit fly bot can be fabricated within a relatively short time. In addition, its low operational voltages (i.e. 70mV) should make it easy to test and deploy in the future.

The second microbot developed by the researchers is a jumping bot that measures 17mm x 6mm x 14mm in size and weighs 75 milligram. The tethered version of this robot can jump 6 times per minute, landing perfectly on its feet. To jump up by 8mm in height, the bot consumes approximately 6.4mW of power.

Just like the fruit fly bot, this tiny robot is the smallest of its kind with its capabilities, at least as far as the researchers are concerned. In fact, the smallest jumping robot reported in past studies carries an onboard power source that weighs approximately 300 mg and can only jump once before its chemical power source is exhausted.

"We aimed to develop something in the sub-100 mg mass scale that could perform repeatable jumps," the researchers said. "Note that here, since we are at a much larger scale compared to the fruit fly bot, we can be more ambitious and thus have an onboard power source, as well."



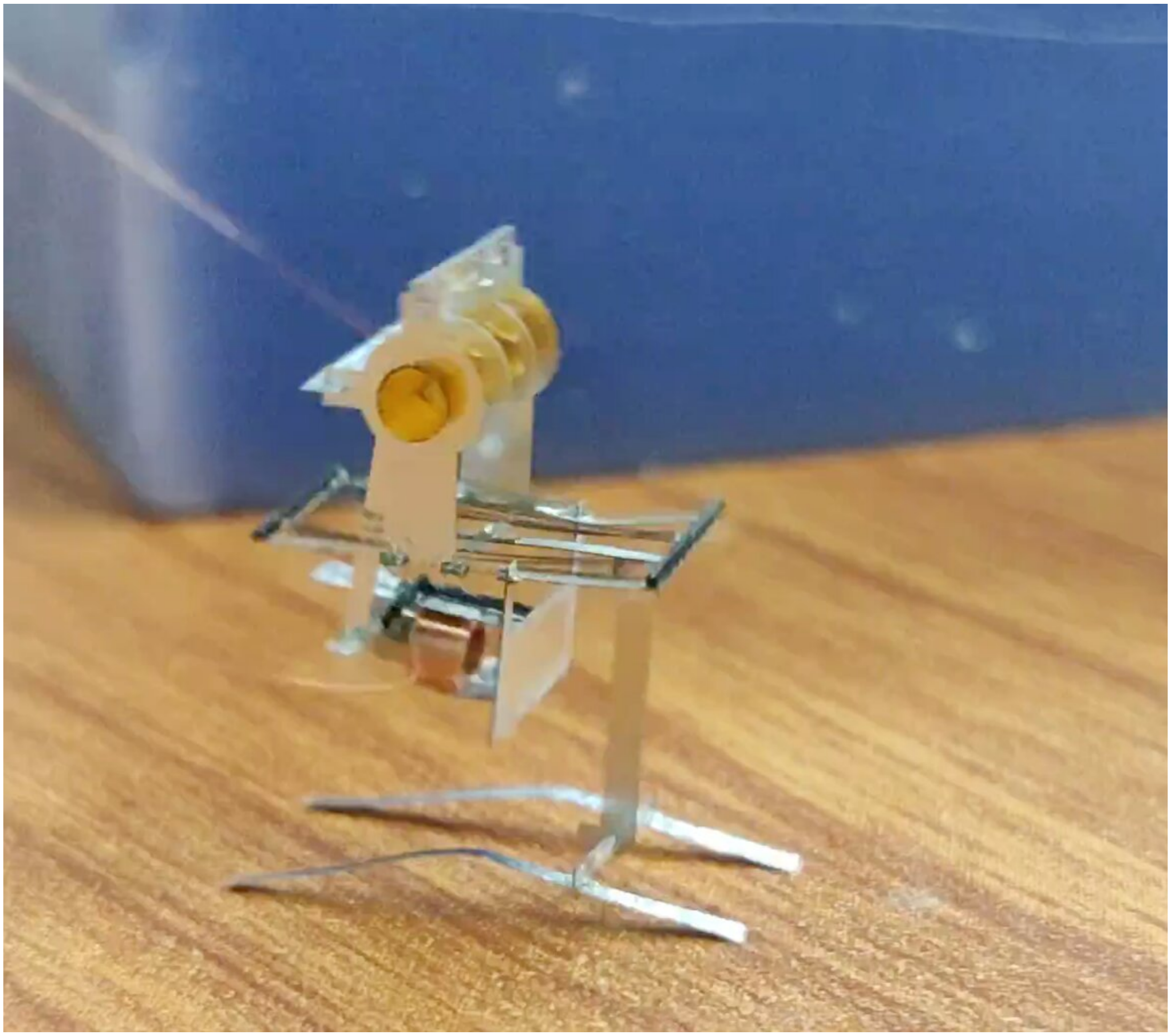
The jumping µbot performing a jump using laser power. Credit: Bhushan & Tomlin.

Small jumping insects generally push the ground rapidly with their legs while performing a jump. This instantaneous power demand is far too high to reproduce using an onboard motor. To overcome this challenge, previous studies have used motors to store energy in an onboard mechanism and then rapidly release this energy, which allows the robot to perform jumps. In their study, the researchers also decided to use this approach.

"Motors are heavy, tough to fabricate at small scales, and require special control signals to operate them," Bhushan and Tomlin said. "In order to simplify fabrication and control, we ensured that our design is able to operate using a single motor by making the other required functions occur passively, plus we design our motor to work with simple ON/OFF control signals to function."

In the jumping bot developed by Bhushan and Tomlin, a single motor generates a continuous rotation motion by accumulating small rotations. This motion is then used to wind a string that is designed to pull a spring in an energy storage mechanism. After the energy reaches a specific threshold, the mechanism rapidly releases the robot's stored energy, which ultimately allows it to jump.

"The simple control requirement of our motor allows us to power it using 1 mg photovoltaic cells that produce current when an infrared laser is shone on them—but this power source is just a placeholder for future micro-batteries when they become available," the researchers added.



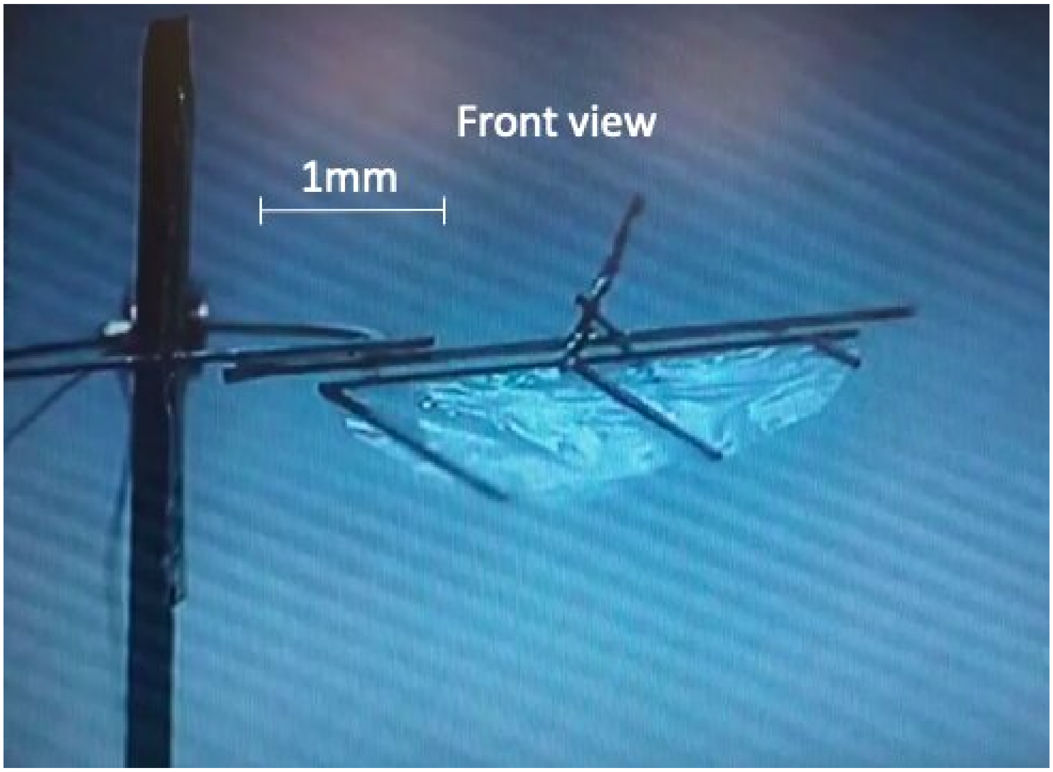
The jumping μbot. Credit: Bhushan & Tomlin.

Most existing 100 mg-scale bots use piezoelectric and electrostatic actuators that require high voltages of 200-5000V to operate. This means that they often struggle with the heavy and inefficient voltage amplifying circuits that are used to drive them. According to the researchers, this is the main reason why very few completely tether-less microbots were successfully created so far.

"We successfully designed novel electromagnetic actuators, which are a magnet plus coil system, just like in your headphones, that need low-voltages to operate—only 0.07V for the fruit fly bot, and 0.8V for the jumping bot," Bhushan and Tomlin said. "Thus, when we will have good micro-batteries in the future (we don't right now), our bots will be much lighter and consume much lower power to function."

In order to operate effectively, all 1 mg-scale bots, as well as several 100 mg-scale bots, require a special 'controlled' environment, for instance characterized by a changing external magnetic field, a hot plate or a vibrating plate. The actuators used by this fruit fly bot and jumping bot, on the other hand, are onboard, thus these tiny robots also perform well in regular environments.

Impressively, the researchers were able to create the smallest wing-span device reported yet, which has the same mass as a fruit fly. They also successfully designed the lightest untethered jumping bot with an onboard power source ever developed so far.



Wing flapping robot's wing. Credit: Bhushan & Tomlin.

Currently, batteries are still unable to support 100 mg-scale flying robots, thus it might take some time for the researchers to successfully power their 1 mg-scale flying bot. Moreover, the bot's motor has a power efficiency of 0.7 percent, while a fruit fly's muscles has an efficiency of 17 percent.

In their future work, the researchers plan to focus on the development of more efficient motors, to perfect their design further and prepare for when batteries small enough to support their bot are finally released. They would also like to create low-power sub-0.1 mg sensors and controllers, as this would allow them to make their fruit fly bot autonomous.

"As for the jumping bot, we plan on adding a horizontal component to the launch velocity which can then help the bot in navigating around," Bhushan and Tomlin explained. "Given the low power requirements of this bot and a larger size compared to the fruit fly bot, we should also be able to add existing batteries to it to make it perform completely self-sufficient jumps."

More information: An insect-scale unthethered laser-powered jumping microrobot. arXiv:1908.03282 [cs.RO]. arxiv.org/abs/1908.03282

Design of the first sub-milligram flapping wing aerial vehicle. arXiv:1908.03203 [cs.RO]. arxiv.org/abs/1908.03203