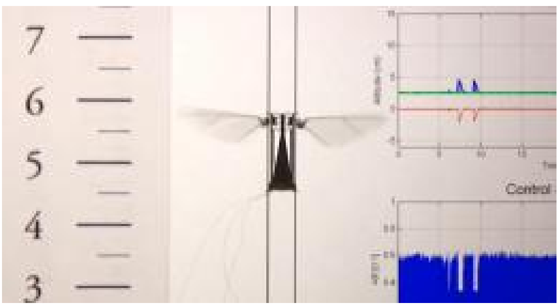
Flying microrobot takes steps toward full autonomy (w/ video)

September 20 2011, by Lisa Zyga



This screenshot from the video below shows the flying microrobot performing vertical flight with closed-loop control. Image credit: Néstor O. Pérez-Arancibia, et al. ©2011 IOP Publishing Ltd

(PhysOrg.com) -- With the goal of designing an insect-inspired flying microrobot capable of sustained autonomous flight, researchers have demonstrated for the first time a microrobot that achieves vertical flight using closed-loop control. The researchers predict that the approach they use for controlling flight on this one axis could also be used for controlling flight on all three axes.

The team of researchers, Dr. Néstor Pérez-Arancibia, Kevin Ma, Dr. Kevin Galloway, Jack Greenberg, and Prof. Robert Wood from the Harvard Microrobotics Lab at Harvard University, has published their study on the first controlled vertical flight of a biologically inspired microrobot in a recent issue of *Bioinspiration & Biomimetics*. The methods they used could provide a key step toward developing completely autonomous flying microrobots.

"Basically, a fully autonomous flying microrobot would do similar things to what natural bees and flies can do: take off, land, and navigate through difficult environments," Pérez-Arancibia told *PhysOrg.com*. "In the long term, I can also envision microrobots that can adapt to their environments, coordinate with other robots to accomplish difficult tasks, and interact with natural insects (this would be very cool, I think)."

As the researchers explained in their study, designing a microrobot with total autonomy is a complex problem for which aerodynamics, sensing, actuators, and other factors must be considered simultaneously. To tackle the problem, the researchers focused on just one degree of freedom: altitude.

After designing and fabricating a 56-mg flapping-wing microrobot, the researchers attached the microrobot to a double-cantilever beam that could move only in the vertical direction. When the robot flapped its wings, the flapping induced inertial and aerodynamic forces that caused the wings to passively rotate. In turn, the passive rotation created a non-zero angle of attack during the wing stroke, which produced lift. In general, the faster the wings flapped (i.e., the higher the frequency and/or the amplitude of their stroke angle), the greater the lift force.

As Pérez-Arancibia explained, to design the controller – the set of rules used to generate input to the system – the researchers used two separate experimental setups. In the first experimental setup, the researchers gathered relevant information about the robot's dynamics by performing static experiments (i.e., the robot flaps, but it does not move). Two sensors measured the actuator output and the force produced by the flapping wings. With this information, the researchers could determine the controller's general structure. In order to fine-tune this structure, the researchers then computed additional parameters by performing experiments in which the robot moves up and down, as shown in the video. This controller resulted in the first demonstration of the closed-loop control of an insect-scale robot.

“The term ‘closed-loop’ implies that feedback is used to generate the input to the robotic system,” Pérez-Arancibia explained. “In this particular case, the robot’s altitude is measured using an external laser position sensor and then this information is used by the controller (a set of rules) to generate the control signal, which is the voltage input to the system that makes the wings flap. Note that altitude is the variable that we control (we make it follow the trajectory we desire, using a feedback controller).”

Using this controller design process, the researchers demonstrated that the microrobot could perform tasks such as hovering in one place and following a trajectory. Also, when the researchers caused a disturbance by blowing air from a hose at the microrobot, the microrobot was able to withstand the disturbance. In addition, the 56-mg microrobot is capable of generating lift forces of up to 3.6 times its own weight, meaning it could carry a payload including steering components, sensors, and power sources. These characteristics could make the flying microrobots appealing for a variety of applications.

“It is reasonable to assume that they will be cheap if manufactured at a large scale,” Pérez-Arancibia said. “Therefore, they will be excellent for going into, exploring, and sending information out from areas inaccessible or too dangerous to humans. I am thinking of buildings on fire, contaminated areas (by dangerous chemicals, radiation, or even pathogens), collapsed structures, etc. They will be excellent to do field biological research. Imagine the use of 1000 or 2000 of these robots for exploring a tree in the middle of the Amazonian forest, for example. Imagine a group of microrobots flying alongside Monarch butterflies on their migration route from Canada to Mexico, etc. Another application often mentioned is artificial pollination."

As Pérez-Arancibia added, the researchers are making swift progress toward the ultimate goal of fully autonomous flying microrobots.

"At the Harvard Microrobotics Lab, as a group, we are and will be working on bringing you autonomous flying microrobots ASAP," he said. "Papers coming soon will present experiments on altitude control using optical flow, on pitch control, on new robotic designs that include steering and control actuators, etc. Stay tuned!"

More information: Néstor O. Pérez-Arancibia, et al. "First controlled vertical flight of a biologically inspired microrobot." *Bioinsp. Biomim.* 6 (2011) 036009 (11pp). DOI:10.1088/1748-3182/6/3/036009