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# Bio-inspired eye stabilizes robot's flight

**Biorobotics researchers at the Institut des Sciences du Mouvement - Etienne-Jules Marey (CNRS/Aix-Marseille Université) have developed the first aerial robot able to fly over uneven terrain that is stabilized visually without an accelerometer. Called BeeRotor, it adjusts its speed and avoids obstacles thanks to optic flow sensors inspired by insect vision. It can fly along a tunnel with uneven, moving walls without measuring either speed or altitude. The study was published on 26 February 2015 in the journal *Bioinspiration & Biomimetics*.**

All aircraft, from drones to the Ariane launcher, are currently equipped with an inertial measurement unit, including accelerometers. This allows these aircraft to stabilize their roll and pitch with respect to the horizon or rather with respect to its perpendicular: the direction of the center of the Earth. An accelerometer measures all the accelerations of the aircraft including gravity, which is always directed toward the center of the Earth. However, this essential tool has no equivalent in insects, which fly quite happily without this information.

Researchers Fabien Expert and Franck Ruffier therefore took inspiration from winged insects to create BeeRotor, a tethered flying robot[1] able for the first time to adjust its speed and follow terrain with no accelerometer and without measuring speed or altitude. With a weight of 80 grams and a length of 47 centimeters, it can, all by itself, avoid vertical obstacles in a tunnel with moving walls. To achieve this, the researchers mimicked the ability of insects to use the passing landscape as they fly. This is known as optic flow, the principle of which can readily be observed when driving along a motorway: the view in front is fairly stable, but looking out to either side, the landscape passes by faster and faster, reaching a maximum at an angle of 90 degrees to the path of the vehicle.

To measure optic flow, BeeRotor is equipped with a mere 24 photodiodes (or pixels) distributed at the top and the bottom of its eye. This enables it to detect contrasts in the environment as well as their motion. As in insects, the speed at which a feature in the scenery moves from one pixel to another provides the angular velocity of the flow. When the flow increases, this means that the robot's speed is also increasing or that the distance relative to obstacles is decreasing.

By way of a brain, BeeRotor has three feedback loops[2], which act as three different reflexes that directly make use of the optic flow. The first feedback loop makes it change its altitude so as to follow the floor or the roof. The second one controls the robot's speed in order to adapt it to the size of the tunnel through which it flies. The third loop stabilizes the eye in relation to the local slope, using a dedicated motor. This enables the robot to always obtain the best possible field of view, independently of its degree of pitch. BeeRotor can thus avoid very steeply sloping obstacles (see video) with no accelerometer and without measuring speed or altitude. A patent was taken out on this technology in late 2013.

With BeeRotor, it is therefore possible to put forward a new, biologically plausible hypothesis to explain how insects can fly without an accelerometer: winged insects may use cues from optic flow to remain stable, thanks to feedback loops similar to those used by the robot.

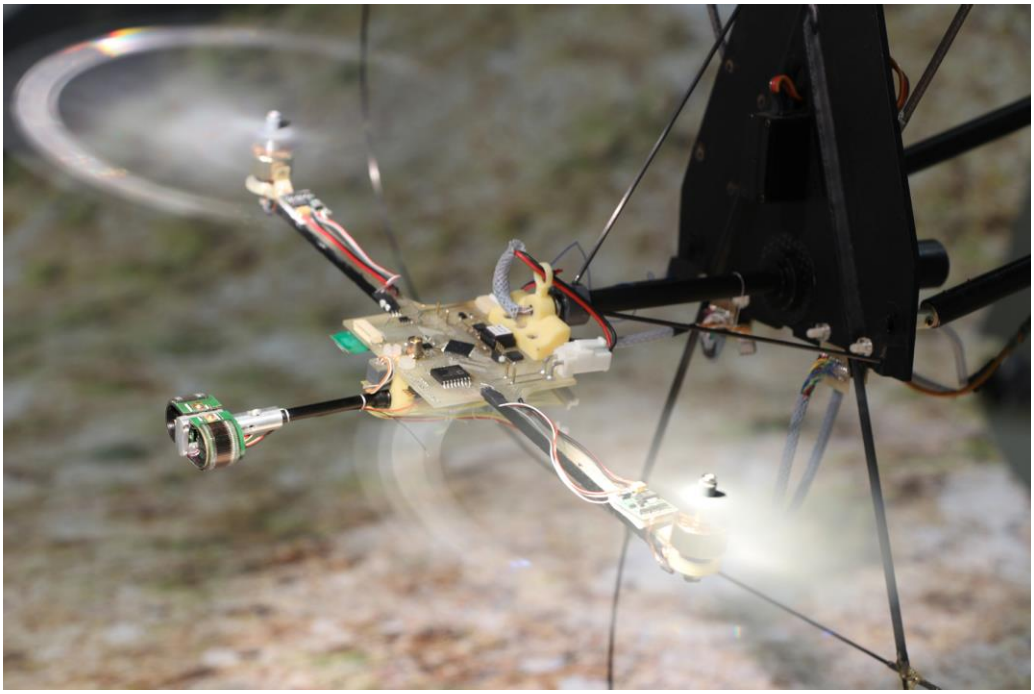
This world first also has industrial applications. Accelerometers, and therefore the inertial reference systems[3] that contain them, are too heavy and bulky for very small robots. With a mass of the order of one gram, they are not suitable for robots weighing around ten grams that could be used, for instance, to inspect piping. Lightness is also required in the space industry, where every kilogram sent into space has a considerable cost. Without necessarily replacing accelerometers, optic flow sensors could be used as an ultra-light backup system in the event of failure on a space mission[4].

***(1) The robot, which has 3 degrees of freedom (pitch, altitude, forward) flies around an axis to which it is attached by an arm, driven by the robot itself (see video).***

***(2) A feedback loop uses the output of a process, in this case optic flow, to calculate the input, in this case the speed of each rotor. This is known as a negative feedback loop, which dampens down the variations in optic flow.***

***(3) An inertial reference system is an instrument used in navigation that is able to process the measurements of a device's motion (acceleration and angular velocity) in order to estimate its orientation (angles of roll, pitch and heading).***

***(4) A subject partially tackled in the following paper in press: Sub-optimal Lunar Landing GNC using Non-gimbaled Bio-inspired Optic Flow Sensors, G. Sabiron, T. Raharijaona, L. Burlion, E. Kervendal, E. Bornschlegl and F. Ruffier,*** **IEEE TAES*****, 2015.***



***The BeeRotor robot, equipped with an eye inspired by that of insects.*** *© Expert & Ruffier (ISM, CNRS/AMU)*

*This image is available from the CNRS photo library, phototheque@cnrs.fr*

A video of the robot in flight is available at: http://youtu.be/8HrKCndp2bM.


## Reference

**Flying over uneven moving terrain based on optic-flow cues without any need for reference frames or accelerometers**, Fabien Expert and Franck Ruffier, *Bioinspiration & Biomimetics*, 26 February 2015.
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