Insect-inspired Autonomous Microflyer

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Autonomous flight in cluttered environments such as houses or offices requires high maneuverability, fast mapping from sensors to actuators and extremely light overall weight. Although flying insects are well capable to solve this problem, roboticists have been at pain to reproduce such capabilities. At the Laboratory of Intelligent Systems, we are taking inspiration from flying insects to progress toward this goal. The latest version of our microflyers, the MC2, takes advantage of principles found in flying insects in order to autonomously fly in a textured experiment room.

The MC2 airframe is a 5-gram fixed-wing airplane (figure 1) made out of carbon fibers and thin Mylar covering foils [1]. Choosing a non-flapping platform is motivated by its simple mechanical design, its robustness, and its capability to fly in tight spaces, e.g., 1m-wide corridors or 9m^2 rooms. Indeed, the research efforts in this project are focused on control rather than aerodynamics or complex flapping mechanisms.

With this kind of microflyers, it is impossible to use classical sensors such as full-featured inertial measurement units, GPS, ultrasonic or laser range finders because they would not fit the available payload (approximately 5g). Inspiration has thus been taken from flies, which possess fast, but low-resolution eyes [2], tiny vibrating organs acting as gyroscopes [3], hairs and antennas allowing for airflow

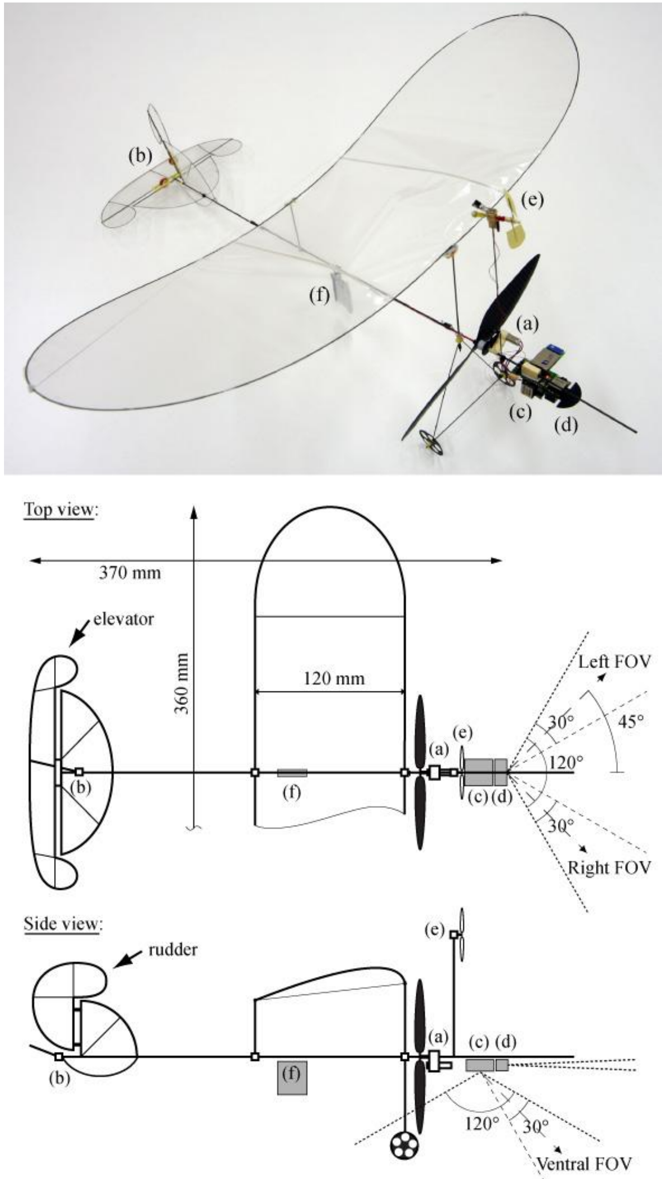

Figure 1. MC2 microflyer. The on-board electronics consists of (a) a 4mm geared motor with a lightweight carbon fiber propeller, (b) two magnet-in-a-coil actuators controlling the rudder and the elevator, (c) a microcontroller board with a Bluetooth module and a ventral camera with its pitch rate gyro, (d) a frontal camera with its yaw rate gyro, (e) an anemometer, and (f) a Lithium-polymer battery.

sensing [4]. Accordingly, the MC2 is equipped with tiny visual sensors – out of which less than 100 pixels are used – small MEMS rate gyros measuring pitch and yaw rotational velocities, and an anemometer to sense airflow.

These sensors are complemented by a small 8-bit microcontroller, in which image sequences are processed to estimate radial optic flow in three different locations at 45° off the forward direction of the airplane: on the right, on the left, and on the bottom (figure 1). These optic flow estimates are then corrected for body rotations using the onboard gyros in order to simulate gaze stabilization present in insects [5]. Autonomous control is achieved by means of simple connections between these optic flow inputs and the control surfaces (rudder and elevator). It essentially relies on the fact that translational optic flow is inversely proportional to distance [6]. In addition, the anemometer input allows for controlling the main motor in order to keep the airspeed within a reasonable range.

Once released in its environment, the microflyer would fly for a few minutes while avoiding collisions with surrounding surfaces (walls and floor) until it is caught by hand (see video at http://lis.epfl.ch/microflyers). This result showing full autonomy of a 10-gram indoor microflyer is based on preliminary studies in lateral and vertical vision-based collision avoidance, both in simulation [7] and reality [5].

Next steps include autonomous take-off and landing as well as the replacement of the onboard cameras with custom-developed neuromorphic vision chips [8] in order to adapt to a wider range of visual contrasts and background light intensites. These efforts will pave the way toward fully autonomous flight in unmodified indoor environments.

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