Bio-inspired Indoor Microflyers

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Objectives & Approach

There are not yet fully autonomous flying robots capable of maneuvering in small cluttered environments as insects do. The substantial weight and energy constraints typically encountered in this kind of robotic applications preclude the use of powerful processors and classical distance sensors. Moreover, due to their highly dynamic motion, flying systems require fast sensory-motor mapping.

To pave the way toward fully autonomous indoor flying robots we take inspiration from flying insects like flies because (i) they generally display efficient flight control capability in complex environments in spite of their limited weight and tiny brain, (ii) the sensory modalities they are using for flight control have artificial counterparts (sensors) that fit the limited available payload, and (iii) a large body of literature has been produced by biologists on their anatomy, sensors, processing pathways, and behaviors.

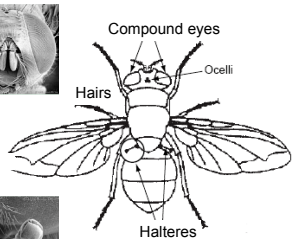
Biological Model

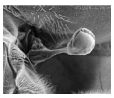
Sensors

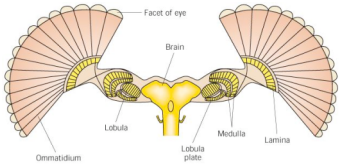
- Vision, inertial sensors and hairs
- No GPS, no distance sensors

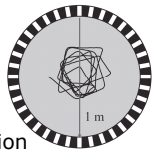
Information processing

- Image preprocessing
- Optic flow detection
- Spatial integration
- Sensor fusion







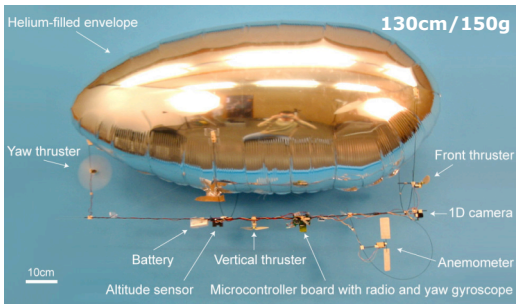


Behavior

- Course stabilization
- Obstacle avoidance
- Altitude control

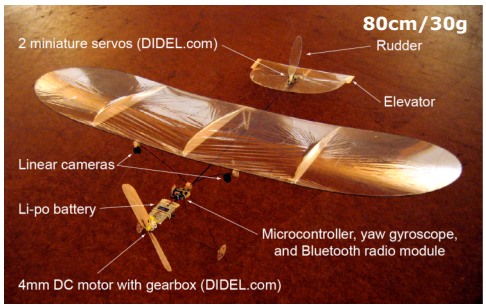
Flying Platforms

Blimp2b (2002)



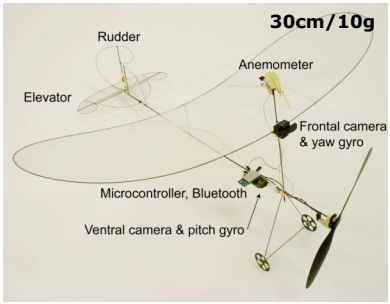
- 1 frontal 1D camera
- 1 yaw rate gyro
- 1 anemometer
- Experimentation room: 25 m^2
- Autonomy: 2 hours

F2 (2004)



- 2 frontal 1D cameras
- 1 yaw rate gyro
- Experimentation room: 256 m^2
- Autonomy: 20 minutes

MC1 (2006)



- 2 1D cameras (frontal & ventral)
- 2 rate gyros (yaw & pitch)
- 1 anemometer
- Experimentation room: 42 m^2
- Autonomy: 10 minutes

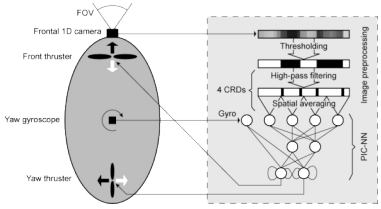
Experiments & Results

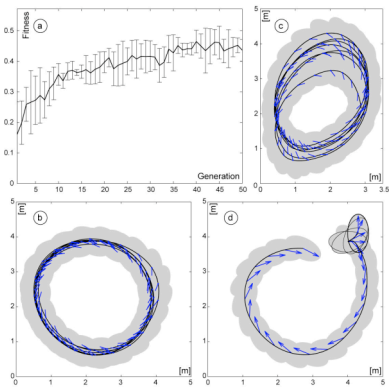
Blimp

With the blimp, simple embedded neural networks were artificially evolved (either in reality or in simulation) to map visual and inertial inputs to motor commands.

The fitness was evaluated according to the integrated forward velocity as measured by the anemometer during 2 minutes trials.

Good evolved individuals were capable of efficiently moving around the room while avoiding collisions.

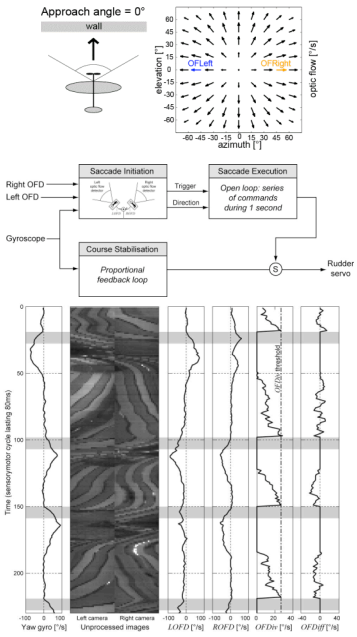




Airplanes

Artificial evolution is not feasible with real airplanes (F2 and MC1). Therefore, we directly copied biological solutions and adjusted the related parameters by trials and errors.

At the end, both models demonstrated robust autonomous steering in textured environments with different control strategies to stabilize their course and avoid collisions. The MC1 is also capable of speed regulation.



Future Work

- Altitude control based on ventral optic flow
- Improved vision sensors with integrated optic-flow detection and light adaptation (ongoing collaboration with Institute of Neuroinformatics, Zurich)
- Artificial evolution in simulation for co-evolution of control and shape
- Systematic variation of visual textures

More information, publications, pictures and movies at
http://lis.epfl.ch/microflyers