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Artificial Moth: Insect-based Neural Models of Course Stabilization and Obstacle Avoidance Applied to a Flying Robot

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AMOTH

Introduction

Navigating within a 3D environment is very challenging for both animal and robots; usually some sensory-based systems have to be used for this purpose.

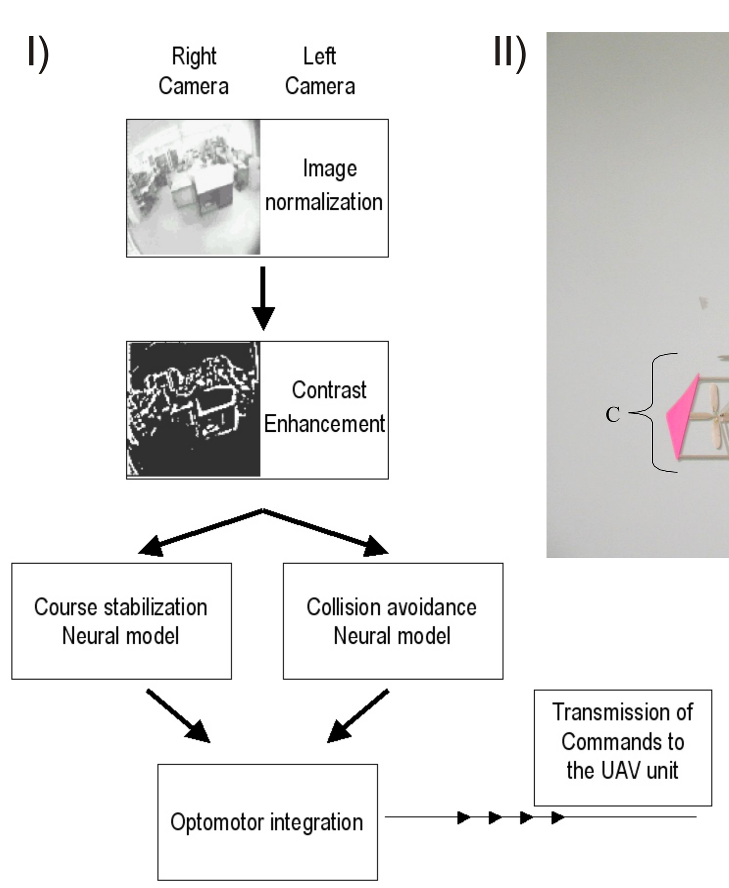
The principal tasks for autonomous navigation are course stabilization, altitude and drift control, and collision avoidance. We have focused on biologically inspired systems, since they show a robust response using simple reactive systems that allow insects to control flight course, avoid collisions, secure takeoff and landing.

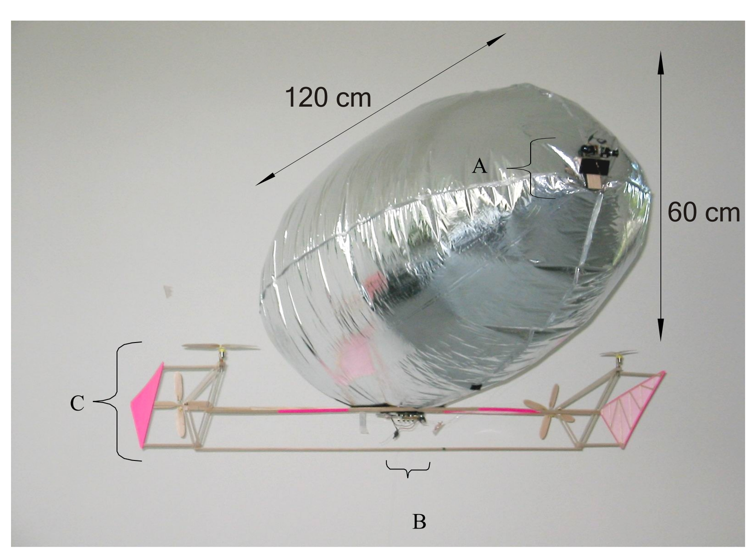
The intention of this project is to study how different insect-based models can be connected in order to perform reliable autonomous navigation.

Methods

Unmaned Aerial Vehicle

We have developed a blimp-based robot designed to work within indoor environments.



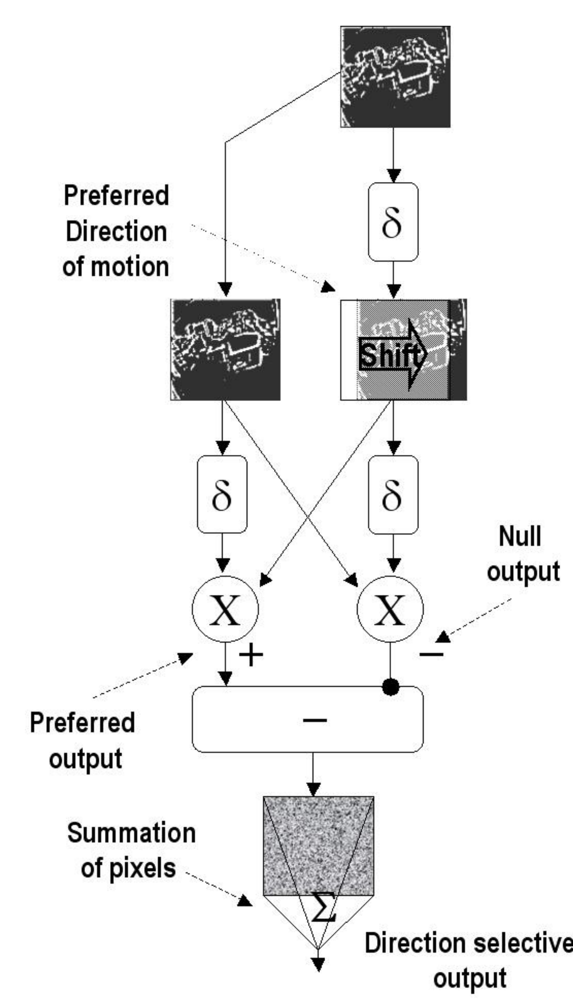


Structure of the implemented models and general characteristics of the UAV.

I) General structure of the implemented models for visual navigation and how they work together.

II) The UAV is equipped with two CCD color cameras on the front part, pointing to left and right sides respectively separated by 110° (A). The UAV is controlled by the neural simulator program IQR421 via a wireless link and has 1 hour of autonomy (B). Four propellers provide the robot with independent control for UP/DOWN and FORWARD/BACKWARD movement (C).

Course Stabilization Model

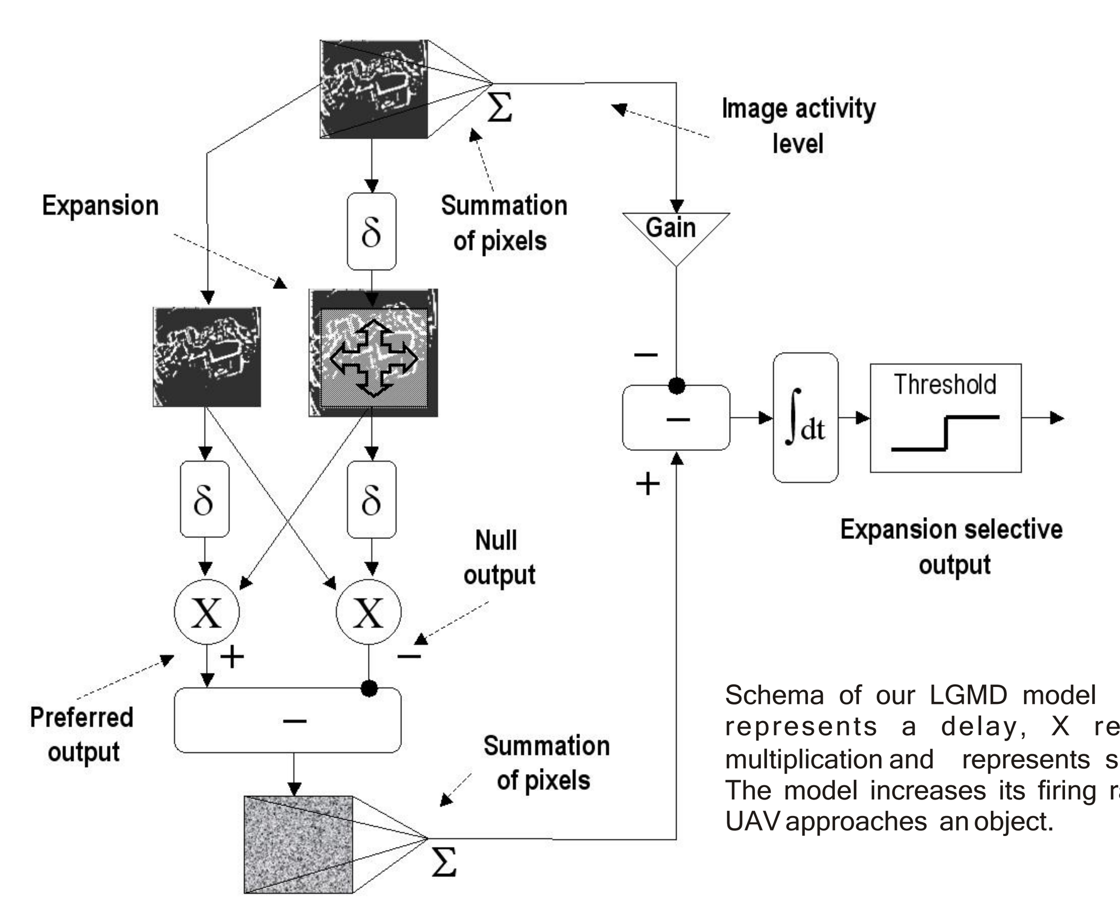


A model based on the fly's stabilization system has been implemented. Some cells (HS and VS) in the fly visual system respond selectively to horizontal and vertical motion in the visual field[1]. Their response is believed to trigger compensation movements for course drifts. Compensatory movements are performed in the oposite direction of the detected[2] visual flow.

Schema of a single Elementary Motion Direction where represents a delay, X represents multiplication and represents summation. The output value is proportional to the optical flow detected[3].

Collision Avoidance Model

A model of the LGMD cell of the locust is used to avoid collisions. The LGMD cell is a wide-field neuron that responds to looming stimulus in the visual field[4].

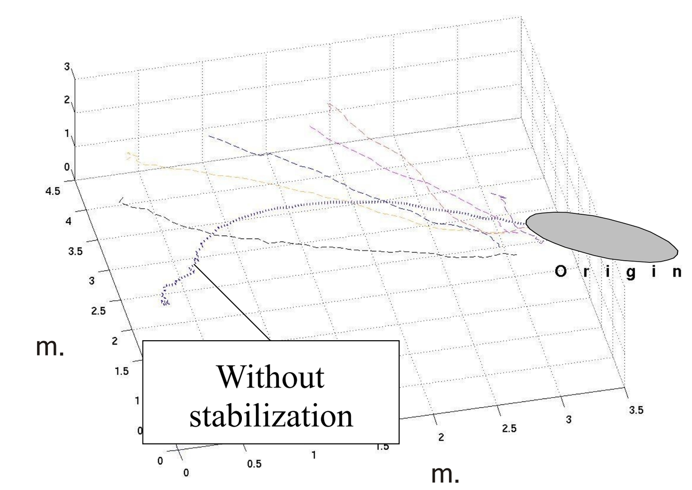


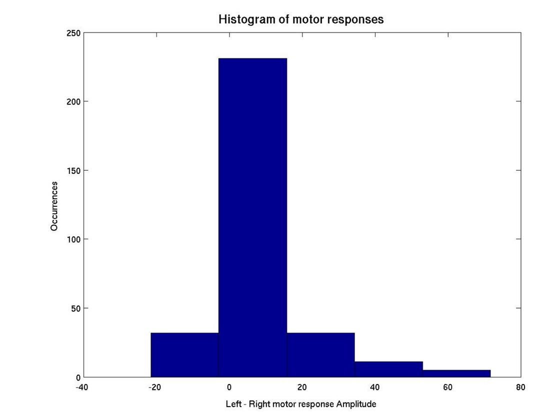
Schema of our LGMD model where represents a delay, X represents multiplication and represents summation. The model increases its firing rate as the UAV approaches an object.

Results

Course stabilization (Lateral compensation)

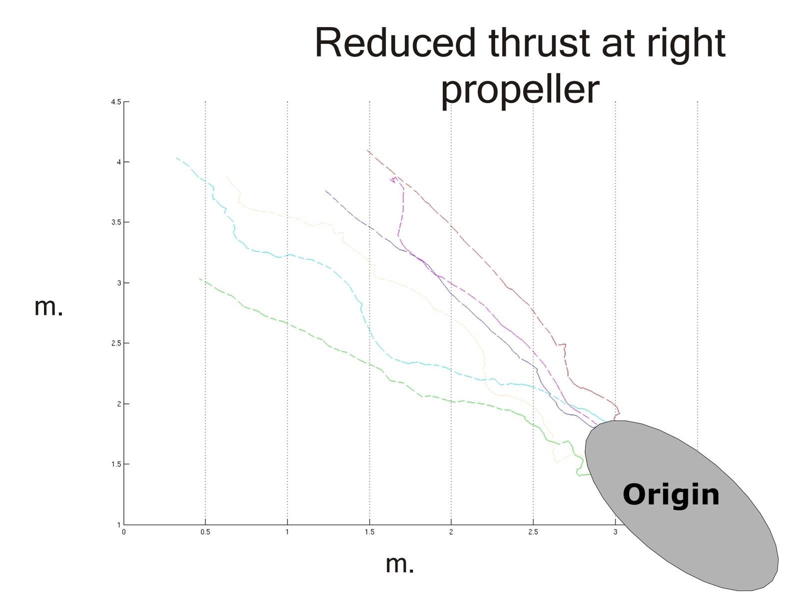
We evaluate the stabilization model referring to the behavior of the UAV for different cases of biased motor control.

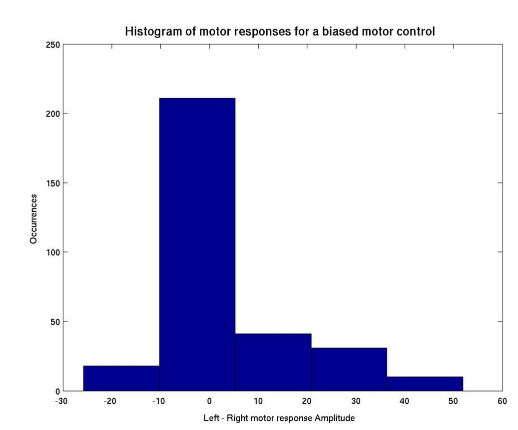




Mean velocity: 0.617 m/s.

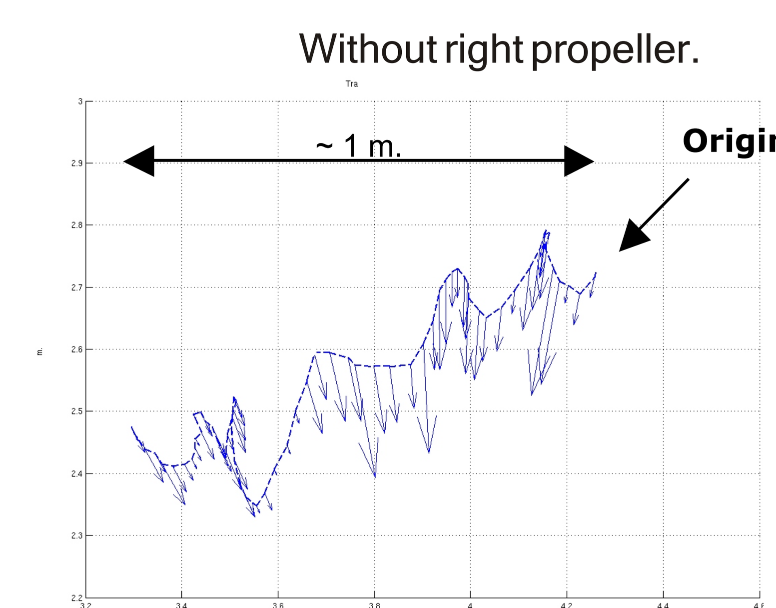
- Traces for unbiased motor control stabilization.
- Left - Right motor compensation histogram.
- Mean deviation of 7° with respect to ideal trajectory.
- Active compensation during 59.5% of the fight time.

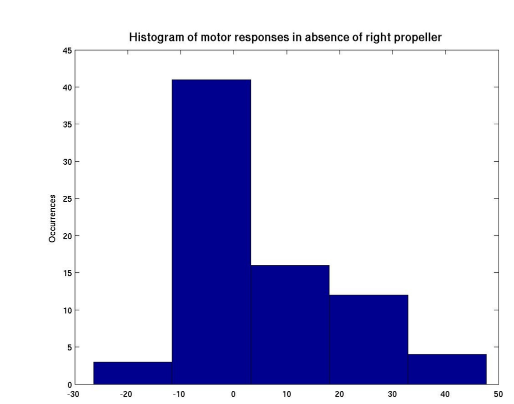




Mean velocity: 0.228 m/s.

- Mean deviation of 7° with respect to ideal trajectory.
- Active compensation during 66.7% of the time.



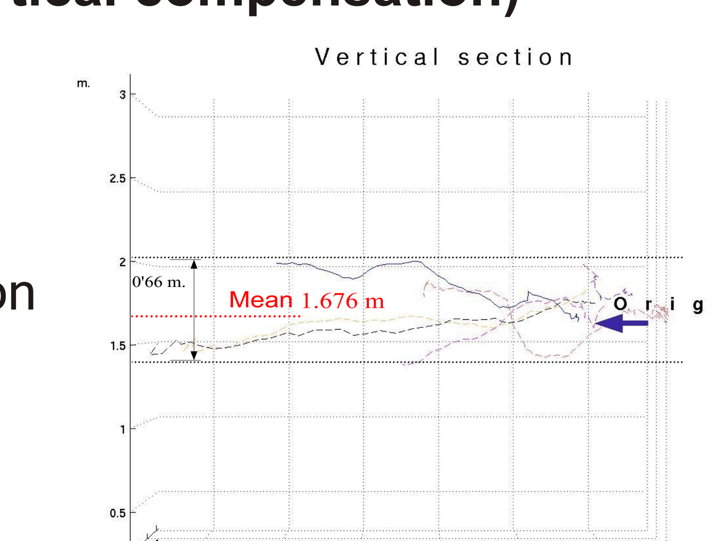


Mean velocity: 0.079 m/s.

- Active compensation during 69.7% of the time.

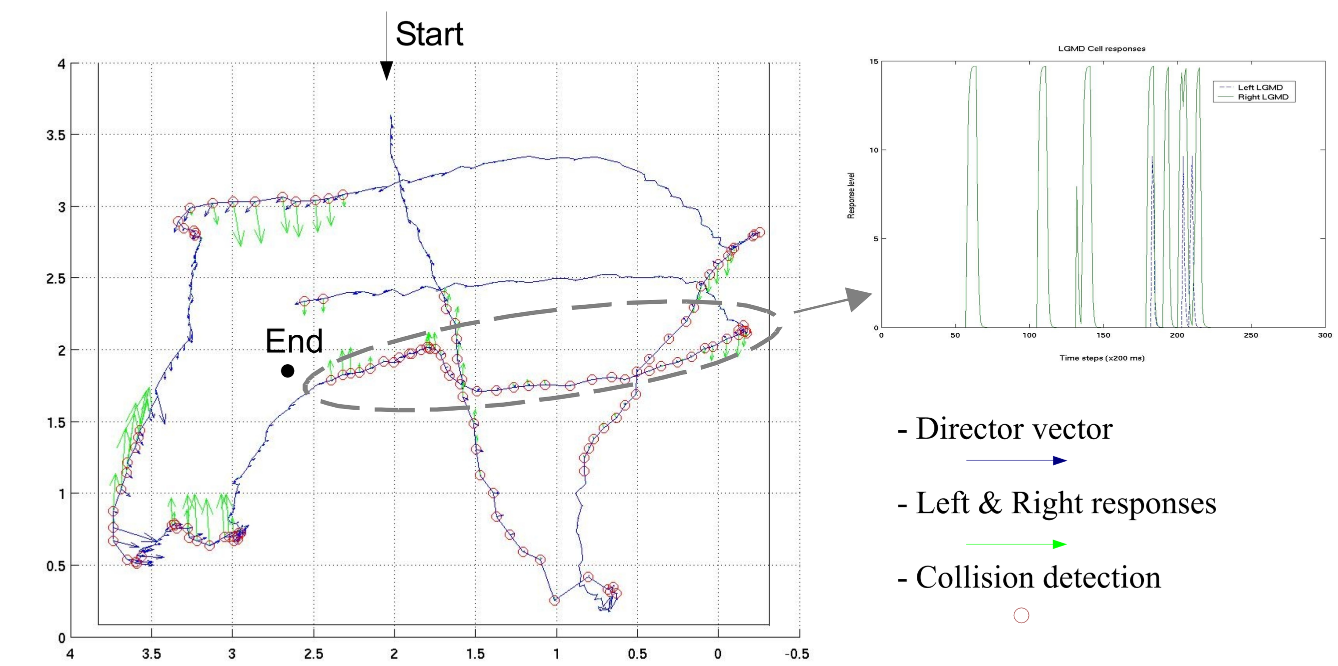
Course stabilization (Vertical compensation)

- Sustained mean altitude of 1.676 m.
- Altitude standard deviation of 0.108 m (about 18% of blimp height).



Collision Avoidance

Free flight experiment in a 4x4 meters room with randomly distributed black filled squares on the walls and also on the floor as visual cues.



- Mean collision detection distance at 1.69 m. [1-2.7 m.] where the longest distance in the test room is about 6 meters.
- A mean of 3.9 seconds is needed to perform an avoidance maneuver.
- Trade-off: Velocity of the UAV vs. Latency.

Discussion

- It is demonstrated that flying navigation can be achieved by the combination of simple insect-based reactive models.
- Making use of just 3 reactive models to navigate (course stabilization, altitude compensation and collision avoidance) using visual flow is reflected in a low computational cost, no use of additional memory or any training period.
- Two chemosensors will be added to the setup to perform olfactory searches of pre-selected compounds with the intention of locating their source.

References

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