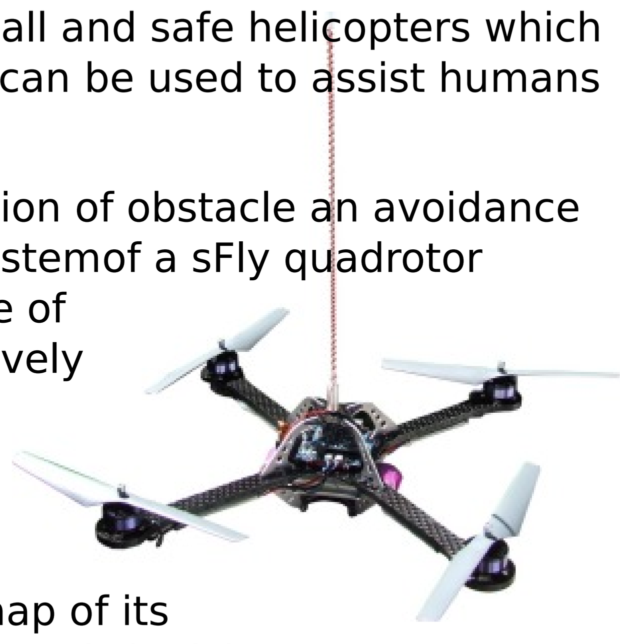
Biologically Inspired Reactive Optical Flow for Control of Flying Micro Air Vehicles

Computer Vision and Geometry Lab

Goals

The objective of the sFly project is to develop several small and safe helicopters which can fly autonomously in city-like enviroments and which can be used to assist humans in tasks like rescue and monitoring.

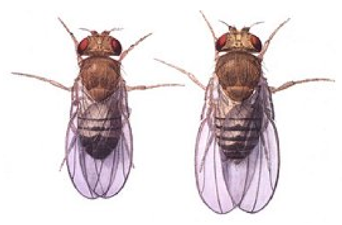
This poster describes a biologically inspired implementation of obstacle an avoidance strategy to be incorporated with the positional control systemof a sFly quadrotor helicopter. The obstacle avoidance mechanism is capable of running in real-time onboard the craft, and should effectively be able to autonomously navigate an indoor corridoor with obstacles.



The algorithm is termed 'biologically inspired' for two reasons; Firstly it does not maintain a persistant depth map of its environment, it relies on self or scene motion for detection of obsticles. Secondly, its success depends on being integrated with a position controller, and finally, its internal implementation consists of two concurrent processes whose totality determine the control output..

Biological Basis

Research undertaken on fruit fly [1] and honey bee [2] flight control behaviour by M.H. Dickenson at Caltech and by M V Srinivasan at the Australian National University have illustrated many of the biological mechanisms which regulate how these insects navigate their environment.



Experiments have shown that these organisms exploratory or goal orientated gross flight behaviour is interspersed with instantaneous control responses such as object avoidance. This arises from the combination of these concurrently running visuomotor modules. Figure 1 shows this scenario.

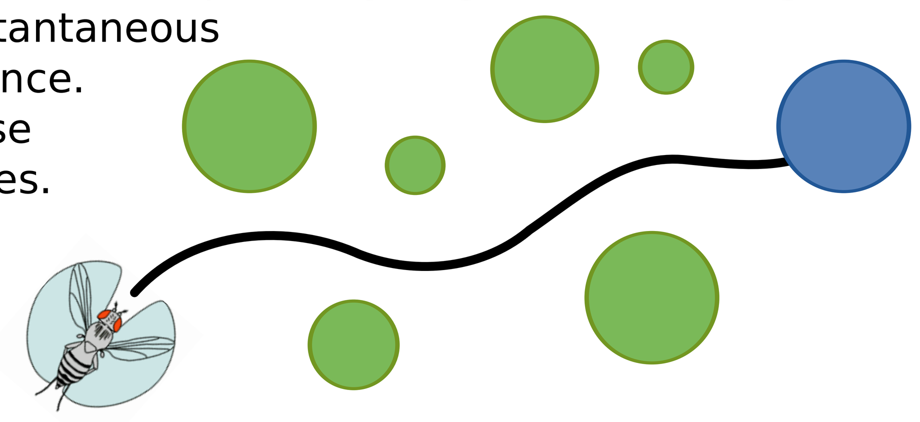


Figure 1: Fruit fly path and obsticles (green) to goal. (blue)

Implementation

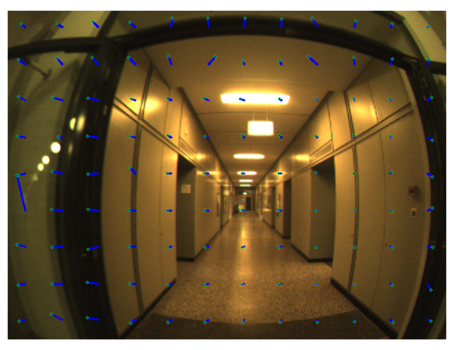
Image Capture → **Optical Flow Computation** → **Clustering** → **Coarse Optical Flow** / **Fine Optical Flow** → **Σ** → **Control Vector**

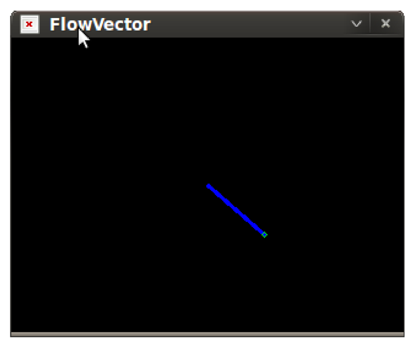
Image Capture: A single forward facing camera, fitted with a wide angle(180°) lens captures 640x480 pixel images at 30fps from the quadrotor helicopter.

Optical Flow Computation: The Pyramidial Lukas-Kanade algorithm computes the optical flow across N regions of the image. The brightness variance for each region is calculated and low values (regions with insufficient texture) are excluded.

Clustering: The optical flow vectors for each region are grouped into clusters using the k-means clustering algorithm. The clustering space includes the magnitude, direction, and distance from the focus of expansion of the image.

Control Vector: Both individual outputs from the fine and course processes are blended to give a single force vector for the position controller.





Coarse Optical Flow

Here we describe a novel approach for coarse obstacle avoidance, that is, avoidance of large features such as walls. It was shown in [3] that in the case of a wheeled robot, undergoing translation, by using a predetermined motion template that one is able to regulate robot motion, and avoid static obstacles providing they are sufficiently textured. Figure 2 shows the biological counterpart to this behaviour, the expansion avoidance strategy observed in insects. .

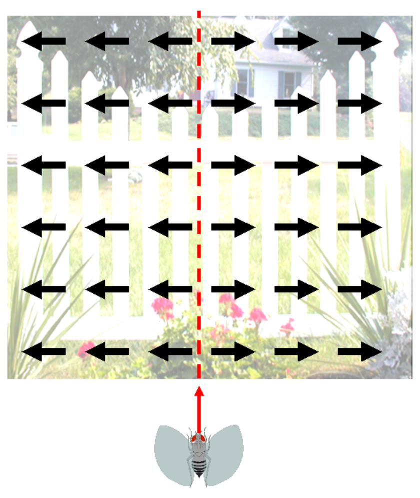
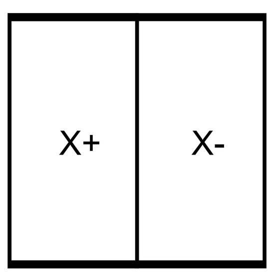


Figure 2: Fruit fly avoidance of regions with large flow

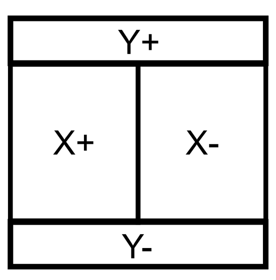
After the optical flow computation the flow vectors are grouped into clusters. Large clusters (remember we are looking at course flow) are sorted into bins described by the motion template, shown in Figure 3. By adjusting the design of the motion template an avoidance strategy can be generated.

That is, a large cluster of motion on one side of the image should generate an opposing force. The shape of the motion template can constrain the forces, for example, figure (b) below is suitable for flight in a hallway, while figure (a) is not.



A motion template for generating a corrective force in the X direction.

(a)



A motion template for generating a stong corrective force in X, and a weaker force in Y

(b)

Figure 3: Motion templates used in flight

Fine Optical Flow

Work is still being undertaken to improve the detection of non static obstacles. The current implementation uses the RANSAC (RANdom SAmple Consensus) algorithm to sort the flow vectors in a region centered about the focus of expansion of the frame. This is the area of the frame that one must be watchful of, inorder to avoid forward collisions.

The inliers after RANSAC represent those vectors which uphold the epipolar constraint under translational motion. The outliers represent objects that do not - such as moving obstacles. A clusters of outliers, particularly in the centre of the frame close to the focus of expansion, should generate a strong opposing force.

Vectors with consistant motion
Vectors with inconsistant motion, outliers

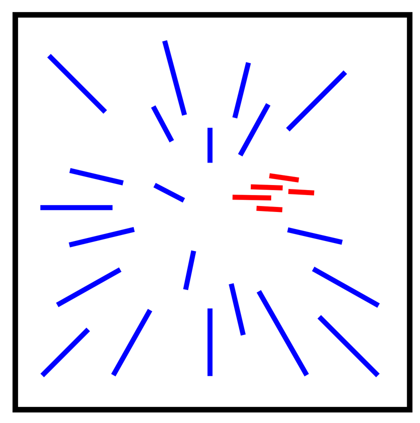


Figure 4: Classification algorithm example results

Results and Future Work

The current implementation is able to generate correct force vectors to steer the quadrotor around coarse obstacles when run against a number of image sequences. The fine optical pathway is also able to detect smaller obstacles in the forward view, although improvements in this process are ongoing.
In addition to improvements, future work will focus on integration of intertial data from the onboard sensors, as others [4] have shown this useful in separating self from scene motion.

Bibliography

[1] L. F. Tammero and M. H. Dickinson, "The influence of visual landscape on the free flight behavior of the fruit fly Drosophila melanogaster." *J. Exp. Biol.*, vol. 205, no. Pt 3, pp. 327–43, 2002.

[2] Srinivasan, "An overview of insect-inspired guidance for application in ground and airborne platforms," *Proceedings of the Institution of Mechanical Engineers Part G Journal of Aerospace Engineering*, vol. 218, no. 6, p. 375, 2004.

[3] D. Coombs, M. Herman, T.-H. Hong, and M. Nashman, "Real-time obstacle avoidance using central flow divergence, and peripheral flow," *Robotics and Automation, IEEE Transactions on*, vol. 14, no. 1, pp. 49–59, Feb 1998.

[4] T. Gandhi, "Detection of obstacles on runways using ego-motion compensation and tracking of significant features," *Image and Vision Computing*, vol. 18, no. 10, p. 805, 2000.

Credits

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