Optic-flow-based Navigation for Ultra-light Indoor Aircraft

Introduction

Goal
The goal of this project is to develop an autonomous micro-flying robot capable of navigating within indoor spaces at small building environments using as main source of information visual feedback.

The Problem at Hand
Flying indoors implies a number of challenges that are not found in outdoor avian flight. These include small size and slow speed for maneuverability, light weight to fly silently, low-reference environments, and the need to avoid obstacles. These challenges require that the robot be equipped with robust and reliable vision-based guidance systems, as well as an efficient control strategy. In particular, the robot needs to be able to estimate its position and orientation within its environment.

Ideal Optic Flow

Typical Patterns of Optic Flow

- **Approach angle = 0°:** Edge detection in the image plane.
- **Approach angle = 45°:** Parabola detection in the image plane.

Translational and Rotational Optic Flow

**OFLeft:** OF viewed by a left linear camera.

**OFRight:** OF viewed by a right linear camera.

Simplified Image Interpolation Technique

**OFDiv:** divergence of **OF**

Estimation of 1D Optic Flow

**OF Diff:** difference of **OF**

Control Criteria

- **OF MSE:** Mean squared error of the optic flow.
- **OF MSE:** Error from the estimated image.

Actual Optic Flow Estimation compared to Yaw Gyroscope

The robot is hold by hand in the test area while subjected to pre-stationary or pre-rotationary rotations.

The robot has been reducted for re-usage in autonomous steering of a 30-gram indoor airplane capable of modeling its course and avoiding environment obstacles in a square 16 by 16 meters.

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Control Strategy

The micro robot is intended to fly along straight trajectories interpolated with pre-defined turning actions (saccades), whenever necessary. The respective direction is defined by a 2D vector x, defined as a vector pointing away as quickly as possible.

Sample of Sensor Data during Autonomous Flight

Camera Orientation and FOV

10 images from left and right linear cameras

Test area (16 by 16 meters)

OF Left detector

OF Right detector

Flow Chart for the Generation of Saccades

Gaze Control


case B: white noise with 30% range
case A: no blur
case B: max blur (sigma=20)
case B: max blur (sigma=20)
case A: high contrast (100%)
case B: max blur (sigma=20)
case A: high contrast (100%)
case A: no blur

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