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ROBUST ATTITUDE STABILIZATION OF A TRACK FOLLOWER MICRO AERIAL VEHICLE USING A VISION-BASED SENSOR

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Autonomous track follower Micro Aerial Vehicles (MAVs) have been considered by researchers for the past few years. Recently there are many studies on achieving a stable and reliable MAV flight to perform accurate missions with high performance. Since human access is highly restricted in harsh environments, conventional navigation systems are not able to complete many of the required tasks. Track follower MAVs are implemented to many applications such as water channels [1] and railways [2] inspections and etc. Here, we propose a line following method and compare two attitude controllers. The aforementioned line following method can be divided into three tasks: 1) image processing algorithm, 2) path planning strategy and 3) attitude stabilization. The environment under study contains a ground floor with predetermined red tracks in which MAV is allowed to move on. Next, we explain each task briefly.

Image Processing

First, a colour detection algorithm is applied to form a thresholded image. Then to make the image smoother and to reduce noise effects, a Dilation algorithms is applied (Fig. 1.b). Thereafter, the edge of tracks in thresholded image is extracted using the Sobel algorithm (Fig. 1.c). Next, Hough Transform and "*Hough peaks*" algorithms are employed to detect the side lines of the tracks (Fig. 1.d). In the next step, the dominant side lines in the previous step are extracted for each side of the track based on their orientations (Fig. 1.e). Then desired lines can be easily found by averaging the side line parameters (Fig. 1.f). Finally the intersections of desired lines and image boundaries tend to providep_1, p_2,p_3 and $p_4$points in the image frame which can be useful for path planning (Fig. 1.f).

Path Planning

The intersections of desired lines and image boundaries in pervious section indicate the correct target. The methodology for selecting the appropriate point is to filter out some points that do not contain any filled pixels in the binary image (Fig. 1.b). For the take-off phase, the point with smaller y in the image frame is chosen and for the rest of iterations, the point with lower distance to the former target is selected. Then, the desired velocity in body frame can be derived using the following equations

$$v_x = k_p dx;\ v_y = k_p dy + k_d \acute{\alpha} \tag{1}$$

where k_p and k_d are positive constants and α is shown in Fig. 1.g schematically. dx and dy can be calculated as

$$dx = \|\hat{d}\| cos\alpha;\ dy = \|\hat{d}\| sin\alpha \tag{2}$$

where $\hat{d}$ is the target direction in the body frame with a unit size (Fig. 1.g).

Attitude Controller Design

Two controllers are considered to stabilise the attitude of the MAV. First, a linear Proportional-Integral-Derivative (PID) controller is selected. Then, a robust nonlinear sliding mode controller is designed and its stability is guaranteed using the Lyapunov's direct method. Due to the limitation in paper pages, both linear and nonlinear controllers are derived for the roll channel and they can be extended to other channels similarly. A linear PID roll torque is

$$\tau_\phi = \kappa_p(\phi_r - \phi) + \kappa_i \int(\phi_r - \phi)\, dt - \kappa_d \acute{\phi} \tag{3}$$

where $[\kappa_p \quad \kappa_i \quad \kappa_d] = [0.011 \quad 0.010 \quad 0.003]$ are PID gains and ϕ_r is the command roll. Next, the conventional sliding surface for roll channel can be defined as

$$S_\phi = -\acute{\phi} + \lambda_\phi(\phi_r - \phi) \tag{4}$$

where λ_ϕ is a positive sliding gain. As a result, by applying the Lyapunov's direct method, the stability of the system can be guaranteed and the roll control torque can be derived as

$$\tau_\phi = I_x \left[\mu_\phi sign S_\phi + \frac{I_z - I_y}{I_x} \acute{\theta}\acute{\psi} - \lambda_\phi \acute{\phi}\right] \tag{5}$$

where μ_ϕ is a positive sliding gain. To avoid chattering phenomenon, one can approximate the discontinuous signum function with the hyperbolic one in Eq. (5) (Fig. 1–3).

Simulation Results

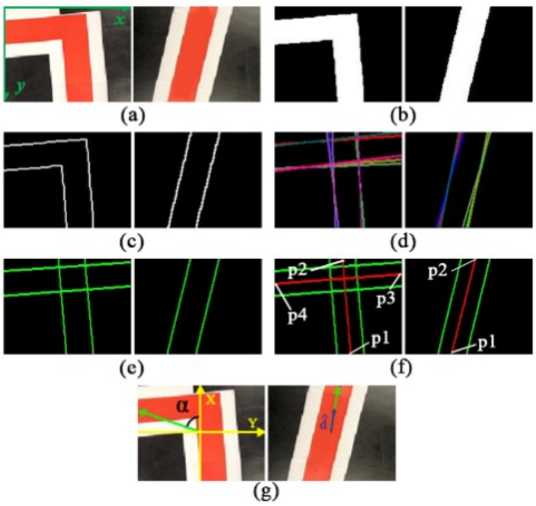

Fig. 1. Image processing and path planning

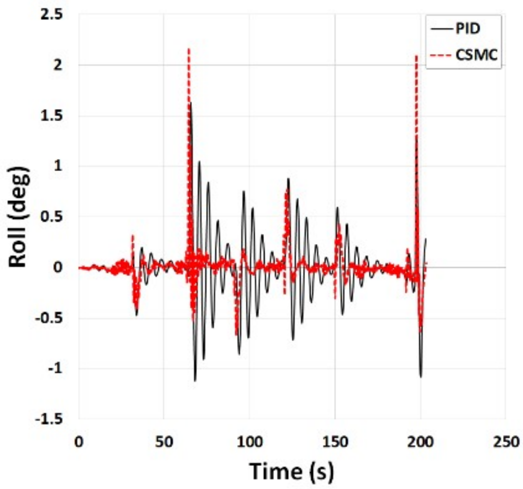

Fig. 2. Time history of the roll angle

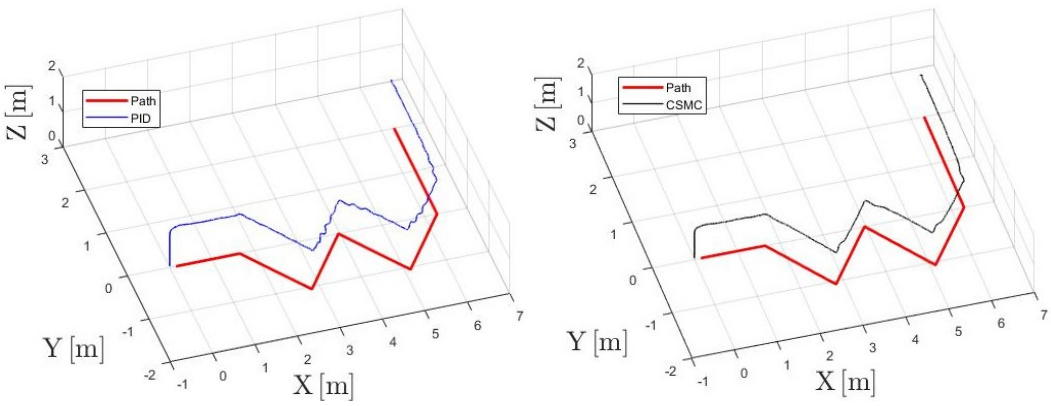

Fig. 3. System trajectory based on the linear PID and nonlinear conventional SMC algorithms

References

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