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Fast, vision-based, line-following schemes for Micro Aerial Vehicles in nuclear environments

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Content

Many nuclear power plants are reaching the end of their economic lifetime and the decommissioning of legacy nuclear facilities is an important challenge in the next few decades. Since the radiation level in these facilities is significant, autonomous robots are likely to be a large part of the solution. For this purpose, the mapping and inspection of nuclear facilities can be performed using autonomous Micro Aerial Vehicles (MAVs). 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 nuclear environments, conventional navigation systems are not able to complete many of the required tasks. Track follower MAVs have been implemented in many applications, such as water channels and railway inspections. To illustrate some of the issues involved, this research considers a line-following method and compares two attitude controllers. The approach can be divided into three tasks: 1) the image processing algorithm, 2) the path planning strategy and 3) attitude stabilisation. The environment under study contains a ground floor with predetermined red tracks over which the MAV moves. We explain each task briefly in the following.

Image Processing

First, a colour detection algorithm is applied to form a thresholded image. To make the image smoother and to reduce noise effects, Dilation and Erosion algorithms are applied. Then, in each iteration, a vector is created by the boundary layer of the provided image. Morphological operations are performed to remove small discontinuities for each cluster. Here the goal is to find the midpoint of each cluster, known as keypoints. Finally, the obtained vector should be re-mapped to its original image matrix.

Path Planning

The methodology for selecting the appropriate target point is to compare the distance between the keypoints and the target. For the take-off phase, the keypoint with smaller y in the image frame is chosen and, for the remaining iterations, the keypoint with lower distance to the target is selected. Then, the desired velocity in the body frame is calculated.

Attitude Controller Design

Two controllers are considered to stabilise the attitude of the MAV. First, a linear Proportional-Integral-Derivative (PID) controller is selected. A linear PID control for yaw torque is derived. Secondly, a conventional sliding surface for the yaw channel is defined and, by applying Lyapunov’s direct method, the stability of the system is guaranteed. The yaw control torque is derived as a function of the designed positive sliding gain. Finally, to avoid chattering phenomenon, one can approximate the discontinuous signum function with the hyperbolic one.