

HOMOGRAPHY-BASED POSE ESTIMATION TO GUIDE A MINIATURE HELICOPTER DURING 3D-TRAJECTORY TRACKING

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Abstract— This work proposes a pose-based visual servoing control, through using planar homography, to estimate the position and orientation of a miniature helicopter relative to a known pattern. Once having the current flight information, the nonlinear underactuated controller presented in one of our previous works, which attends all flight phases, is used to guide the rotorcraft during a 3D-trajectory tracking task. In the sequel, the simulation framework and the results obtained using it are presented and discussed, validating the proposed controller when a visual system is used to determine the helicopter pose information.

Keywords— Aerial Vehicles, Planar Homography, Underactuated Machines, Nonlinear Control.

I. INTRODUCTION

In the last decades the research effort related to Unmanned Aerial Vehicles (UAV) has grown substantially, aiming at either military or civil applications, such as inspection of large areas in public safety applications, natural risk management, intervention in hostile environments, infrastructure maintenance and precision agriculture (Kendoul *et al.*, 2010). In such cases, the use of a UAV is extremely advantageous, compared to the use of one or even several Unmanned Ground Vehicles (UGV), due to its 3D mobility.

Consider, for instance, a miniature helicopter, similar to a real helicopter, this UAV is one of the most complex flying machines, due to its high maneuverability, which allows it to takeoff and land vertically, to hover, to rotate, to move aside or ahead while keeping the height, to change the direction of its movement very quickly, as well as to completely stop (Castillo *et al.*, 2005). For these capabilities, it is quite useful for many tasks as aforementioned. Moreover, the complexity of the dynamic model of such rotorcraft makes the use of nonlinear flight controllers a good option to take into account that such vehicles represent an inherently unstable, nonlinear, multi-variable and underactuated system, with complex and highly coupled dynamics.

Actually, a meaningful research effort has been devoted to design flight controllers to guide miniature helicopters autonomously. Traditionally, such controllers involve inner and outer loops, which are responsible, respectively, for stabilizing the vehicle dynamics and for controlling its navigation based on its kinematics model

(Antunes *et al.*, 2010). However, guaranteeing the stability and the performance of the two control systems when working independently is not enough to guarantee the stability and performance of the whole control system, due to the highly coupled dynamics. Another research line considers an integrated solution for the dynamic and kinematic systems, commonly based on nonlinear control techniques.

In Dzul *et al.* (2003), for instance, it is proposed a robust controller based on classical and adaptive pole placement techniques, to control the yaw angle and the height of a mini-helicopter, whose dynamic model was obtained using the Euler-Lagrange formulation. In Palomino *et al.* (2003), it is proposed a system to control the pose of a PVTOL (Planar Vertical Takeoff and Landing) aircraft, which is based on the linearization of the simplified dynamic model (such simplification is associated to the planar movement). The stability of such system is also analyzed, using the theory of Lyapunov for linear systems. In Kahn and Foch (2003) and Buskey *et al.* (2003), it is implemented the pose control of a mini-helicopter, using an adaptive neural controller and a group of nested PID controllers, respectively. In Marconi and Naldi (2006), it is designed a robust controller for reference tracking, considering longitudinal, lateral, vertical and yaw movements, and considering the parametric uncertainties associated to the aircraft model as well. In Budiyo and Wibowo (2007), it is discussed a trajectory tracking control based on optimal control techniques for a UAV, using a linearized complete dynamic model for the aircraft. In Martini *et al.* (2008), robust control with state observer is applied to a nonlinear Lagrangian model of a helicopter to control it under vertical wind gust. In Antunes *et al.* (2010), it is proposed a trajectory tracking controller based on gain-scheduling, applied to the linearized dynamic model of a UAV, considering the issues of the multiple time-varying sensor used during navigation. In Kendoul *et al.* (2010), a nonlinear model-based controller is designed to a quad-rotor, using inner-outer loop control scheme. A multi-variable PD controller is proposed in Lara *et al.* (2010) to stabilize the attitude of a quad-rotor, considering the data transmission delay in the stability analysis.

It is known that one of the major problems in UAV navigation is the difficulty to define its pose and linear velocities, i.e, its non-inertial variables. An approach to overcome such difficulty is to use vision based sensors, due to their ever-growing capability to capture infor-