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Decentralized control and estimation of a flying parallel robot interacting with the environment

Aerial manipulation is an emerging domain where multirotor Unmanned Aerial Vehicles (UAVs) are equipped with onboard end-effectors for grasping, transporting and manipulating objects. To enhance the payload capacity and achieve full manipulability in 3-dimensional space, a flying parallel robot (FPR) was previously proposed in which a number of UAVs are used to collectively support a passive parallel architecture. While the previous works has focused on design, modelling and motion control of the robot, it is significant to further investigate the FPR interacting with the environment.

In this thesis, the estimation and control methods dealing with the interaction with the environment are presented, which are applied to a specific FPR composed of a moving platform and a number of rigid legs attached with quadrotors actuating the system. Several momentum-based observers are implemented to estimate the external wrench exerted on the robot. An impedance-based controller is designed with the desired wrench tracking capability. Experiments show that the overall estimation and control methods can deal with modelling uncertainties, external disturbances such as additional payload and wind perturbations, as well as contact-based interaction tasks.

The second main contribution of this thesis is proposal of decentralized strategies based on onboard and intrinsic measurements of the UAVs. A vision-based estimation technique using the ArUco marker system is firstly presented, shown to be capable of reconstructing the partially the robot pose sufficient for the control in absence of any external localisation system. The previously proposed motion or interaction control algorithms can then be deployed in a decentralized manner, allowing each UAV to perform its own control based on its own measurements and information shared within all the UAVs. Experiments show the effectiveness of the proposed methods in regulating the robot configuration, achieving precise positioning tasks through teleoperation and performing contact-based interactions.

In addition, a detailed analysis on the wrench feasibility of the FPR is presented. Notions of Feasible Thrust Space and Feasible Wrench Space are introduced, with detailed computation and case studies conducted. A quantitative metric named feasibility margin is furthermore adopted, which is applied to determine the optimal leg configurations of the FPR in different platform orientations maximising the wrench feasibility of the robot accordingly to specific task requirements.

Mots-clés : Aerial Systems: Mechanics and Control; Parallel Robots; Multi-Robot Systems; Vision-based Estimation; Decentralized Control; Aerial Manipulation.