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TITRE DE LA THESE

Theoretical developments and experimental evaluation of a novel collaborative multi-drones grasping and manipulation system of large objects

Résumé

Unmanned Aerial Vehicles, because of their versatility, are expected to accomplish increasingly complex tasks, such as grasping and manipulating objects. Previous works embed additional mechanisms on quadrotors, such as grippers and/or serial manipulators. Adding motors reduces the energetic autonomy, furthermore, it is difficult for those approaches to deal with large objects, as a larger object often requires a larger gripper/manipulator thus reducing its payload.

This thesis proposes a new concept of aerial manipulation robot named Flying Gripper. This robot is a 6 DOF aerial manipulator that is intended to perform grasping, manipulating, and transporting of large objects autonomously. The Flying Gripper robot is composed of four quadrotors, four self-adaptive fingers and a body structure. The four quadrotors are linked to the body structure such that the robot is able to exert forces and torques in any direction. Each finger, actuated by one quadrotor's yaw rotation, has two phalanges and is self-adaptive so that it can adapt to the size and shape of the object and deal with position uncertainty. We present two different architectures of Flying Gripper: one with fixed-attitude quadrotors, and a modified one with mobile-attitude quadrotors.

The study of the dynamic models of the two architectures highlights that they can manipulate objects with six degrees of freedom, three in translation and three in rotation. Two different controllers are proposed for these two architectures. The main contributions of these works are, from a mechanical point of view: (1) the proposition of an original mechanical concept relying on the use of multiple quadrotors to obtain full manipulation capabilities in SE(3) and taking advantage of quadrotors yaw rotation to actuate a self-adaptive and intrinsically safe grasping mechanism (2) the proposition of a method to generate the available wrench set of a system actuated by quadrotors considering equality and inequality constraints imposed by actuation limits, mechanical stops and equilibrium relations. From a control point of view, the main contributions are: (3) for the architecture with fixed-attitude quadrotors, we propose a model predictive controller to deal with unknown mass, inertia and center of mass due to the grasped object; (4) for the architecture with mobile-attitude quadrotors, we exploit a Dynamic Control Allocation algorithm for control effort distribution, energy efficiency and continuity, considering the robot mechanical limits. A numerical simulation has been performed for each robot to validate the controller performances: (1) closing/opening of the fingers while tracking the trajectory; (2) dealing with varying dynamic parameters due to grasping objects and robustness against external disturbances and noise.

Experimental tests have been carried out on the Flying Gripper with mobile-attitude quadrotors.

Mots-clés : Aerial Systems, Mechanics and Control, Grasping, Dynamic model, Model Predictive Control, Dynamic Control Allocation.

Visa du Directeur de thèse