SOUTENANCE DE THÈSE

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Soutiendra sa thèse de **Doctorat** sur le sujet :

Suivi robuste des cibles dynamiques avec véhicules aériens à l'aide de techniques basées en quaternions

Dans l'Unité de Recherche **:**

HEUDIASYC UMR CNRS 7253

Vendredi 26 avril 2019 à 14h

à l'UTC, bâtiment Blaise Pascal, salle GI 42

devant le jury composé de :

M. Frédéric Mazenc, directeur de recherche, INRIA, CentraleSupelec, Gif sur Yvette
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The aim of this PhD work is to design control and navigation algorithms for tracking dynamic ground targets using aerial vehicles. An object was considered to navigate in the ground over a planar surface such that one or multiple aerial vehicles can autonomously describe trajectories to follow it. Control algorithms were also developed to robustly track the proposed trajectories.

Most works currently found in the literature for quadrotors are based on classical approaches such as Euler angles, which can be understood intuitively, but arise problems such as discontinuities, singularities, gimbal-locks, and highly non-linear equations. Quaternions provide an alternative to classical representations, giving advantages such as their lack of singularities and gimbal lock effect, but the main one is their mathematical simplicity when handling rotations, which helps in the design of robust controllers and aggressive navigation algorithms.

Quadrotor quaternion controllers:
The first part of this thesis consisted on developing quadrotor controllers with the aim of robustly tracking trajectories and performing precise navigation tasks. Initially, a simple linear feedback control algorithm based on unit quaternions was introduced, this controller revealed mathematical properties, which made it possible to map the quadrotor model such that its dynamics can be analyzed as a fully actuated system. Later on, more quaternion-based approaches were profoundly explored, resulting in more advanced algorithms such as:
- State-feedback quaternion controller.
- Passivity-based quaternion control.
- Energy-based controllers.
- Cilindrical bounded control.
- Spherical chattering-free sliding mode controller.

Autonomous navigation algorithms:
In order to validate the previous quaternion-based controllers, several autonomous and semi-autonomous navigation schemes for aerial vehicles were introduced, the control algorithm for each scenario was selected from the ones previously developed.

Firstly, a quaternion feedback attitude controller was used along a safe navigation algorithm for piloting a quadrotor in semi-autonomous mode, using intuitive gestures from a user wearing an armband equipped with accelerometers, gyroscopes, and electromyographic sensors which trigger different actions in the quadrotor.

Then, autonomous trajectory generation and control approaches were explored for systems consisting on multiple aerial vehicles. In the context of a collaboration with the CRAN at the Université de Loraine, a path planning algorithm for quadrotors was proposed which generates vehicle trajectories in real time as a result of an online optimization of a distributed cost function, the trajectory was then robustly tracked using a quaternion-based controller.

In order to improve the capabilities of aerial vehicles, and to facilitate their operability in unfavorable scenarios and spaces, an aggressive deployment strategy was proposed where a quadrotor is hand-tossed trough the air with its motors turned off, then it autonomously recovers from its free falling conditions using quaternion-based strategies to perform an autonomous or semiautonomous mission.

Autonomous target tracking algorithms:
The last part of this thesis was dedicated to the conception of autonomous navigation techniques for tracking static and dynamic ground targets, combined with quaternion-based controllers to ensure system robustness.

First, a trajectory generation algorithm based on Hopf bifurcating differential equations was introduced for a single quadrotor for tracking a ground vehicle while describing circles, this technique inherently includes takeoff, tracking, centering and landing stages as part of the solution of a dynamic differential equations set.

Finally an extension of a distributed path planning algorithm was developed for two drones to autonomously follow a target ground vehicle while describing coordinated circles, the trajectory is obtained as the solution of an online optimization problem.