Fast and Furious Computation for Drone Navigation

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I. Introduction

To successfully navigate a race track, a drone has to continually sense and interpret its environment and be robust to cluttered and possibly dynamic track layouts. It needs precise planning and control to support the aggressive maneuvers required to traverse a track at high speed.

We attempted to solve these problems by using robust Stereo V-SLAM along with IMU for localization, and classical PID control for position and attitude. The result shows that the drone can complete the track of 11 gates with a speed of 4 m/s.

II. Methodology

- *Navigation :*
  We represent a track by coarse locations of a set of gates, waypoints are adjusted to fit as much as possible these possibly changing positions. The Trajectory Planner outputs the desired path as a simple linear interpolation of these waypoints. A cascade PID controller is implemented to output the appropriate Thrust and Angular rates to be passed to the built-in low-level angular speeds controller. More details about control architecture can be found in section 3.
- *Perception :*
  Stereo V-SLAM is used along with IMU to estimate respectively the poseand attitude of the drone. More information about the perception system are present in section 4.

III. Control Architecture

A cascade PID controller is chosen for its ease of implementation and tuning simplicity.
The outer loop aims to control the tracking problem of the system along a given trajectory, which is given in a 4D subspace encompassing the position and yaw of the quadcopter. The inner loop of the controller achieves pursuit of the desired attitudes.

We first present experiments in a controlled, simulated environment. The aim of these experiments is to get a sense of the capabilities of the presented approach, and also to tune quickly the two nested PIDs.
The dynamics of the quadcopter presented in [1] are simplified, assuming that angular speeds are perfectly regulated by the provided low level controller.

To achieve straight paths, a simple, yet efficient error limitation technique is used.
Refer to the **source code** for more details.

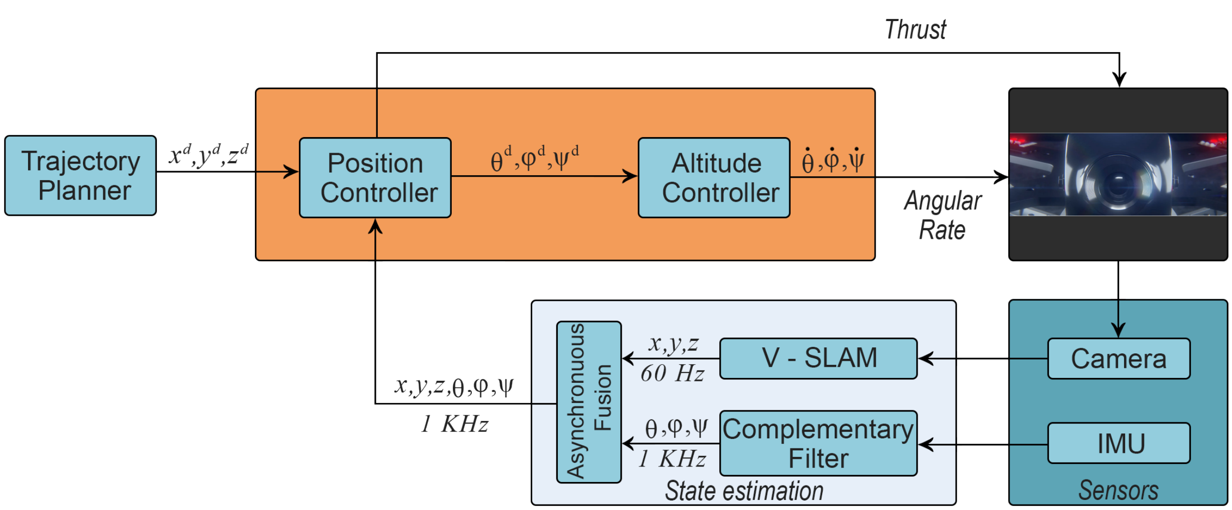

Fig. 1: System Architecture overview

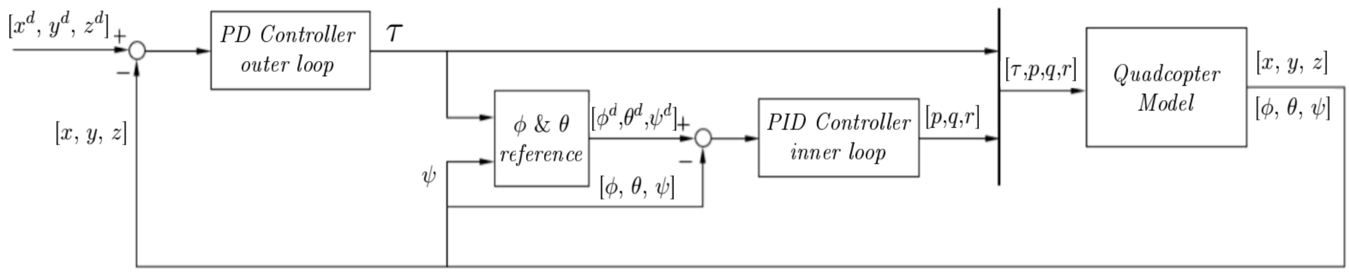

Fig. 2: Control schematic

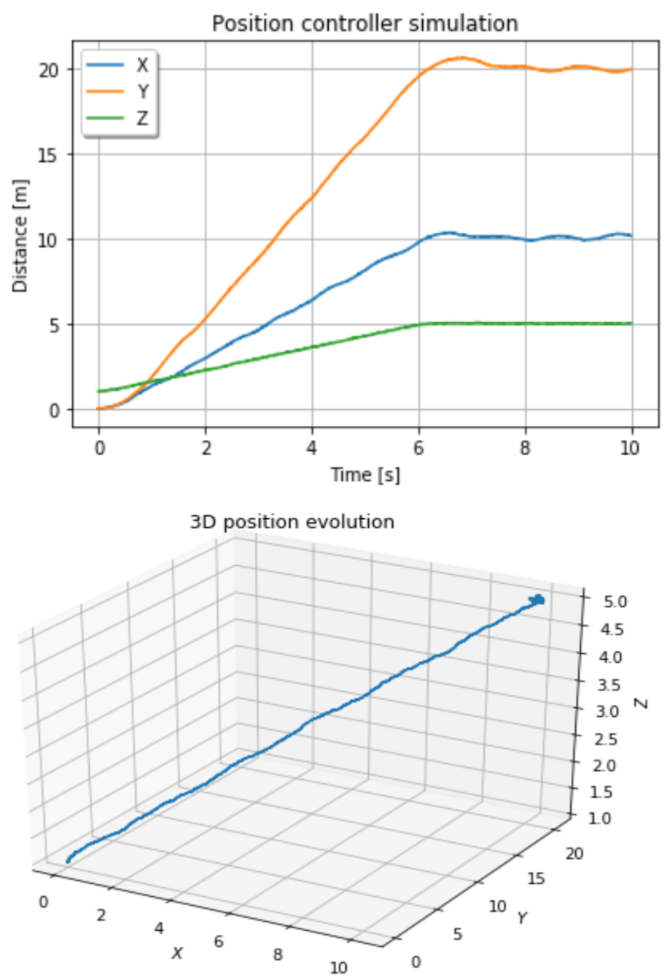

Fig. 3: Position control simulation

IV. Perception

We use state of the art Stereo Visual SLAM method as our main resource for position estimation. This choice is motivated by the unknown but static environment.
monocular SLAM suffers from scale drift and may fail if performing pure rotations in exploration. By using a stereo camera all these issues are solved and allows for the most reliable Visual SLAM solutions.
To overcome heaviness and operate in real-time, we chose the open-source library ORB-SLAM2 [3] to implement the Stereo V-SLAM algorithm. ORB-SLAM2 includes a lightweight localization mode that leverages visual odometry tracks for unmapped regions and matches to map points that allow for zero-drift localization.
Attitude estimate is achieved using Inertial Measurement Unit (IMU).
A classic complementary filter fuses the informations from gyro and accelerometer.

V. Future work and conclusion

Recent work has explored the problem of autonomous navigation by imitating a teacher and learning an end-to end policy [9], which directly predicts controls from raw images.
Motivated by this, we will attempt to surpass human level performance in drone racing by applying Deep Imitation Learning paradigm.

In this work, we presented one of the ‘experts’ to be imitated in our final approach. more sophisticated algorithms have to be considered to handle aggressive, high-speed autonomous driving [8]: Model predictive controller, Flatness-based nonlinear control strategy or global Minimum Jerk Trajectory generation [4].

References

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[4] Kaufmann et al. Deep Drone Racing: Learning Agile Flight in Dynamic Environments 2017.

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