Ph.D. 35° Cycle

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Artificial Intelligence Applications for Drones Navigation in GPS-denied or degrated Environments

In this period of fast growth for service robotics platforms, autonomous UAVs are increasing their applications daily. This phenomenon involves sectors as diverse as agriculture, search and rescue, warehouse logistics, structure inspections, and military applications. This work discusses several applications, platforms, and sensors used for UAVs autonomous navigation.
A reliable localization system is the basis of any autonomous driving application. For this reason, in environments where there is no GPS coverage, the task certainly increases in complexity. This work aims to analyze state-of-the-art techniques in terms of GPS-independent localization, based solely on onboard sensors. Furthermore, innovative techniques based on artificial intelligence for the path planning and strategic coverage of a fleet of UAVs are proposed. To do this, a study of low-level control techniques for attitude is first presented. After an overview of the main control logics for the different types of aircraft in question, a very common case study rotary-wing aircraft topology was selected: the quadcopter. In this case, an LQR-based approach is proposed, out of line with the classic PID controller adopted for this category of aircraft. At the same time, a Matlab/Simulink-based simulation model for the quadcopter is proposed and validated through experimental tests. Furthermore, following various flight tests, the developed controller was found to be able to manage the attitude of the aircraft even in uncontrolled environments.
Once we are aware of the attitude control laws of the aircraft, we move on to the analysis of the state-of-the-art techniques for the autonomous localization of the aircraft in a GPS denied/degraded environment. The goal is to obtain a system completely based on onboard sensors; therefore, sensor fusion techniques as visual-inertial odometry are needed. The latter uses optical sensors in combination with inertial sensors to estimate the relative position with respect to a known starting point and therefore does not require any external auxiliary system. In this field, avi study of the effects of the sampling frequency and the resolution of the optical flow on the localization performance, the robustness, and the computational cost of the system is presented. Interesting results were found in terms of the innovative trends highlighted, as well as the use of cpu, stability and localization error contained on a light and inexpensive commercial board.

Once the problem of localizing the robot is solved, it can be considered how to guide it in 3D space from point A to point B, assuming that there are obstacles in the surrounding environment. Several state-of-the-art approaches for this topic are presented. In this work, we present a path planner based on particle swarm optimization. With this approach it was possible to obtain promising results in terms of time needed to elaborate the trajectory.
Finally, once achieved the ability to guide individual aircraft in environments of varying complexity, we move on to an analysis of aircrafts' fleet management, with variable density, for the exploration of critical areas. Three different approaches based on artificial intelligence are proposed in this theme: cost-map-based, neural networks, and deep learning approach. The different approaches yielded interesting and distinct results in terms of computational time, quality of map exploration, and stability.