EDS 4900 Literature Review

Autonomous navigation is a major topic in Unmanned Aerial Systems (UAS), while a more specific topic is flying UAS autonomously without the use of GPS. There have been many different solutions to determining location of the aircraft without GPS attempted. Primarily, they have used some form of camera setup and onboard or exterior sensors have been used to determine their location. A consensus is that it is entirely possible, through the use of a variety of different software filters, for a UAS to fly within an indoor or outdoor space using only a camera and its internal sensors and to navigate within that same area autonomously. Sources are available primarily in the form of papers from universities such as the Massachusetts Institute of Technology and the Georgia Institute of Technology and occasionally from the databases of IEEE.

Experiments by Achtelik et al. with autonomous exploration using a quadcopter UAS carrying a stereo camera and a laser scanner in conjunction with the Inertial Measurement Unit (IMU) onboard were performed before UAS were seen by the general public. They used an Extended Kalman Filter to combine the estimates from the sensors with the IMU data to determine a more accurate estimate of the vehicles position and velocity. They then took all the previous data and gave it to a SLAM algorithm that provided delayed corrections to the external sensors’ data to ensure consistency. Lastly, they used a planner to generate and coordinate tasks and goals. Due to the computational requirements, all but the stabilization calculations were done at the ground station instead of onboard the UAS.

Expanding on Achtelik’s work, Wu et al. worked with a similar setup, except he used only one (1) camera and the IMU. His method made use of their camera by tracking objects within its frame and then measuring their movement in the camera frame and comparing it with the data from the IMU to get an idea of how the craft had moved. In his paper, he went into detail on the math involved and what was done with the data. His data also shows why GPS is used during flight, and the error that can develop when GPS is no longer used.

Landry used the same airframe that I am using for his work on generating trajectories through an obstacle rich environment using external cameras to find the UAS’s location in the 3D space. He used a couple of different pieces of software to develop a control system to find collision free trajectories through the environment. The software in question worked together in a linear fashion to determine the best possible route after lots of calculations and processing.

After reviewing the work that others have done, it appears that the most common way of working without GPS is to use some form of camera setup in conjunction with the IMU to determine where the UAS is in a 3D space. Once the location is known, it is then possible to calculate trajectories for the UAS within the known 3D space. Others may have tried using the IMU only, but there is no documentation readily available. Due to the availability of other sensors such as cameras, ultrasonic sensors, and Lidar, flying using with only the IMU may not be considered practical. I intend to give it a chance anyways.

Sources

Landry, Benoit, et al. "Aggressive quadrotor flight through cluttered environments using mixed integer programming." *Robotics and Automation (ICRA), 2016 IEEE International Conference on*. IEEE, 2016.

M. Achtelik and A. Bachrach and R. He and S. Prentice and N. Roy, “ Autonomous Navigation and Exploration of a Quadrotor Helicopter in GPS-denied Indoor Environments”, Proc. of the 1st Symposium on Indoor Flight, Mayaguez, PR, 2009

Wu, Allen D., et al. "Autonomous flight in GPS-denied environments using monocular vision and inertial sensors." *Journal of Aerospace Information Systems* (2013).