Cell Phone Navigation Research

In 2013, the Department of Homeland Security (DHS) approached the UMN UAV Research Lab to solve the following problem. There are many law enforcement concepts of operation (CONOPS) where Small Unmanned Aerial Vehicle (SUAV) deployment would be of tremendous value. The model application was border patrol in relatively vacant airspaces. However, with the current heavy reliance of SUAVs on GPS for navigation, there is a danger that if GPS is jammed, spoofed, or otherwise lost, then the SUAV would be unable to complete the mission. Moreover, it could be lost or damaged leading to increased costs for law enforcement agencies that don’t have surplus budgets. Thus, DHS tasked us with designing a system within one year for a small UAV (hand-launched) using current technology that would allow the safe recovery of such SUAVs. Safe recovery was defined as the SUAV would be able to return near enough to its home base that it could be located and another system or pilot could take over for landing.

We decided that the quickest solution would be using cell phone signals to supplement the SUAV navigation system when GPS is lost. After analyzing various approaches such as using Received Signal Strength Indicator to conduct RF Fingerprinting techniques, we settled upon using time-of-arrival information in the form of Timing Advances (TAs) that are available in some cell phone receivers. Using a multilateration approach with these TAs, we incorporated these measurements into an airspeed-based Dead Reckoning (DR) filter. This dead reckoning filter was provided with estimates for the aircraft’s attitude from an Attitude Heading Reference System (AHRS).

We built up an UltraStick 25e aircraft equipped with a Goldy Flight Control System following the designs and hardware developed by the UMN UAV Research Lab. This new SUAV, named Tyr, was flight tested to prove it was safe to fly. Next, a Multi-Tech Systems cell phone receiver was integrated into the Goldy FCS. Simultaneously, the cascaded filters of the AHRS-DR system were integrated into the flight-code of the system. Several iterations of ground testing and flight testing was conducted to validate and verify the performance and operation of the cell phone receiver and the AHRS-DR system. Finally, the cell phone-aided AHRS-DR system was designated as the navigation system to provide state estimates to the guidance and control loops of the FCS, and final flight data tests with software-enforced GPS outages were conducted at the University of Minnesota Outreach Research and Education (UMORE) Park.

However, the Certificate of Authorization (COA) that the UMN UAV Research Lab has with the FAA did not provide enough airspace to fully characterize the performance of the system. Thus, Hardware-in-the-Loop (HIL) simulations were conducted to test extended GPS-outages over longer distances that our flight test area could provide. After conducting 25 Monte Carlo simulations, a final report was created for the DHS to complete the project. Additionally, this work was submitted and accepted to the Institute of Navigation (ION) International Technical Meeting (ITM) held January 26-28, 2015.

This project archive contains all the associated documentation and technical material created by this project. Included in this project archive: the final DHS report, ION-ITM paper, ION-ITM presentation, flight-code, HIL simulation MATLAB/Simulink files, test data, and much more applicable reference material.
Future work for this project includes improving upon the accuracy of the system which is limited by the inherent design of the Timing Advance data. Higher resolution time-of-arrival information may be available through alternative cell phone receivers or through custom designed hardware. Additionally, a brief exploration of RF fingerprinting using cell phone signal RSSI was conducted, but a deeper evaluation may yield improved performance with little additional hardware required.