Reference Position and Attitude with Raw Sensor Data from Seven Small UAV Flights

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Reference trajectory and sensor data for seven UAV flights are detailed. The flights were collected over the span of 2011-2012 by the University of Minnesota UAV Research Group[1] and were retrieved for research purposes in 2013-2014. All seven flights have been successfully used to study navigation systems[2] and are being shared to serve as a working data set for testing new concepts and ideas.

1 Data Files

The names of flights collected and archived by the University of Minnesota UAV Research Group:

Date	Aircraft *(flight number)*	URI	Original File Name
08/07/2012	Thor (60)	http://hdl.handle.net/11299/164228	thor_flight60_basline_control_ekf15_alt_speed_test_08_07_2012.mat
Comments: Series of maneuvers conducted using the controller with altitude/airspeed hold on outer loop. Involved approximate 180 degree turns, doublets, and 45 degree constant banks. Airplane maintained airspeed within ± 3 m/s during straight and level flight, and ± 5 m/s during maneuvers.			
10/10/2012	Thor (75)	http://hdl.handle.net/11299/165375	thor_flight75_WaypointTracker_150squareWaypointNew_2012_10_10.mat
Comments: Nice repeated 150 ft square path.			
10/30/2012	Thor (77)	http://hdl.handle.net/11299/165376	thor_flight77_StraightLevel_basline_quat_2012_10_30.mat
Comments: Manual flight used to test on-board navigation filter.			
10/30/2012	Thor (79)	http://hdl.handle.net/11299/165377	thor_flight79_ExpandingSquare_waypoint_2012_10_30.mat
Comments: Semi-repeated expanding rectangular pattern flown using waypoint guidance.			
11/17/2011	GPS Faser (1)	http://hdl.handle.net/11299/165378	gpsfaser_flight01_studentcontrol_15stateEKF_2011_11_17.mat
Comments: Testing student controllers using standard roll/pitch doublets			
10/10/2012	GPS Faser (3)	http://hdl.handle.net/11299/165379	gpsfaser_flight03_Baseline_SystemValidation_2012_10_10.mat
Comments: Completely manual flight to test GPS antenna installation and navigation filter.			
08/07/2012	Faser (05)	http://hdl.handle.net/11299/164222	faser_flight05_basline_control_ekf15_baseline_validation_08_07_2012.mat
Comments: Series of maneuvers conducted using new gains on baseline controller (no altitude/airspeed hold). Involved approximate 180 degree turns, doublets, and 45 degree constant banks. During banking maneuvers the airplane lost significant altitude (e.g. 80 m), due to too low trim throttle setting (50%). There were lots of oscillations throughout the flight, possibly due to windy day or poorly tunned controller.			

[1] http://www.uav.aem.umn.edu/

[2] An attitude heading reference system and an airspeed-based dead reckoning navigation system were implemented

2 Processing Original Data

In order facilitate a flexible simulation architecture that could handle variable numbers of flights, the original .MAT data files were processed and parsed systematically to .CSV data files. The data processing procedure was:

1. Original .MAT data loaded
2. Reference INS/GPS lat, lon solution converted to degrees
3. Gyro and accelerometer bias estimates added back to stored measurements. For these flights the flight computer stored the *corrected* measurements (as determined by on board INS/GPS). This step gives back original sensor measurements.
4. Flip sign on the stored magnetometer y and z axis measurements. This is necessary to get the values in the common body-frame as the logged magnetometer measurements sensor frame did not match the body frame and this transformation was not yet implemented on the flight computer.
5. Calibrate the 3-axis magnetometer measurements by finding and applying a constant bias on each axis.
6. Convert baro-altimeter measurements from Above Ground Level (AGL) to absolute altitude values. This is accomplished by adding back the reference altitude (logged during startup).
7. Remove GPS measurements (position and velocity) where there is no GPS lock (i.e. navValid != 0).
8. Remove INS/GPS solutions prior to first GPS fix.
9. Round the time vector to 2 digits (e.g. t = 476.179977 becomes 476.18).
10. Crop the flight data to cuts out the initial transients, while still including the entire flight.
11. Shift time indices so that the cropped time becomes $t = 0$.
12. Add a constant lat and lon bias to both INS/GPS and standalone GPS positions.[3]
13. Write flight data to CSV files.

Future changes to the flight computer logging interface may required changes to the above steps.

3 Parsed Data

Among all the logged flight parameters, the following were finally saved into .CSV and HDF5 files:

File Name	Description	Units
	Sensors	
`accel_data.txt`	body-axes accelerations	m/s^2
`gyro_data.txt`	body-axes rotations	rad/s
`mag_data.txt`	body-axes magnetic field	Gauss
`baroalt_data.txt`	baro-altimeter pressure altitude (NOT AGL)	meters
`speed_data.txt`	pitot-probe airspeed	m/s
`control_input_data.txt`	control input commands	[normalized to 0-1]
	GPS	
`gps_traj_data.txt`	latitude, longitude, and altitude	degrees, meters
`gps_velocity_data.txt`	Vnorth, Veast, Vdown	m/s
	On Board INS/GPS	
`nav_traj_data.txt`	latitude, longitude, and altitude	degrees, meters
`nav_attitude_data.txt`	Euler angles yaw, pitch, roll	rad

The following notes are in order:

- Control inputs are the sum of human and on-board controller inputs where:

  autopilot_mode 1 *human control*
  autopilot_mode 2 *on-board control*

- GPS measurements are repeated until new data arrives ($\approx 1\ Hz$)
  - An empty log is saved when GPS unavailable (e.g. "92.22,,,")

[3] All seven flights occurred from the same runway. This step gives a spatial distribution to the flights so they are not overlaid.