Homework 5: INS Mechanization
Due: 12/11/2019 4:00 PM

1) *IMU Calibration:* Download the gyro output data gyro.mat from canvas. This is the output for a rate gyro (time in seconds and ω in rad/s). The gyro is static and inside a temperature controlled (i.e., constant temperature) chamber. Using the data, determine an error model for the gyro (bias stability, output noise, turn on bias). What limitations, if any, would you put on the model you developed?

2) *Coarse Levelling Using Earth Rate and Gravity*: A commercial jet liner is parked at the gate of an airport located at 35° latitude. The accelerometer and gyro triads in the Inertial Navigation System (INS) used by this airplane make the following readings:

$$\vec{f}_{ib}^{b} = \begin{bmatrix} -0.1710 \\ -0.2564 \\ 9.7925 \end{bmatrix} \frac{m}{s^2}$$

$$\vec{\omega}_{ib}^{b} = \begin{bmatrix} -.5245 \\ -0.2879 \\ -0.4168 \end{bmatrix} \text{ x } 10^{-4} \frac{rad}{s}$$

Compute the Euler angles for the initial platform tilt?

3) *IMU Coarse Alignment – Heading:* A strapdown inertial navigator is installed in an airplane located at the following position coordinates: N37.6195° latitude, W122.3739° longitude and 10' altitude. It is perfectly level and pointed at a true heading of 060°.

(a) What will the readings (in deg/hr) be on the three orthogonally mounted rate gyros?
(b) Suppose the inertial navigator has high-grade tactical quality rate gyros (i.e., bias instabilities on the order of 0.1 deg/hr). You stick to the same longitude as the airport and start going south. The navigator is still pointed at a true heading of 060°. How far south would you have to go (in degrees of latitude) before you can distinguish, with certainty, based on gyrocompassing alone, that you are not at the airport you started at anymore? Note: Gyrocompassing will be unsuccessful if the change in the rotation rates measured by the rate gyros as we move south is smaller than the bias stability of the gyros.
(c) Repeat (b) assuming you have gyros with bias instabilities of 1, 10 and 20 deg/hr.

4) *INS Velocity and Position Mechanization* Down-load the Inertial Measurement Unit (IMU) data file imudata.mat (or imudata.txt) from canvas. The file contains the simulated IMU outputs of vehicle flying a trajectory for 300 sec. The data matrix should have seven columns. The first column is time in 0.05 second increments. The next three columns are the three Euler angles yaw, pitch and roll (in radians) respectively. The last three columns are the accelerometer outputs, f_{ib}^{b}, in m/s2. Given the following initial conditions on velocity and position, propagate the outputs forward in time:

$$v_{nb}^{n} = [0 \quad 206 \quad 0]^T \text{ m/s}$$

$$p_{nb}^{g} = [44.8805\ deg \quad -93.2169\ deg \quad 256.3\ m]$$

5) *Geodetic Mechanization:* Derive the INS mechanization equations (steps 1 – 4) to calculate the attitude of the body frame relative to a local NED frame fixed to the body, the velocity of the body in the body-fixed NED frame, and the position of the body in geodetic coordinates (latitude, longitude, altitude). You can use the notes (Geodetic_Mechanization.pdf) posted on canvas to help with the derivation.