EE 570: Project 3

Project 1 involved the development of a MATLAB program to generate consistent, synthetic "ground truth data." This data was then utilized to test our ECEF INS mechanization implementation assuming perfect sensors. In project 2 you have created an IMU function to mimic an actual IMU with non-ideal measurements.

In this project you will develop a GPS aided INS.

1 Ground Truth Generation

Exactly the same as before. Use a 100Hz update rate.

2 ECEF Mechanization (from Project #1)

Develop a function to perform the "**high-fidelity**"ECEF mechanization (code skeleton is provided) and plot the errors between the ground thruth PVA and the PVA derived from the output of your INS mechanization

1. Initialize (i.e., $t = 0$) the PVA with the "truth"
2. Plot the error in the position as truth - INS estimate (i.e., $\delta\vec{r}^{\,e}_{eb} = \vec{r}^{\,e}_{eb} - \hat{\vec{r}}^{\,e}_{eb}$)
3. Plot the error in the velocity as truth - INS estimate (i.e., $\delta\vec{v}^{\,e}_{eb} = \vec{v}^{\,e}_{eb} - \hat{\vec{v}}^{\,e}_{eb}$)
4. Plot the three components of the error in the attitude defined by truth DCM $\times$ INS estimate DCM^T, i.e.,

$$\delta C^e_b = C^e_b(\hat{C}^e_b)^T \approx \mathcal{I}_{3\times3} + \Psi^e_{eb}$$

where

$$\Psi^e_{eb} = [\vec{\psi}^{\,e}_{eb}\times] = \begin{bmatrix} 0 & -\psi_z & \psi_y \\ \psi_z & 0 & -\psi_x \\ -\psi_y & \psi_x & 0 \end{bmatrix}$$

3 IMU Implementation (from Project #2)

Develop a function to perform the IMU implementation (code skeleton is provided as imu.m and an updated load_constants.m file). The IMU takes the error free version of the specific force $\vec{f}^{\,b}_{ib}$ and angular velocity $\vec{\omega}^{\,b}_{ib}$ as inputs and outputs measured versions of the same, namely,

$$\tilde{\vec{f}}^{\,b}_{ib} = \vec{f}^{\,b}_{ib} + \delta\vec{f}^{\,b}_{ib} = \vec{b}_a + (\mathcal{I} + M_a)\vec{f}^{\,b}_{ib} + \vec{w}_a$$

and

$$\tilde{\vec{\omega}}^{\,b}_{ib} = \vec{\omega}^{\,b}_{ib} + \delta\vec{\omega}^{\,b}_{ib} = \vec{b}_g + (\mathcal{I} + M_g)\vec{\omega}^{\,b}_{ib} + G_g\vec{f}^{\,b}_{ib} + \vec{w}_g$$

For this project we will consider a commertially available kvh 1750 IMU. For the questions below you will need to plot the errors between the ground truth PVA and the PVA derived from the output of your ECEF-frame INS mechanization, now using measurements provided by a simulated (imperfect) IMU.

1. Use the datasheet to obtain all of the relevant IMU error characteristics:

Gyroscope Bias stability ($b_{g,BS} = 0$), bias instability ($b_{g,BI}$), assume that fixed bias has been calibrated and is zero ($b_{g,FB} = 0$), ARW ($\vec{w}_g$), scale factor stability (s_g). Also, assume that the gyro g-sensitivity (G_g) is 0.5°/hr/g and the misalignment terms (e.g., $m_{g,xy}$) are as given in the code skeleton (see `imu.m`).

Accelerometers Bias stability ($b_{a,BS} = 0$), bias instability ($b_{a,BI}$), assume that fixed bias has been calibrated and is zero ($b_{a,FB} = 0$), VRW ($\vec{w}_a$), scale factor stability (s_a). Also, assume that the accel offset error is zero and that misalignment terms (e.g., $m_{a,xy}$) are as given in the code skeleton (see `imu.m`).

4 Design an Aided INS

The following are the parameters used for the aided INS

- GPS (position: $\sigma_p = 3$m; velocity: $\sigma_v = 0.01$m/s)
- GPS rate: 1Hz
- INS rate: 100Hz
- IMU specs (same as in project 2, see above)
- Simulation run time: at least 300sec

Develop an aided INS system using the GPS signal (develop a GPS sensor function based on the parameters listed above). Your system should be able to handle corrupt GPS measurements.

Your report should include the following:

1. Description of the aiding system you are designing
2. What are your aiding measurement
3. Explicitly define your system equations and define the matrices with units: $F(t)$, $G(t)$, $Q(t)$, H, P, and R.
4. Describe how you create your discretize system, i.e., what is $\phi(k)$ and $Q(k)$
5. Show a diagram of your closed-loop system
6. Figures showing the performance of the system including
   (a) The INS system alone without noise
   (b) The INS with IMU and no aiding
   (c) The INS with aiding
7. Simulate GPS outage or corruption, from $t = 30$s to $t = 60$s, by adding bad values to its position and velocity values
8. What is the effect of the IMU sampling rate on your results (use simulation to support your claims).
9. Provide your code with comments in the apendix

5 10% Bonus Credit

Design a GPS aided INS in the navigation frame. For the GPS develop a new GPS sensor function with the following parameters

- GPS latitude and longitude: $\sigma = 40\mu$deg
- GPS height: $\sigma_h = 3$m/s
- GPS velocity: $\sigma_v = 0.01$m/s
- GPS rate: 1Hz