HW3: Complementary Filtering

It's time to build up your EduMiP kit so you can power the BeagleBone with a battery and protect the BeagleBone Black and Robotics Cape while doing this exercise. Please follow the directions on the EduMiP GitHub page to assemble your kit. Also in the same repository are all of the CAD files and technical drawings should you wish to 3D print replacement or modified parts.

https://github.com/StrawsonDesign/EduMiP/blob/master/EduMiP%20Assembly%20Instructions.pdf

For this assignment you will submit a single PDF file to mae143c@renaissance-press.com instead of just your source code. Please write out the answers to all questions and requested plots in this PDF. Also put your source code on the last page.

Question 1:

Now connect your BeagleBone Black, with Robotics Cape attached, to your computer over USB and SSH in. With the Robotics Cape Revision C installer running, try running the test_imu and calibrate_gyro examples from the command line. An explanation of how to use these example programs and how they work are documented in the Robotics Cape manual here: http://strawsondesign.com/#!manual-imu

What are the units of the gyro reading displayed with the test_imu program? Note on the Robotics cape is a symbol indicating the direction of the X, Y, and Z axis for the IMU's internal coordinate system. Rotate the BeagleBone about each of these axis and observe the gyro measurements. Do these measurements adhere to the right-hand rule? The IMU is called the MPU-9150 by Invensense and its datasheet is easily discoverable online with a google search. Based on the datasheet, what is the resolution of the sensor? What are the available Full Scale Ranges of this gyroscope?

Question 2:

To see what the FSR is configured to in software you can use the following code:

```
unsigned short gyro_fsr; //full scale range of gyro

mpu_get_gyro_fsr(&gyro_fsr);
```

Modify the test_imu example to print a floating point value for the angular rates in radians per second instead the raw integer value returned by the ADC. Include this code in your PDF here below your answer to Question 1.

Question 3:

Using the Description of the mpudata_t struct described in the manual's IMU page, modify the test_imu program further to also print out a BeagleBone angle estimate from vertical using only the Z and Y accelerometer angles. The math.h library in already included in the robotics cape library and contains the atan2 function documented here http://www.cplusplus.com/reference/cmath/atan2/. This should be printed out in both radians and degrees.

Once you are confident that the values are accurate, remove the printf("\r") line so each new reading prints on a new line. Slow down the IMU sample rate to 20hz so there is less data to print. Use excel or matlab to plot this angle estimate as you move the beaglebone through the following motion:

- Hold upright with the Ethernet jack pointing towards to sky
- Lean forwards 90 degree
- Lean backwards 90 degrees
- Return to vertical.

Your plot can be made from copying the values from the console into excel or matlab. Please include that plot and your source code here in the submitted pdf.

Question 4:

Now we will make the angle estimate more accurate. Make a complementary filter angle estimator using the X-axis Gyro measurement along with your existing atan2 accelerometer estimate. In your complementary filter you should be using a low pass filter on the accelerometer-derived angle data and the high pass filter on the gyroscope-derived angle estimate. For a sensor sample rate of 50hz, choose a rise time for your two filters and justify it. Provide the poles and zeros of the continuous time filters along with their discrete time equivalents derived with Tustin's approximation. Provide a bode plot with both filters plotted.

Question 5:

Finally move your Beaglebone through the same motions as from question 3 but plot simultaneously the low-passed angle, the high passed angle, and the sum of both. Comment of the accuracy of each of those 3 plots in the frequency domain.