MPU9250 Calibration Analysis Tool

Purpose

The purpose of this tool is to allow the user to view the calibration process, understand how and where calibration variables (biases, scale factors) are stored in both software (MPU9250 Library variables) and hardware (Teensy EEPROM), and to test calibration results to make sure results are as expected.

Instructions

Load the sketch, and the IMU will initialize. The MPU9250 library completes a gyro calibration upon bootup. and will store the gyro calibration biases in the gxb, gyb, and gzb variables. The user should see bootup information displayed to the screen, along with a summary of current MPU9250 Library and EEPROM calibration values.

Commands

'd' Displays calibration values in both hardware (EEPROM) and software (stored in variables by IMU9250 library).

'p' Streams the 9 raw IMU and heading values in this order: ax, ay, az, gx, gy, gz, hx, hy, hz, and heading (degrees). Hit 'p' again to stop streaming.

'z' Zeroes out cal values in both Teensy EEPROM and in MPU9250 Library

'a' Executes the MPU9250 accel calibration routine

'g' Executes the MPU9250 gyro calibration routine

'm' Executes the MPU9250 mag calibration routine

'l' Stores MPU9250 Library calibration values (accel and gyro only) into EEPROM

's' Executes a "static cal" of the gyro, accel, and mag. IMU must be on level surface, away from metal, with +X axis aligned towards magnetic North.

'e' Stores static cal (accel and gyro only) values into Teensy EEPROM

'i' Stores static cal (accel, gyro, and mag) values into MPU9250 Library

'r' Solves for the one-sigma values for all 9 accel, gyro, and mag sensors. These values can then be used for the Rx or R matrices as appropriate in the EKF.

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Sample Use Cases

Use Case #1. What You Should See Following Bootup

- Following IMU initialization, you should see the current EEPROM and IMU biases and scale factors listed, along with a list of available commands.
- To clear the current EEPROM and IMU biases, enter ‘z’, then enter ‘d’ (display) to verify.

Use Case #2. Perform Static Calibration of IMU Accel, Gyro, Mag Sensors

- Enter ‘z’ if desired, to clear out all existing biases and to reset scale factors to 1.
- Enter ‘d’ to display EEPROM and IMU biases for verification.
- Enter ‘s’ to perform static calibration of IMU accel, gyro, and mag sensors. Should see display of results. Verify no values are zero, and that they look reasonable. Note that JUST biases are solved for, so scale factors will remain 1.
- Enter ‘e’ to store biases to EEPROM.
- Enter ‘d’ to verify load to EEPROM.
- Enter ‘i’ to load biases to MPU9250 Library (IMU).
- Enter ‘d’ to verify load to MPU9250 Library (IMU).

Use Case #3. Perform MPU9250 Library Calibration of IMU Gyro

- Enter ‘z’ if desired, to clear out all existing biases and to reset scale factors to 1.
- Enter ‘d’ to display EEPROM and IMU biases for verification.
- Enter ‘g’ to perform MPU9250 Library calibration of IMU gyro sensors.
- Enter ‘d’ to verify gyro biases and scale factors are in MPU9250 Library (IMU). Saving the gyro biases and scale factors to EEPROM is not an option at this time.

Use Case #4. Perform MPU9250 Library Calibration of IMU Accelerometers

- Enter ‘z’ if desired, to clear out all existing biases and to reset scale factors to 1.
- Enter ‘d’ to display EEPROM and IMU biases for verification.
- Enter ‘a’ to perform MPU9250 Library calibration of IMU accel sensors. Follow the steps displayed on screen.

- Enter ‘d’ to verify accel biases and scale factors are in MPU9250 Library (IMU).
- Enter ‘l’ to load accel biases EEPROM.
- Enter ‘d’ to verify accel biases from IMU are now loaded in EEPROM

Use Case #5. Perform MPU9250 Library Calibration of IMU Magnetometers

- Enter ‘z’ if desired, to clear out all existing biases and to reset scale factors to 1.
- Enter ‘d’ to display EEPROM and IMU biases for verification.
- Enter ‘m’ to perform MPU9250 Library calibration of IMU mag sensors. Follow the steps displayed on screen.
- Enter ‘d’ to verify mag biases and scale factors are in MPU9250 Library (IMU).
- Enter ‘l’ to load mag biases EEPROM.
- Enter ‘d’ to verify mag biases from IMU are now loaded in EEPROM

Use Case #6. Perform IMU Noise Statistics Analysis

- In main routine, set bufSize to desired level. Typically this will be 64 to 2048 (must be a power of 2!). The Teensy 3.6 will handle buffer size 2048, but others may not.
- Enter ‘r’ to run the IMU statistics. Review the results displayed on screen.

Analysis Suggestions

Here are some things you might try to help understand and analyze calibration of your MPU9250.

1. Make sure your version of Brian Taylor’s MPU9250 Library is calculating the ayb bias correctly. Check the cpp file in the calibrateAccel() function to make sure it reads

   ```
   _ayb = (_aymin + _aymax) / 2.0f;
   ```

   otherwise the two biases, ayb and axb, will show as the same value after calibration.

2. Be sure to set the magnetic field levels in the main routine for your geographic area. See the site ndgc.noaa.gov for details.

3. In a typical navigation setup, gyro cals are solved for each time the IMU is initialized. But even this can be done ahead of time, like accel and mag cals usually are done.
4. When you run a calibration, be sure to then load the cal values where you want them. For example, zero ('z') all call value registers. Then run "p" for second or two. Then enter 'p' again to stop streaming. Then do a static cal, 's'. Then load the cal values into the IMU, 'l'. Then run 'p' again and see if the now-calibrated IMU raw values look better.
5. The Teensy EEPROM is often used to store accel and mag cals so that they can simply be read upon filter startup. Try writing to EEPROM, writing to the MPU9250, and zeroing them both out.
6. Try running calibration multiple times to see how much they vary.
7. While streaming mag data, bring a cell phone nearby and see how the fields are disturbed. Also try bringing other metal objects nearby.
8. Run the IMU sigma calculations repeatedly, see how much they vary. The size of the circular buffer can be varied in the code as well (always keep it a power of 2 though!).
9. Practice calibrating the magnetometers in different settings. A cell phone can be used to get an initial North alignment, but it will disturb the field so must be kept away during calibration.
10. Try the two forms (static and MPU9250 Library) for magnetometer calibrations. Then see how each matches known heading angles (0, 90, 180, 270 degrees).