ME 132B - Inertial Navigation

Released: Monday 04/10/2017 Due: Tuesday 04/18/2017

In part a of the first lab for ME 132B you will be using an Inertial Measurement Unit (IMU) to log the acceleration and rotation rate of a remote control car and attempt to reconstruct the path it takes using sensor data. The IMU in use is the SparkFun 9 DOF Sensor Stick which includes 3-axis accelerometer, gyroscope, and magnetometer. Values from all of these sensors are taken in by an Arduino Due and written to an SD card at a rate of 50Hz.

Hardware demonstration

1. Sign up for a time slot when the schedule is sent out via email. This demo will be much less involved than those of last quarter so each student will have a 5 minute allocation.

2. Show up to your allotted time slot preferably with a laptop that can read an SD card, although if you do not have one available the TAs will email you the data from your test.

3. You will be given a short amount of time to get familiar with the controls of the remote control car before the actual test. Following this, the Arduino will be powered on to begin logging sensor values and we leave it to sit for a few seconds to get a baseline reading used for eliminating any offsets.

4. With the data logger running, you will then have 20 seconds to drive the vehicle around the test area before bringing it back to stop exactly on top of the starting location, ideally in the same orientation as it began. You may then retrieve the data from the SD card to process for the lab submission.

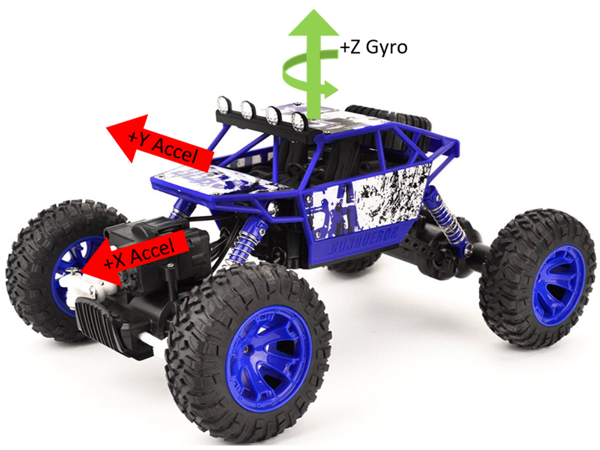

Figure 1: Orientation of sensor axes on vehicle

IMU Data processing

The following steps can be completed in your favorite data processing software such as Excel or MATLAB. Note the raw values from the accelerometer and gyroscope have already been converted into m/s^2 and deg/s respectively, whereas it is only the relative magnitude of the magnetometer readings needed to determine orientation. See Fig. 1 for the orientations of each of the useful sensor axes. Include the equations you use in processing in your homework submission.

1. First we'll start out with a simple integration of the altitude of the system, given by the Z axis acceleration measured by the IMU. Subtract the static offset observed at the start of the test when the car was stationary, which should be around $9.81m/s^2$ given this axis is biased by gravity.

2. Double integrate the Z axis value using the timestep of 0.02s, or if you want a more accurate estimate you could use the program time counter in the first column which is measured in milliseconds. For the homework submission, plot the vertical position of the system over the duration of the test, and comment on the final altitude compared to the initial. How different are they despite the fact that we were driving along a flat surface?

3. Next we'll be implementing the equations for inertial navigation taught in class to try and track the vehicle's position in the XY plane. You'll need to use the Z axis gyroscope reading to track the orientation of the vehicle on the plane, and the X and Y accelerations to track its position, as represented in Fig. 2. Remember to calibrate the sensor values by subtracting the static offset from all of the values and set initial velocity and position to zero.

4. In the homework submission, plot the vehicle's position in the X Y plane over the course of the test run. Comment on the shape of the trajectory compared to what you remember of the path you drove, recalling that we attempted to stop the car right on top of the starting position. How does the final orientation of the vehicle compare to the initial?

5. Lastly, we'll see how accurate our orientation estimates can be when tracking external stimuli such as the Earth's magnetic field with exteroceptors like a magnetometer. Using the relation $atan2(X_{mag}, Y_{mag})$ to give you the angle the vehicle is facing relative to magnetic north, plot the orientation of the vehicle over the duration of test. Does it end up facing the right direction?

Extra credit: Integrate the complete 3 DOF orientation of the vehicle using all three gyroscope readings via the methods taught in class, and plot the resulting Euler-Angles over the course of the test run.

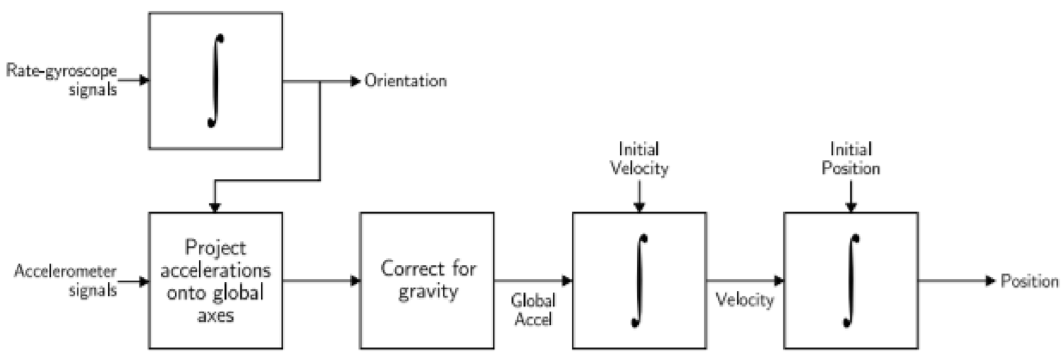

Figure 2: Inertial navigation with accelerometer and gyroscope