Physics 524

Survey of Instrumentation and Laboratory Techniques

2023

George Gollin

University of Illinois at Urbana-Champaign

Unit 3a: Motion… acceleration, rotation, orientation

Goal for this unit

- Learn to use an LSM9DS1 "9 axis" motion sensor.

First things first

If you don't already have an LSM9DS1 on your bread board, wire up a simple circuit in which you drive it using I2C. You can find the pinouts and sample code on the Adafruit web site. Please install any libraries you might need, and run the example code.

Note that the device's designers decided to use a left-handed coordinate system! From the Adafruit site:

> Inside the chip are three sensors, one is a classic 3-axis accelerometer, which can tell you which direction is down towards the Earth (by measuring gravity) or how fast the board is accelerating in 3D space. The other is a 3-axis magnetometer that can sense where the strongest magnetic force is coming from, generally used to detect magnetic north. The third is a 3-axis gyroscope that can measure spin and twist.

Trashing the magnetometer

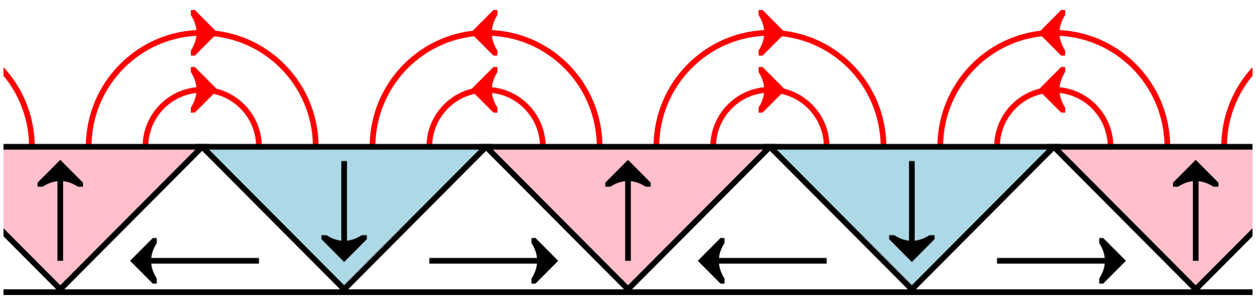
The device uses a magnetometer to figure out its orientation in space. (Of course, when at rest on the earth's surface it could also assign z according to the apparent acceleration it experiences that's actually caused by the earth's gravitational pull.)

According to Wikipedia[1], in 2020 the earth's "North geomagnetic pole" was at 80.7°N 72.7°W, in northern Canada. Here it is!

[1] https://en.wikipedia.org/wiki/Geomagnetic_pole, visited September 11, 2023.

This is approximately due north of New Haven CT. (Urbana, IL is at 40.1° N, 88.2° W.) Recall that this is the point at which a compass needle's north end will point, which means that the "north geomagnetic pole" is actually a south magnetic more thing: the field is approximately dipole in nature, so the field in Urbana contains a significant downwards component.

Please do this: figure out the direction of the local magnetic field by changing the orientation of your breadboard. After you've done that, please hold a strong magnet (I have them for you) a reasonable distance away from the LSM9DS1 and record what the magnetometer sees. Note that the magnetic field leaving the faces of the disk-shaped magnet is complicated, with the field lines NOT generally pointing directly away from a face of the magnet. I can explain… Image is from Wikipedia.[2]



Oh, about magnetic field units: the standard SI unit is the Tesla, though some of us grew up using the CGS unit "Gauss" as the field strength unit. 1 T = 10,000 G, and the earth's field is very roughly one Gauss, or a hundred μT.

Pirouette

Now put your laptop and breadboard on a chair and spin it around. Have someone time the rotations to determine an approximate rotation rate. How does it compare to the LSM9DS1's gyro measurement?

Linear acceleration

Put your laptop and breadboard on a chair again and—out in the hall if necessary—try to push it briefly with constant acceleration. How did the LSM9DS1 do?

Homework assignment for this unit

Inertial navigation

By integrating the acceleration twice, it is (in principal!) Possible to determine the change in position of an object initially at rest. Code up, to run on your Arduino, an algorithm that will sample the LSM9DS1 acceleration at a high rate, determine the time interval between

[2] https://en.wikipedia.org/wiki/Refrigerator_magnet#/media/File:Fridge_Magnet_Halbach.svg

measurements, and figure out how much it has moved during the course of a few seconds of being pushed around in a horizontal plane.

