HW6 IMU Integration

Johns Hopkins University

Real Time Software for Embedded Systems

Fall 2014

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Tutorial

Parts List

- (1) BeagleBone or BeagleBone Black
- (1) spool of hobby wire
- (1) USB 2.0 A/B cable
- (1) breadboard
- (1) Ethernet cable
- (1) 6 DOF Gyro, Accelerometer IMU - MPU6050

Software

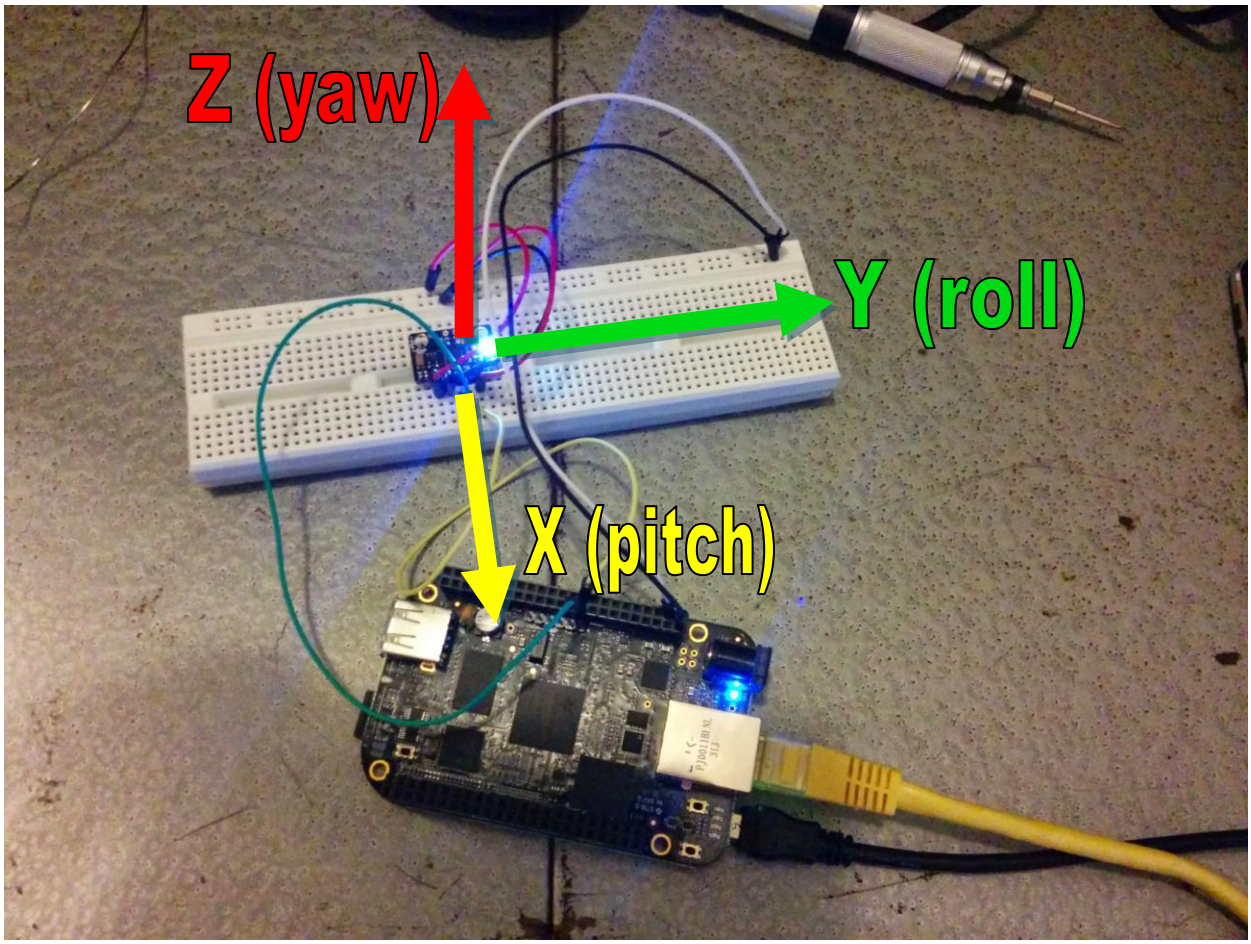
- Windows 8.1
- Latest version of Putty

Quick Start

This tutorial will demonstrate the steps needed to set up the development environment on a BeagleBone and execute the test application that satisfies the requirements for the IMU Integration homework.

- Download the latest image
  - http://beagleboard.org/latest-images
- Extract and copy image to SD card
  - https://learn.adafruit.com/beaglebone-black-installing-operating-systems/windows
- Flash image to BeagleBone
  - https://learn.adafruit.com/beaglebone-black-installing-operating-systems/flashing-the-beaglebone-black
- SSH into BeagleBone using Putty
  - SSH over USB or plug in an Ethernet cable
  - Default IP address is 192.168.7.2
  - Login at root, no password
- Install mpu6050 package
  - `npm install mpu6050`
- Install python-smbus
  - `sudo apt-get install python-smbus`
- Download the application
  - `wget https://jshare.johnshopkins.edu/tflorid1/public_html/imu.py`
- Execute
  - `python imu.c`

Photograph



Equations

Convert raw accelerometer data into pitch and roll in radians:

```
pitch = atan (x / sqrt(y^2 + z^2))
roll = atan (y / sqrt(z^2 + z^2))
```

Convert radians into degrees:

```
pitch = (pitch * 180) / PI
roll = (roll * 180) / PI
```

Implementation

The following file, *imu.py*, is written in Python. It reads raw I2C values. The values read are accelerometer and gyroscope values. The values converted into roll, pitch and yaw values in degrees. A median filter is used to avoid outliers in the data. Yaw is outputted as **angular yaw** due to yaw drift and a lack of a manometer.

```
# Tony Florida
# 2014-10-28
# JHU RTSW HW 6 - IMU

from Adafruit_I2C import Adafruit_I2C
from time import sleep
import math

# Filter enum
ROLL = 0
PITCH = 1
YAW = 2

# Filter index
index = 0

# Filter array len
FILTER_SIZE = 5

# Filters
roll_filter=[0,0,0,0,0]
pitch_filter=[0,0,0,0,0]
yaw_filter=[0,0,0,0,0]

def median_filter( filt,  val ):
        if filt == ROLL:
                roll_filter[index]=val
                sorted(roll_filter)
                return roll_filter[2]
        elif filt == PITCH:
                pitch_filter[index]=val
                sorted(pitch_filter)
                return pitch_filter[2]
        elif filt == YAW:
                yaw_filter[index]=val
                sorted(yaw_filter)
                return yaw_filter[2]
        else:
                print "Filter error"
                return 0;

# initialize i2c connection to MPU6050
# i2c address is 0x68
i2c = Adafruit_I2C(0x68)

# wake up the device (out of sleep mode)
# bit 6 on register 0x6B set to 0
```

```
i2c.write8(0x6B, 0)

print "Roll   Pitch  Yaw"

while True:
        #Accel
        #read i2c accelerations in m/s^2
        ax = (i2c.readS8(0x3b)*256+i2c.readU8(0x3c))/16384.0
        ay = (i2c.readS8(0x3d)*256+i2c.readU8(0x3e))/16384.0
        az = (i2c.readS8(0x3f)*256+i2c.readU8(0x40))/16384.0
        #print "{:+03.3f}".format(ax),
        #print "{:+03.3f}".format(ay),
        #print "{:+03.3f}".format(az)

        #Gyro
        #read i2c gyroscope in degree/s
        gx = (i2c.readS8(0x43)*256+i2c.readU8(0x44))/131.0
        gy = (i2c.readS8(0x45)*256+i2c.readU8(0x46))/131.0
        gz = (i2c.readS8(0x47)*256+i2c.readU8(0x48))/131.0
        #print "{:+03.3f}".format(gx),
        #print "{:+03.3f}".format(gy),
        #print "{:+03.3f}".format(gz)

        #Calculate Roll, Pitch, Yaw as degrees
        # ** is exponent in Python
        #To get Radians, remove the... * 180) / math.pi
        pitch = (math.atan(ax / math.sqrt(ay ** 2 + az ** 2)) * 180) /
math.pi
        roll = (math.atan(ay / math.sqrt(az ** 2 + az ** 2)) * 180) / math.pi
        yaw = gz

        #Median filter
        roll = median_filter(ROLL, roll)
        pitch = median_filter(PITCH, pitch)
        yaw = median_filter(YAW, yaw)

        print "{:+03.3f}".format(roll),
        print "{:+03.3f}".format(pitch),
        print "{:+03.3f}".format(yaw)

        index = index + 1
        if index >= FIlTER_SIZE:
                index = 0

        sleep(0.01)
```

Results

Raw I2C Data

```
Roll   Pitch  Yaw
+0.000 +0.000 +0.000
+0.000 +0.000 +0.000
+4.323 +1.429 +0.046
+4.323 +1.429 +0.046
+4.323 +1.429 +0.046
+4.323 +1.429 +0.046
+4.323 +1.429 +0.046
+4.783 +1.484 +0.237
+4.783 +1.484 +0.237
+4.783 +1.484 +0.237
+4.783 +1.484 +0.237
+4.783 +1.484 +0.237
+4.868 +1.188 -1.916
+4.868 +1.188 -1.916
+4.868 +1.188 -1.916
+4.868 +1.188 -1.916
+4.868 +1.188 -1.916
+4.758 +1.226 -0.435
+4.758 +1.226 -0.435
+4.758 +1.226 -0.435
+4.758 +1.226 -0.435
+4.758 +1.226 -0.435
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+4.392 +0.949 +0.229
+4.392 +0.949 +0.229
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+4.052 +2.332 -4.496
+4.052 +2.332 -4.496
+4.052 +2.332 -4.496
+4.052 +2.332 -4.496
+4.052 -2.496 -4.771
+4.052 -2.496 -4.771
+4.052 -2.496 -4.771
+4.052 -2.496 -4.771
+4.052 -2.496 -4.771
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+4.546 -9.697 -8.511
+4.546 -9.697 -8.511
+4.546 -9.697 -8.511
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+4.221 -16.069 -7.779
+4.221 -16.069 -7.779
+4.221 -16.069 -7.779
+4.221 -16.069 -7.779
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+4.347 -24.097 -2.031
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+5.173 -34.809 +1.603
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+6.082 -43.470 -4.618
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+7.687 +22.910 +9.061
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+9.632 +89.653 +21.328
+9.632 +89.653 +21.328
+37.919 +86.346 +10.450
+37.919 +86.346 +10.450
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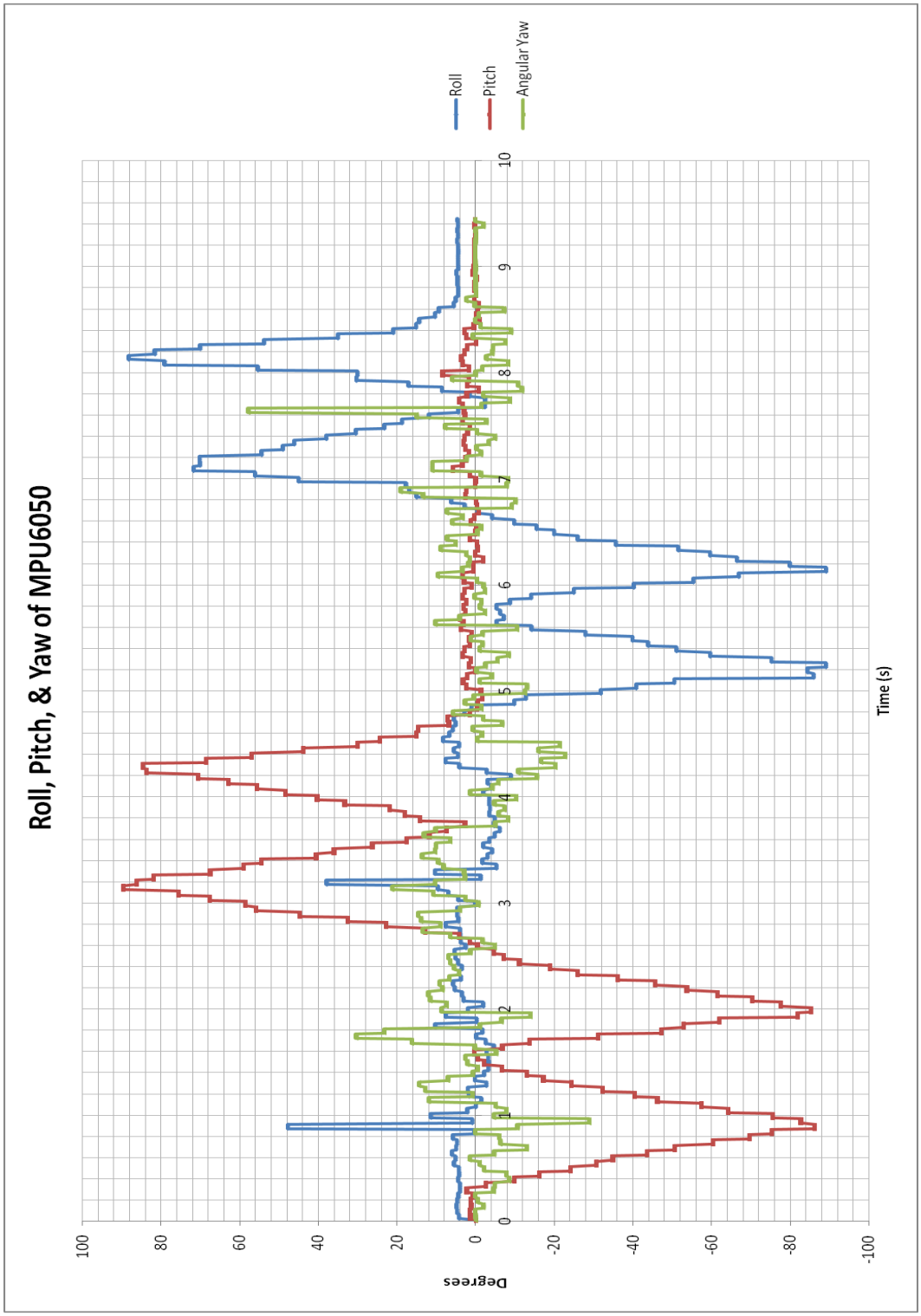
Plot


Roll, Pitch, & Yaw of MPU6050
Roll
Pitch
Angular Yaw
Degrees
100
80
60
40
20
0
-20
-40
-60
-80
-100
0
1
2
3
4
5
6
7
8
9
10
Time (s)

Video Presentation

https://www.youtube.com/watch?v=aHcPScUt5aw

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[6] http://forums.adafruit.com/viewtopic.php?f=8&t=52581

[7] http://www.snip2code.com/Snippet/85741/Beaglebone-GY-86-driver

[8] http://taylor-robotic.co.uk/?p=64