ECE 6310: Introduction to Computer Vision - Lab 7 Report
Motion Tracking

Objective: To calculate motion using accelerometers and gyroscopes. The goal of the lab is to automatically segment the data into periods of motion and periods of rest, and calculate the motion along and about each axis during the periods of motion.

Implementation and steps:

1. The data: A file of data recorded using an iPhone is available at the course website. There are 7 columns in the file, containing the following data: time, x_acc,y_acc,z_acc,pitch,roll,yaw. The units for time are seconds. Data was sampled at 20 Hz, so there are 0.05 seconds between each row. The units for the accelerometer data are gravities (G). The units for the gyroscope data are radians per second. The iPhone was moved individually along or about each axis independently for a period of 2-3 seconds. Between each motion, the iPhone was held at rest for 2-3 seconds. The data was read from file and stored in a linked list.

2. As we can see, there is noise in the raw data of accelerometer and gyroscope. To reduce that, data was smoothed by averaging it with 2 values before and 2 values after it. (total 5 values)

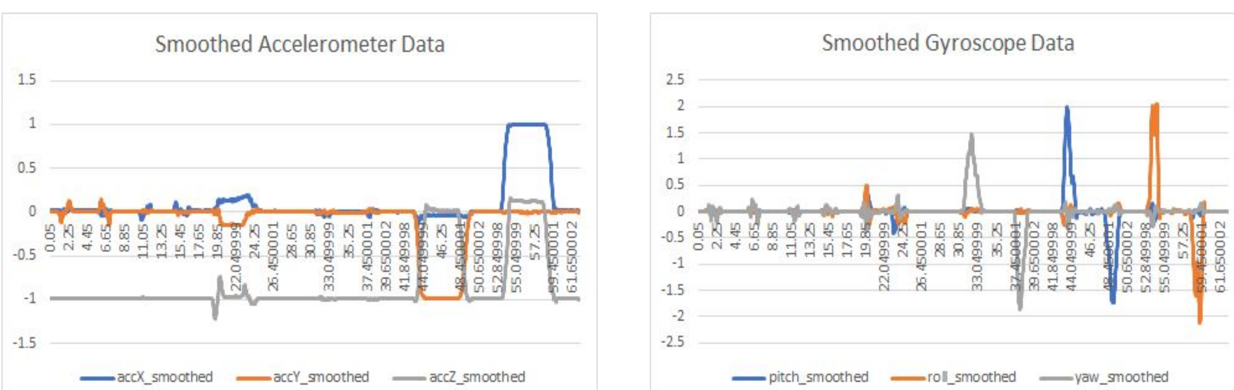


Fig 1 & 2. Raw and smoothed accelerometer, gyroscope data plots

3. For segmenting data, window of 2.5 seconds was used and variance was calculated along all 6 axes. 2 seconds= 2* 20 = 40 data points. Initially, sum and average was calculated using a for loop for window size, then over the same window variance was calculated by the standard variance formula. The variance values were stored for each window.

4. Motion detection: When all the variance values were less than some threshold, the iPhone was considered to be at rest, and when any of the 6 variance values were greater than threshold, the iPhone was considered to be in Motion. Since the units for accelerometer and gyroscope were different, the thresholds were different.

Accelerometer final threshold used : 0.003, Gyroscope final threshold used: 0.009

5. Motion calculation for gyroscope was completed using single integration. For each window, the current smoothed value was multiplied by sample time (0.05) and results were integrated.

```
rotation_pitch_axis = rotation_pitch_axis + current->pitch_smoothed * sample_time;
rotation_roll_axis = rotation_roll_axis + current->roll_smoothed * sample_time;
rotation_yaw_axis = rotation_yaw_axis + current->yaw_smoothed * sample_time;
```

6. Motion calculation for accelerometer was completed using double integration. For each window, below 3 values were calculated: the velocity at the end of a sampling period, the average velocity during the sampling period, and then the distance traveled during the sampling period. Assuming the zero initial velocity and constant acceleration, The velocity at the time of a data sample was equal to the velocity at the time of the previous sample plus the acceleration reading multiplied by the time between samples. The average velocity during the sampling period was the average of the initial and final velocities. The distance traveled during the sampling period was the average velocity multiplied by the time between samples.

```
prev_x_vel = x_vel;
x_vel = x_vel+current->accX_smoothed * sample_time;
avg_x_vel  = (x_vel + prev_x_vel)/2;
distance_x_axis = distance_x_axis + avg_x_vel*sample_time;

prev_y_vel = y_vel;
y_vel = y_vel+current->accY_smoothed * sample_time;
avg_y_vel  = (y_vel + prev_y_vel)/2;
distance_y_axis = distance_y_axis + avg_y_vel*sample_time;

prev_z_vel = z_vel;
z_vel = z_vel+current->accZ_smoothed * sample_time;
avg_z_vel  = (z_vel + prev_z_vel)/2;
distance_z_axis = distance_z_axis + avg_z_vel*sample_time;
```

Results and Observations:

Time	Activity	Angular Rotation for pitch axis(deg)	Angular Rotation for roll axis(deg)	Angular Rotation for yaw axis(deg)	Linear Distance for x axis (meters)	Linear distance for y axis (meters)	Linear distance for z axis (meters)
0.05-2.55	Motion	-1.24670	-0.13860	-2.21530	0.50986	-0.29457	-30.2820
2.55-5.05	Rest	0	0	0	0	0	0
5.05-7.55	Motion	0.10092	-1.39107	1.21214	0.76342	0.38137	-60.5498
7.55-10.05	Rest	0	0	0	0	0	0
10.05-12.55	Rest	0	0	0	0	0	0
12.55-15.05	Rest	0	0	0	0	0	0
15.05-17.54	Rest	0	0	0	0	0	0
17.54-20.04	Motion	5.50558	8.8141	-3.8196	1.20771	0.48522	-91.2640
20.04-22.54	Motion	3.6508	-1.2768	-0.9615	5.1759	-3.7694	-119.644
22.54-25.04	Motion	-9.8243	-9.6965	3.47727	9.61457	-5.6605	-148.981
25.04-27.54	Rest	0	0	0	0	0	0
27.54-30.04	Rest	0	0	0	0	0	0
30.04-32.54	Motion	2.81035	-1.4260	**61.2955**	9.7836	-5.6718	-179.295
32.54-35.04	Motion	-0.22706	1.3239	**28.2819**	9.4966	-5.74449	-209.731
35.04-37.54	Rest	0	0	0	0	0	0
37.54-40.04	Motion	-0.29282	-0.0297	**-86.4859**	9.4214	-5.4546	-240.200
40.04-42.54	Rest	0	0	0	0	0	0
42.54-45.04	Motion	**91.3835**	-5.0900	-4.0193	8.1935	-16.5215	-262.662
45.04-47.54	Rest	0	0	0	0	0	0
47.54-50.04	Motion	**-90.2300**	3.1953	3.1320	7.0070	-41.9404	-270.387
50.04-52.54	Rest	0	0	0	0	0	0

52.54-55.04	Motion	0.1053	**95.9861**	-4.0863	16.1099	-41.9537	-294.202
55.04-57.54	Rest	0	0	0	0	0	0
57.54-60.04	Motion	-2.2240	**-92.5260**	2.5869	42.8697	-42.0024	-298.811
60.04-62.54	Rest	0	0	0	0	0	0

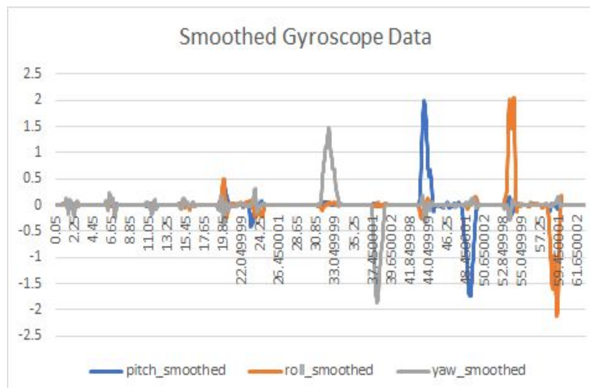
Table 1. Motion detection and corresponding rotation, distance statistics

From the table, we can see that there are a total of 12 periods of motion, with a period of rest in between. The gyroscope axes values are highlighted for 3 rotational motions and the results seem to be accurate. We can see the motion values in yaw, pitch, roll axis respectively as seen in the plots:

1. Yaw: 30.04-32.54 with magnitude: 61.2955,
   32.54-35.04 with magnitude: 28.2819,
   37.54-40.04 with magnitude: -86.4859

2. Pitch: 42.54-45.04 with magnitude 91.3835
   47.54-50.04 with magnitude -90.230

3. Roll: 52.54-55.04 with magnitude 95.9861
   57.54-60.04 with magnitude -92.5260



However, the accelerometer results are not close to the actual values as compared to gyroscope ones. Overall, we can conclude that estimation of orientation using gyroscope has more accuracy than estimation of linear distance using accelerometer.