BRADLEY UNIVERSITY

SELF-ACTIVATING FALL ALARM

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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PRESENTATION OUTLINE

- **Introduction**
- **Our Solution**
- **Results**
- **Take Aways**
- **Financial Aspect**
- **Conclusion**
- **Future Plans**
- **Acknowledgements**
- **References**
- **Questions**

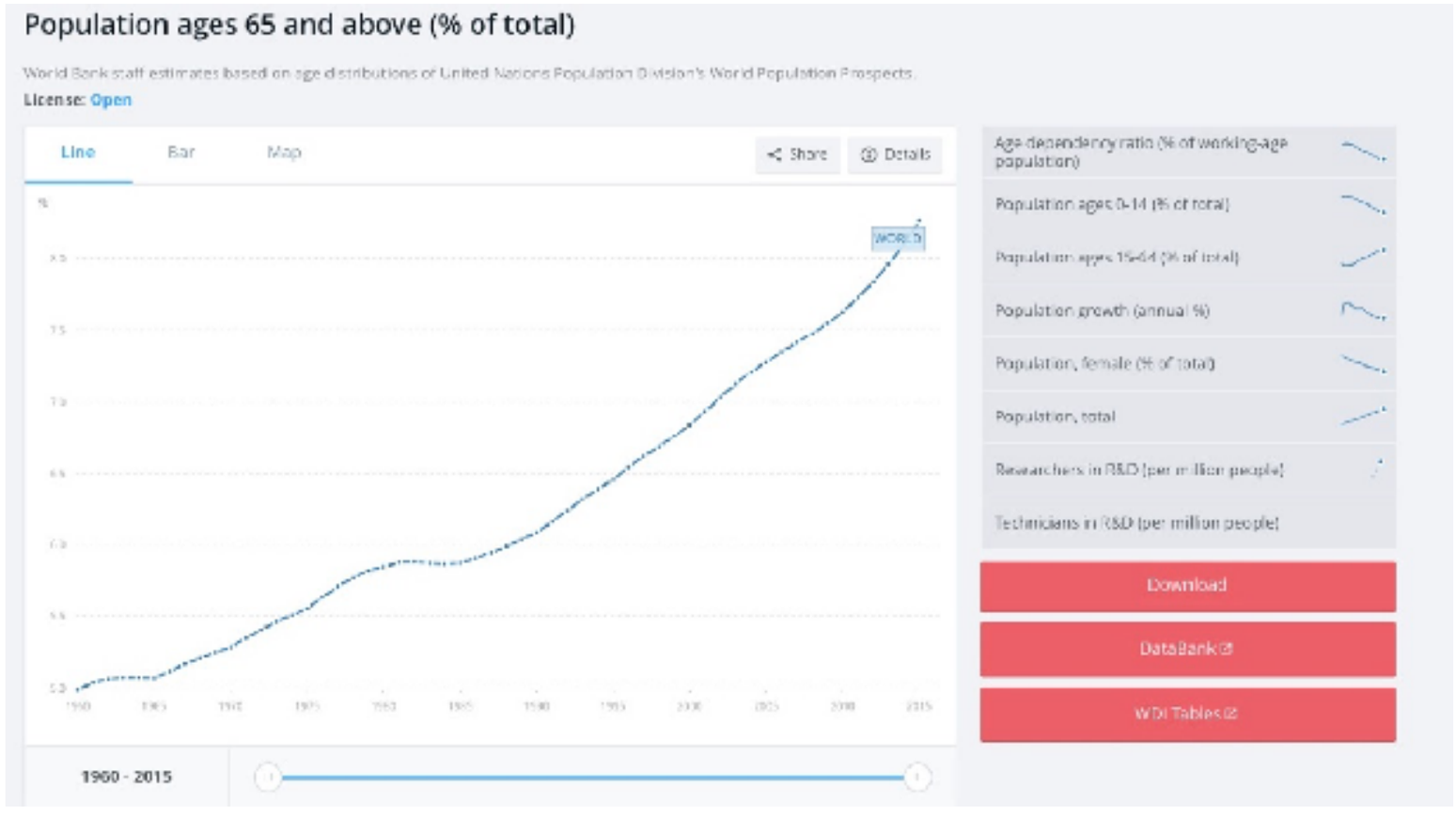
WHY DO WE NEED IT?

"Every 11 seconds, an older adult is treated in the emergency room for a fall; every 19 minutes, an older adult dies from a fall." (CDC)

- The elderly population (those aged 65 and older) has increased from 35.9 million to 44.7 million between 2003 and 2013

- 1 out of 5 falls results in a serious injury (CDCP)

- About 28% (12.5 million) of non-institutionalized older people live alone (8.8 million women, 3.8 million men), and almost half of older women (46%) age 75+ live alone



HERE'S THE REAL PROBLEM

- **"Lying on the floor for a long time was strongly associated with serious injuries admission to hospital, and subsequent moves into long term care."**
- 62% of elderly victims who don't receive help within an hour won't be able to live independently after hospitalization. (Consumers Advocate)
- 90% of seniors who aren't helped within 6 hours will have to live in a nursing home. (Consumers Advocate)

Reduce rescue time

WHAT IS CURRENTLY BEING DONE

- **There are issues with current fall alarms:**
  1. Not having one: Fear of alarm systems, e.g. keeps going off inappropriately, difficult to maintain etc.
  2. Having one, but not using it: not practical in design; very bulky and evident; is not self-automated; forgot they were wearing it
  3. Fees: Currently, all medical alert require users to pay a monthly fee for the cellular charges

OUR PROPOSAL

- Take user action out of the picture: **self-activating alarm**
- A device that detects and analyzes movement, orientation, and acceleration of a user to identify whether the he/she has fallen.
- Once a fall occurs, the device will send an alert to care takers and EMT professionals to notify the user has fallen.
- Also alerts in case of extended lack of movement (ex when user is inactive)

OBJECTIVES

- Design a wearable (as in part of clothing or jewelry) fall alarm system, which is **self-activating,** "invisible" to user, and dependable

- Collect pre-fall data for post analysis to prevent future falls

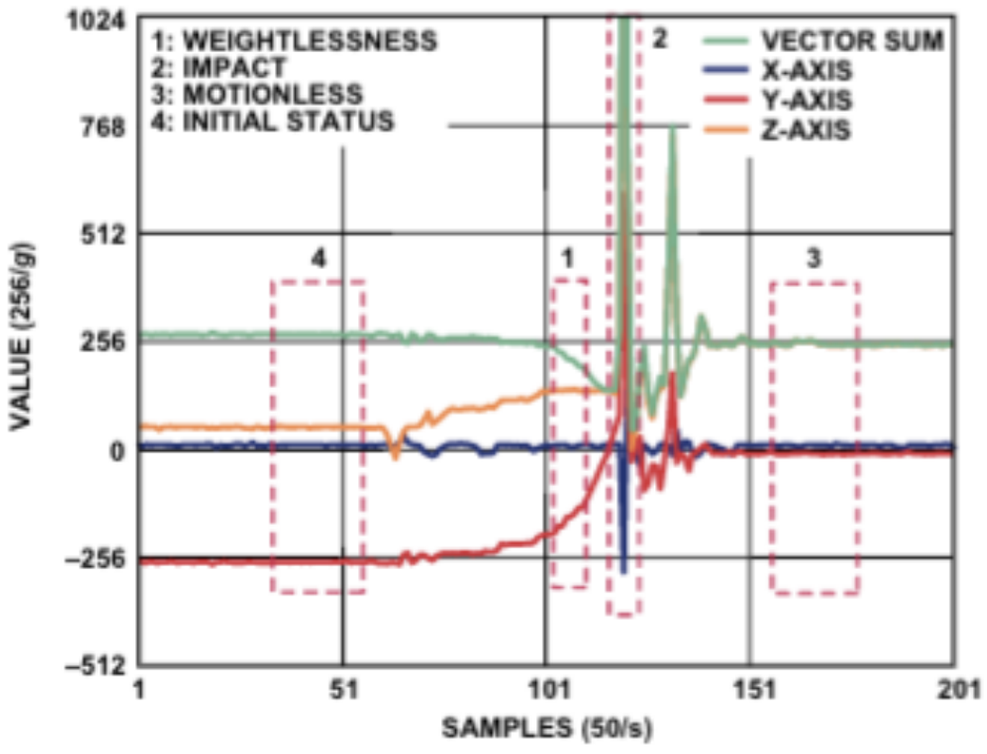
WHY WE CHOSE THE PROJECT

- A challenging project which utilizes and apply current engineering skills, as well as, broaden our engineering knowledge
- Personal interest:
  - Will: grandfather has dementia
  - Maisha: passion for the healthcare world
  - Mike: very practical project with a wide scope of possibilities

GETTING STARTED

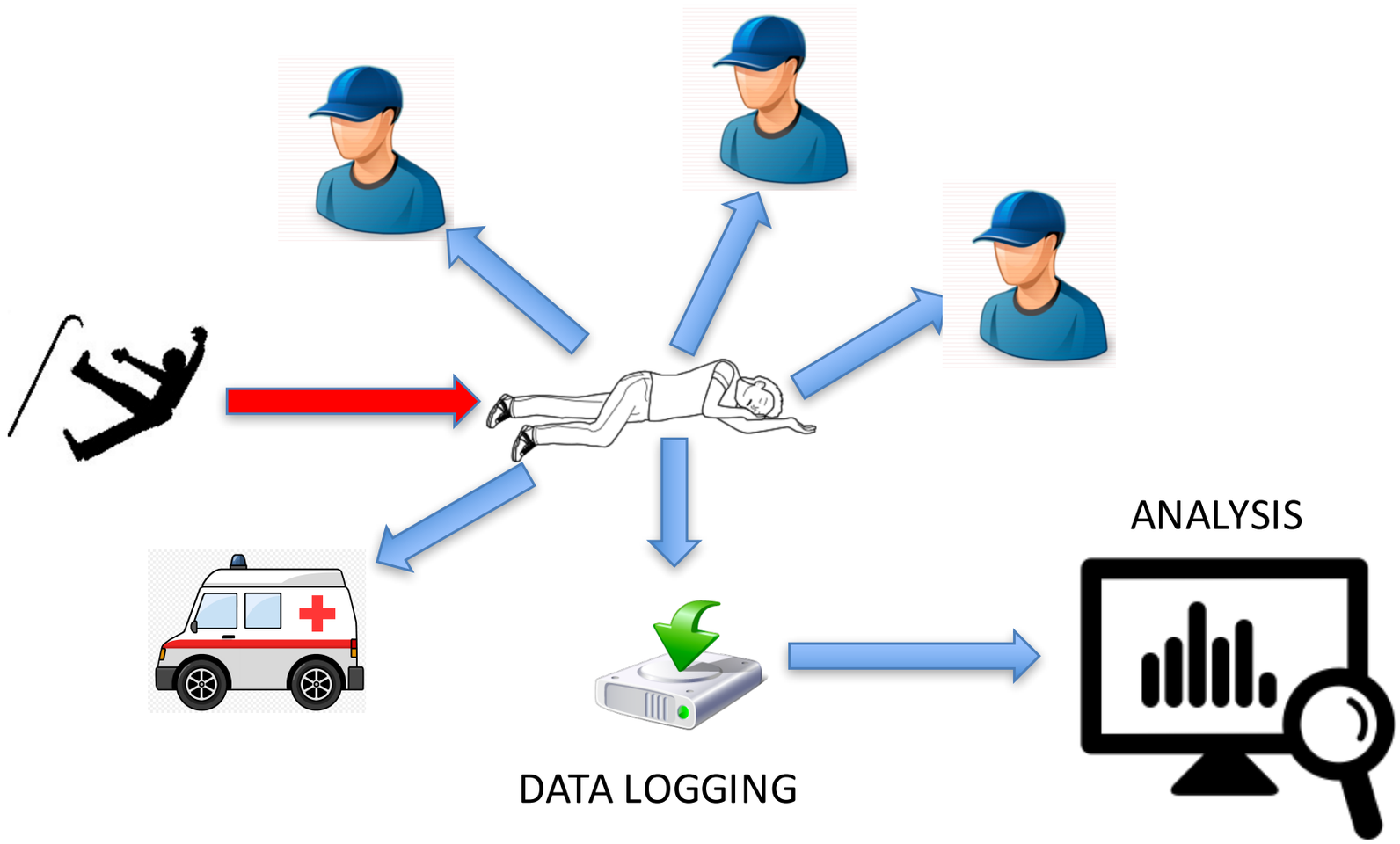
Literature Search-

- Get an understandings of what research has currently been done
- Give us some direction
- Found two articles that pertained to what we were looking for
- What we gathered:
  - ideal location to collect acceleration data is the waist
  - they used an ADXL345 which contains a 3-axis accelerometer
  - using the magnitude of the 3-axis of acceleration can help establish a threshold
  - got an understanding on what type of data to expect (shown below)

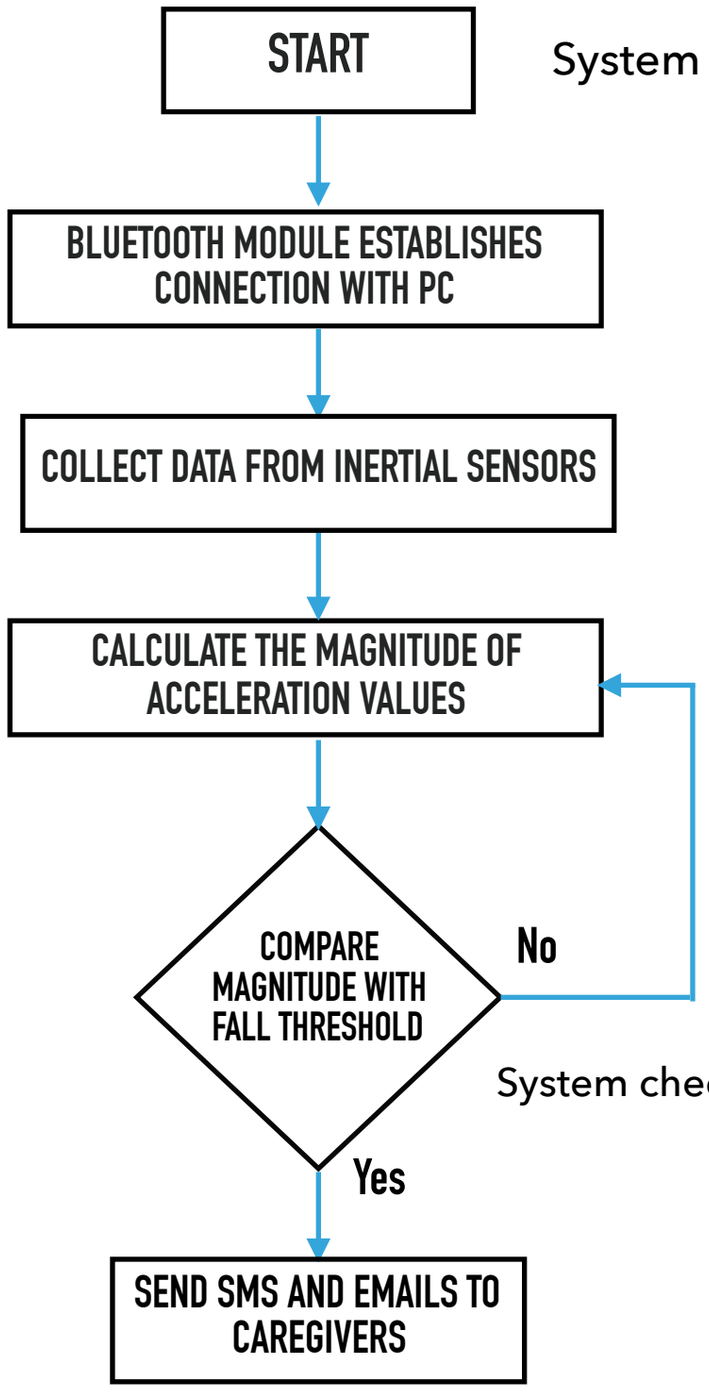


DESIGN PROCESS

COLLECTING SENSOR DATA → COMMUNICATING THE SENSOR DATA → ANALYSIS AND PROCESS THE SENSOR DATA



SYSTEM FLOWCHART – BROAD OVERVIEW

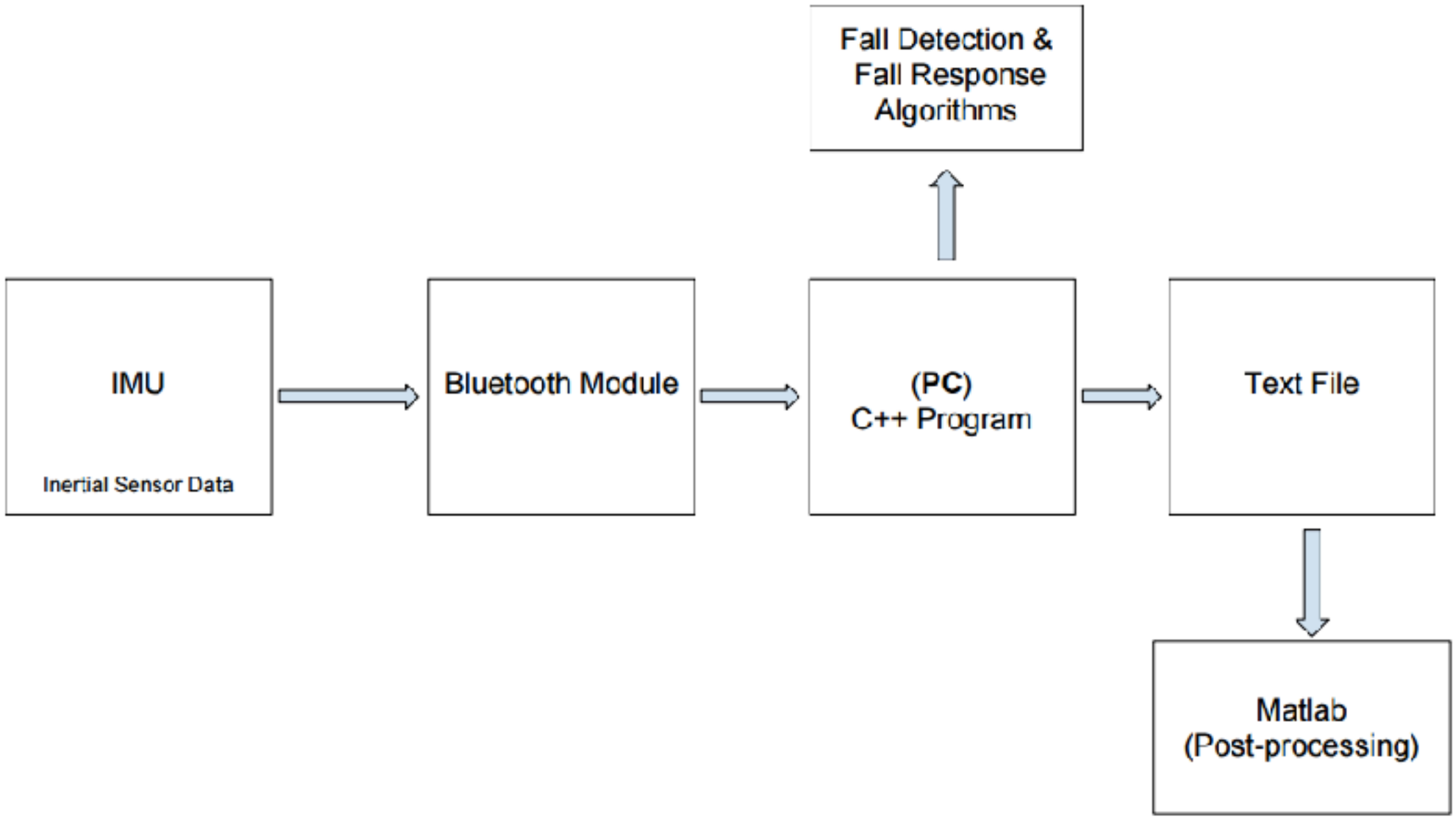


System has been powered on

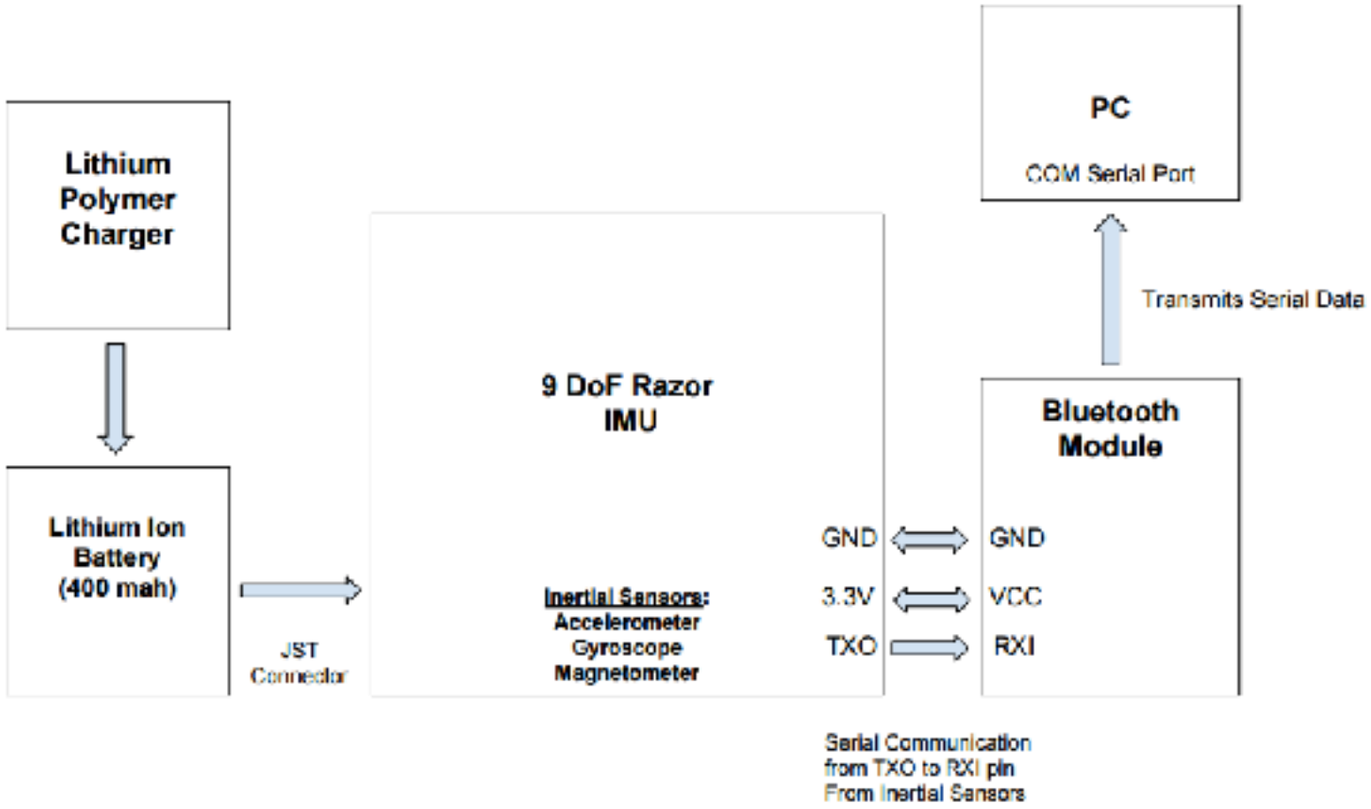
Program cycles back to determine whether an 'actual' fall has occurred or a 'false' alarm

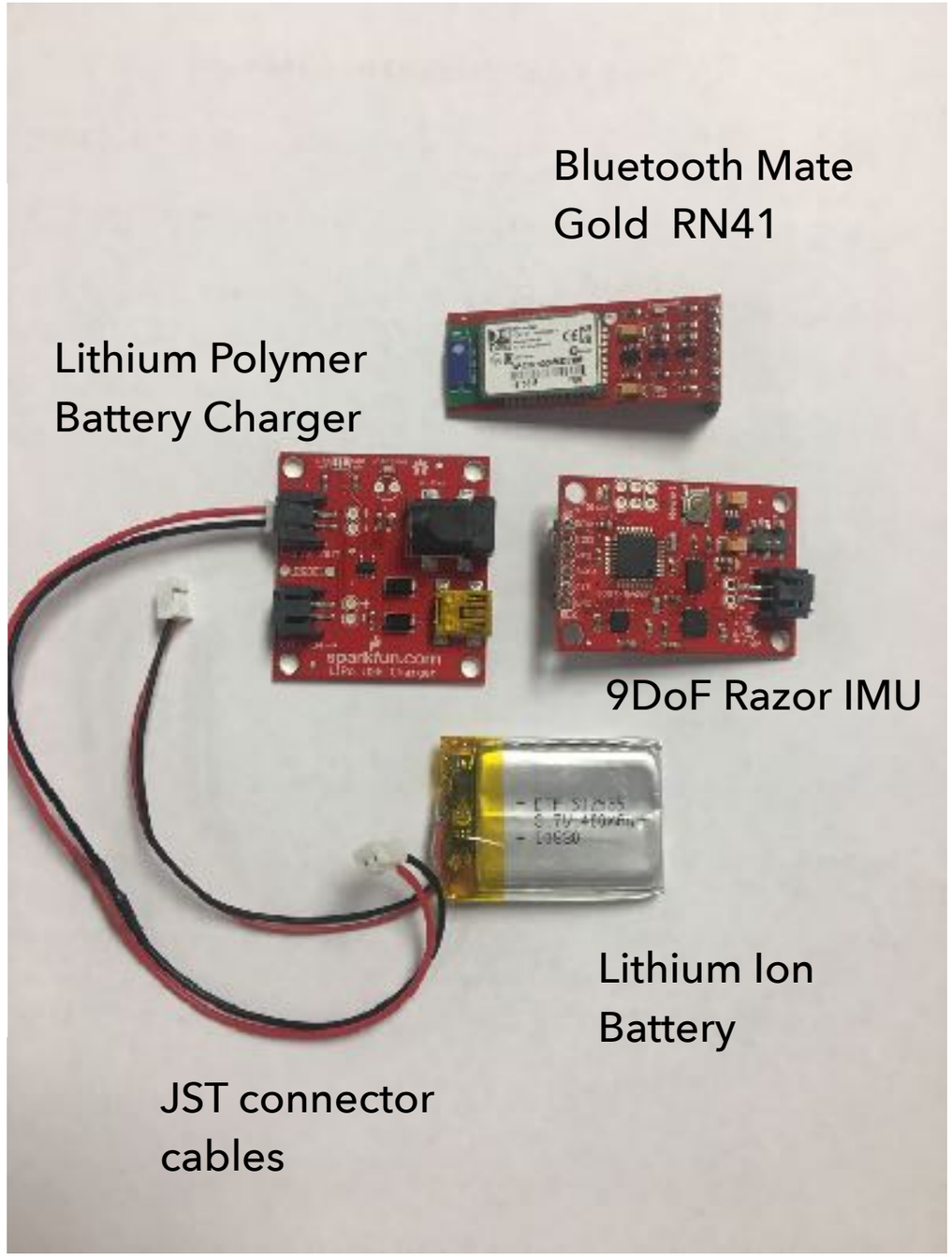
System checks if acceleration passes threshold

SOFTWARE/HARDWARE BLOCK DIAGRAM



SYSTEM BLOCK DIAGRAM



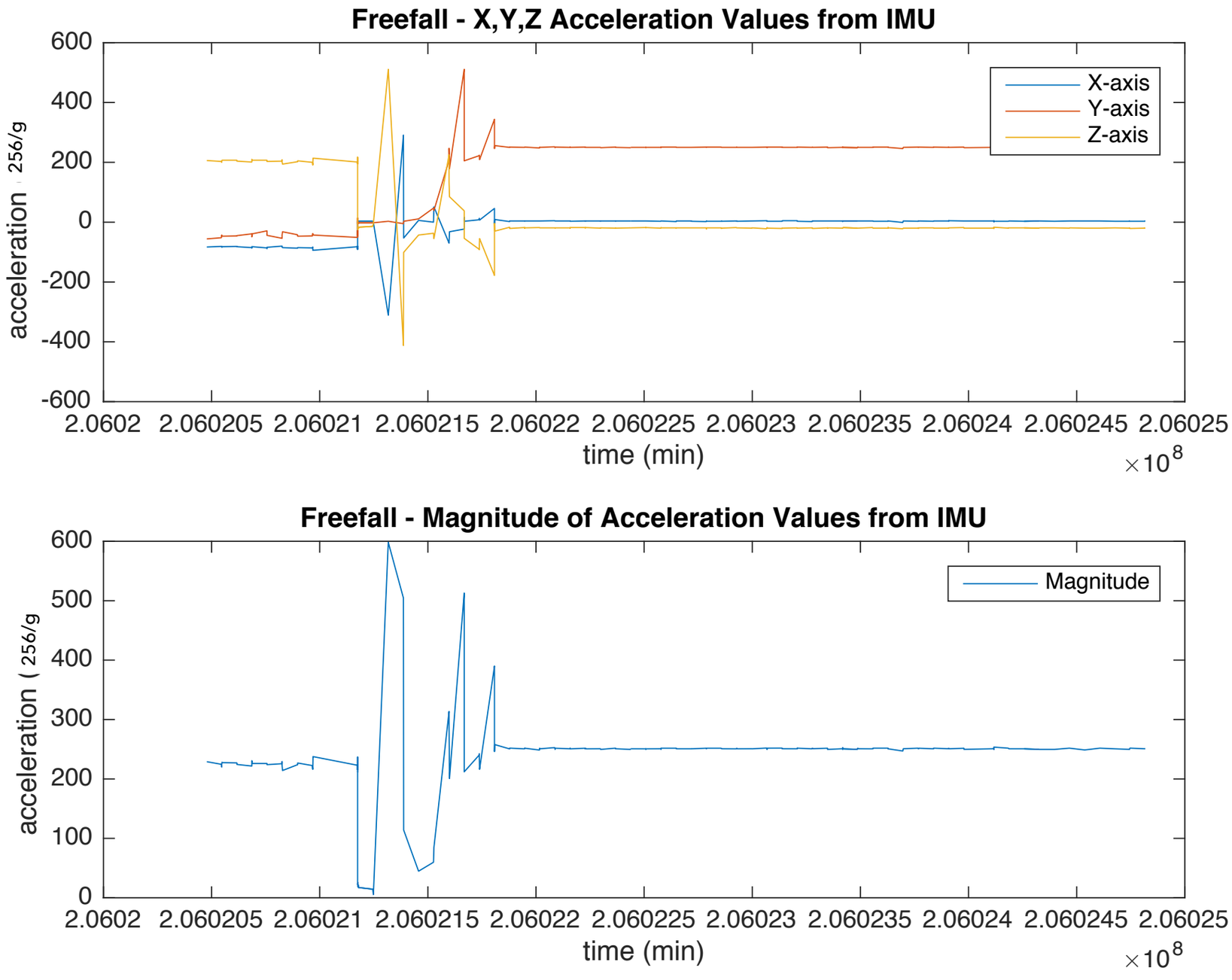


FALL DETECTION ALGORITHM

- The magnitude of acceleration from the accelerometer equation:

$$|\mathbf{a}| - \sqrt{{a_x}^2 + {a_y}^2 + {a_z}^2},$$

- Free-fall test



FALL-DETECTION ALGORITHM (CONT.)

- The algorithm was designed using the C++ code

```
float magnitude = (data[0]*data[0] + data[1]*data[1] + data[2]*data[2]);
bool falldetected = 0;
time(&t);                  //set t to current time
float deltat = t - t2;   //deltat is difference between current time and t2
```

This is the magnitude equation

data[0] = x-axis
data[1] = y-axis
data[2] = z-axis

```
if (magnitude > 360000) {
    falldetected = 1;
}

if ((falldetected == 1) && (deltat > 30)) {
```

POST-FALL PROCESSING

- Initially started off using a sendmail function in Matlab to send SMS and emails
  - was successful
- Switched to C++ to allow for real time response
  - configured postfix to send emails and SMS through SMTP Gmail server
  - used the system function to call the sendmail function in C++

```
    cout << "   " << "A fall has been detected" << endl;
    system("sendmail 7082698107@vtext.com < message.txt");
    time(&t2);
}
```

DEBOUNCING

Current time= T_Current

Time fell= T_2 (T_2 is a global variable which is set to 0)

Delta_T= T_Current - T_2

```
float magnitude = (data[0]*data[0] + data[1]*data[1] + data[2]*data[2]);
bool falldetected = 0;

time(&t);                 //set t to current time

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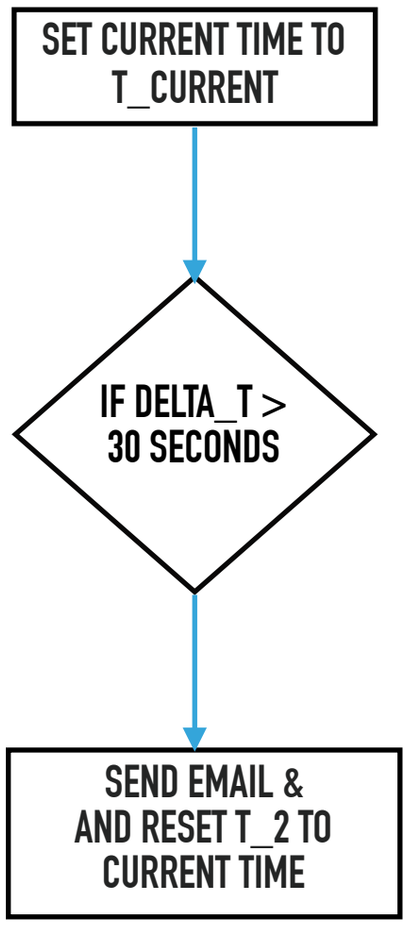


BLUETOOTH

- a C++ program, found on GitHub, connects the PC to a Bluetooth module with a specified serial port

- Compile the C++ code to pair the device

```
// Set your serial port here!
const string serial_port_name = "/dev/cu.RNBT-79BF-RNI-SPP";
```

- Now the Bluetooth module will show as connected on the bluetooth settings of the PC

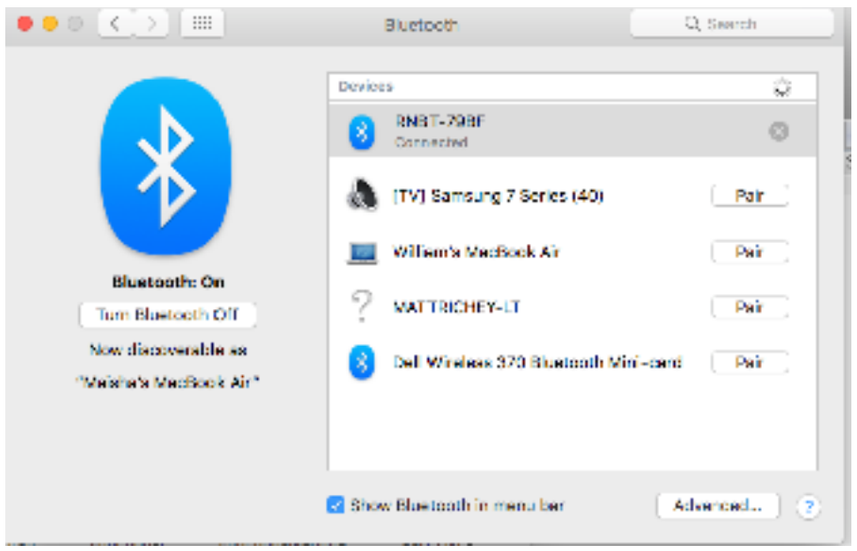
Serial port name

```
Last login: Mon Apr 17 17:50:10 on ttys000
[Maishas-MacBook-Air:~ maishatalukder$ cd /Users/maishatalukder/Desktop/SENIOR_PROJ_CODE
 Maishas-MacBook-Air:SENIOR_PROJ_CODE maishatalukder$ g++ Example_test.cpp RazorAHRS.cpp -Wall -D_REENTRANT -lpthread -o Example_test
[Maishas-MacBook-Air:SENIOR_PROJ_CODE maishatalukder$ ./Example_test fall.txt
```

Name of C++ code

Name of text file which will allocate the data

G++ command to compile program



BLUETOOTH (CONT.)

- Bluetooth transmits sensor data for biometric analysis
- Critical for post-fall analysis

Starting recording at time: Thu Apr 6 17:36:32 2017

time_ms	ACC_x	ACC_y	ACC_z	MAG_x	MAG_y	MAG_z	GYR_x	GYR_y	GYR_z
206117435,	-61.0,	-53.0,	213.0,	-39.0,	53.0,	204.0,	-20.0,	8.0,	24.0
206117436,	-65.0,	-50.0,	204.0,	-38.0,	52.0,	206.0,	-37.0,	11.0,	43.0
206117469,	-64.0,	-44.0,	204.0,	-37.0,	53.0,	206.0,	-54.0,	-20.0,	26.0
206117471,	-65.0,	-46.0,	205.0,	-48.0,	42.0,	208.0,	-45.0,	-51.0,	10.0
206117510,	-68.0,	-45.0,	204.0,	-39.0,	51.0,	208.0,	-14.0,	-29.0,	-9.0
206117511,	-65.0,	-49.0,	210.0,	-36.0,	33.0,	207.0,	5.0,	11.0,	13.0
206117545,	-65.0,	-48.0,	212.0,	-37.0,	55.0,	207.0,	-16.0,	-1.0,	20.0
206117547,	-65.0,	-51.0,	211.0,	-36.0,	56.0,	206.0,	-32.0,	5.0,	43.0
206117580,	-68.0,	-35.0,	221.0,	-36.0,	51.0,	205.0,	-71.0,	-10.0,	28.0
206117583,	-68.0,	-41.0,	211.0,	-45.0,	22.0,	205.0,	-89.0,	-17.0,	-11.0
206117617,	-66.0,	-39.0,	211.0,	-40.0,	57.0,	207.0,	-48.0,	-6.0,	-10.0
206117653,	-66.0,	-44.0,	206.0,	-37.0,	52.0,	213.0,	37.0,	28.0,	-11.0
206117685,	-65.0,	-52.0,	207.0,	-38.0,	49.0,	206.0,	47.0,	34.0,	7.0
206117685,	-64.0,	-54.0,	207.0,	-39.0,	54.0,	207.0,	-41.0,	20.0,	32.0
206117689,	-65.0,	-41.0,	209.0,	-50.0,	32.0,	212.0,	-132.0,	-22.0,	61.0
206117728,	-67.0,	-38.0,	203.0,	-35.0,	56.0,	208.0,	-92.0,	-37.0,	12.0
206117729,	-68.0,	-43.0,	207.0,	-37.0,	49.0,	206.0,	52.0,	13.0,	15.0
206117763,	-67.0,	-52.0,	207.0,	-36.0,	57.0,	206.0,	72.0,	33.0,	14.0
206117764,	-73.0,	-61.0,	207.0,	-46.0,	47.0,	202.0,	23.0,	28.0,	10.0
206117798,	-67.0,	-49.0,	209.0,	-35.0,	57.0,	203.0,	-94.0,	-33.0,	29.0
206117834,	-66.0,	-46.0,	210.0,	-39.0,	55.0,	209.0,	-121.0,	-46.0,	2.0
206117837,	-70.0,	-50.0,	209.0,	-38.0,	35.0,	208.0,	-6.0,	29.0,	39.0
206117871,	-65.0,	-43.0,	209.0,	-39.0,	60.0,	208.0,	32.0,	41.0,	46.0
206117874,	-66.0,	-42.0,	209.0,	-42.0,	52.0,	211.0,	-25.0,	-16.0,	24.0
206117913,	-69.0,	-45.0,	209.0,	-36.0,	51.0,	206.0,	-27.0,	-21.0,	16.0

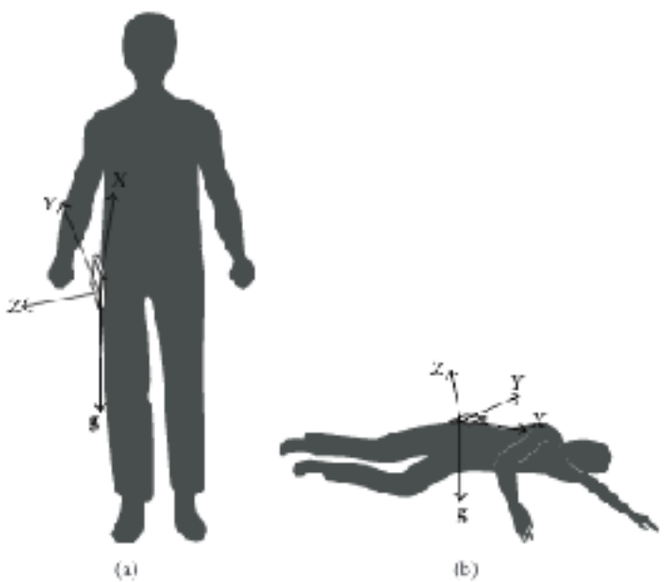
This text file displays the x,y,z values corresponding to the accelerometer, gyroscope, and magnetometer sensors at each time in milliseconds

DIFFICULTIES

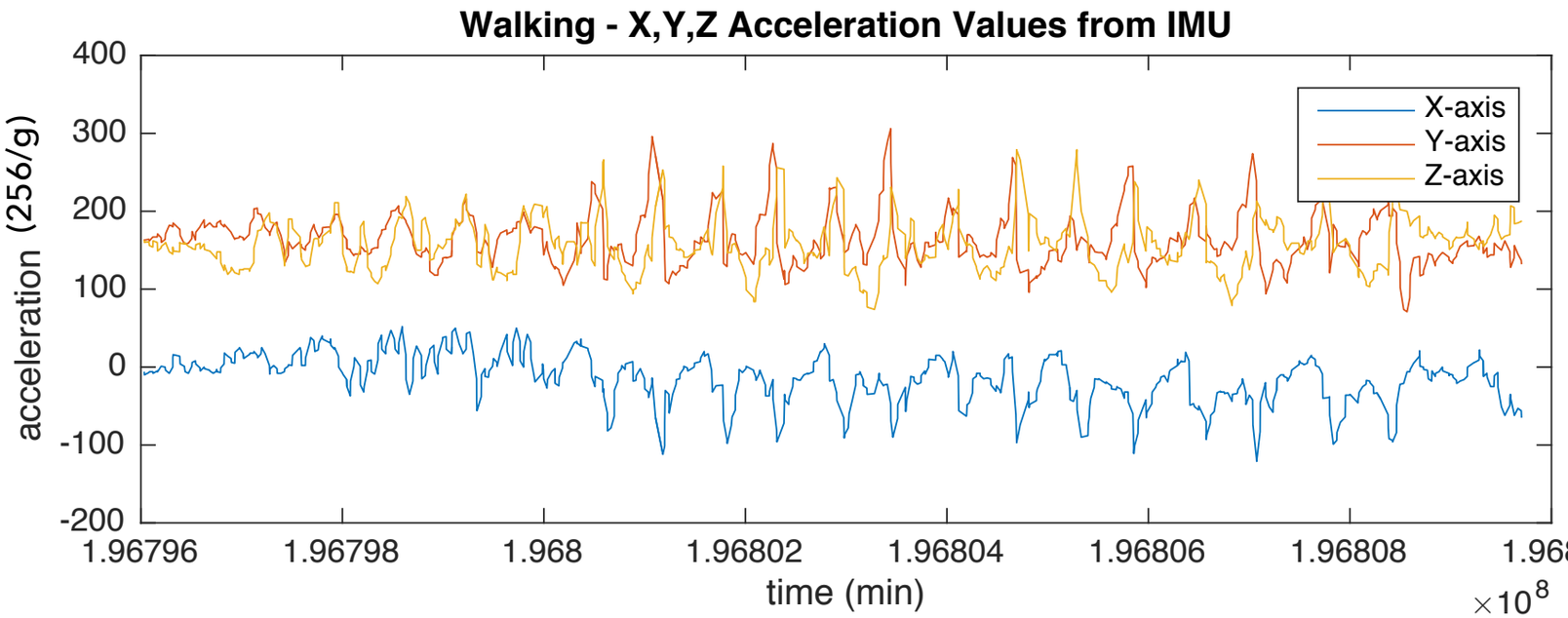
- ***Matlab-***
  - Originally used Matlab to create algorithm, but couldn't run continuously
    - *Solution:* Switched over to C++
- ***Bluetooth connectivity-***
  - Bluetooth would disconnect
    - *Solution:* Used a four-pin connector cable to remove the DTR and the CTS pin connection
- ***Algorithm-***
  - Distinguishing between a 'false-positive' and an 'actual' fall
    - *Solution:* Collecting multiple sets of data to find a threshold for a fall
  - SMS through C++ programming - authentication issues with Gmail
    - *Solution:* created a Gmail account with settings to allow SMTP
  - Debouncing to prevent multiple alarms from triggering
    - *Solution:* create time threshold to only allow one fall per threshold

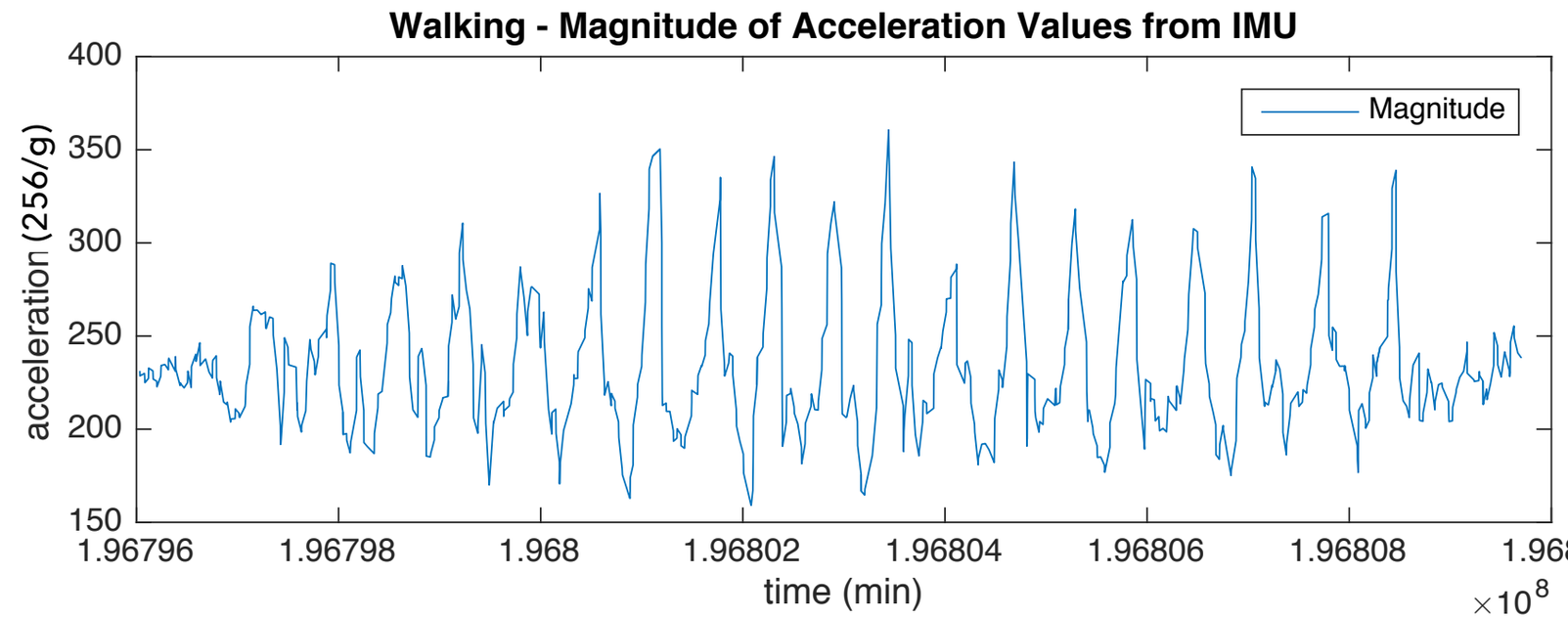
TESTING

- Found bluetooth connected over a 100 feet of open air range
- Found the Signal to Noise Ratio to be 8.56 dB- which is suitable for our application because noise is insignificant compared to threshold
- All hardware parts were secured in compact box with the measurement 3.25”. x 1.4”. x 2”

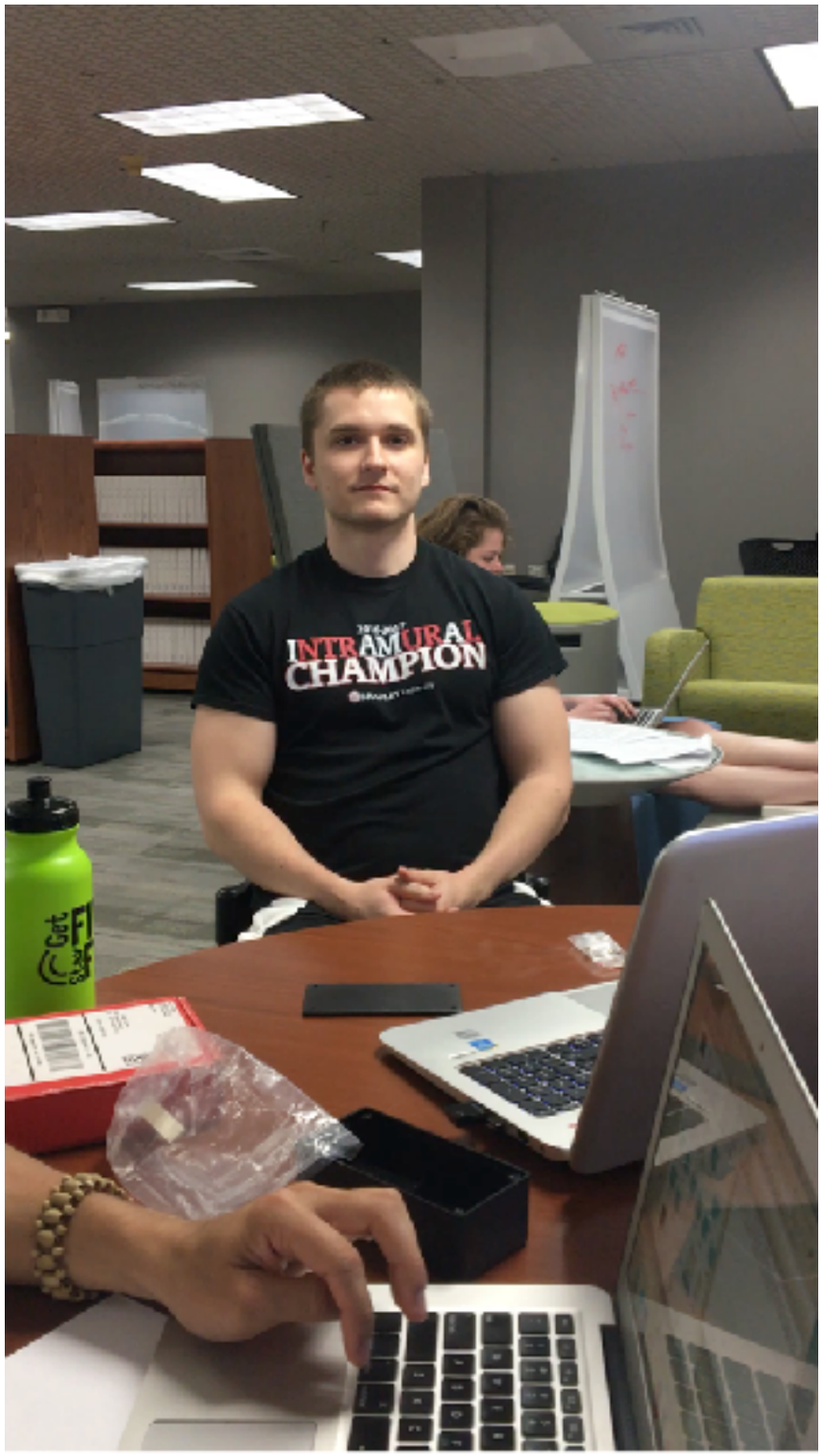


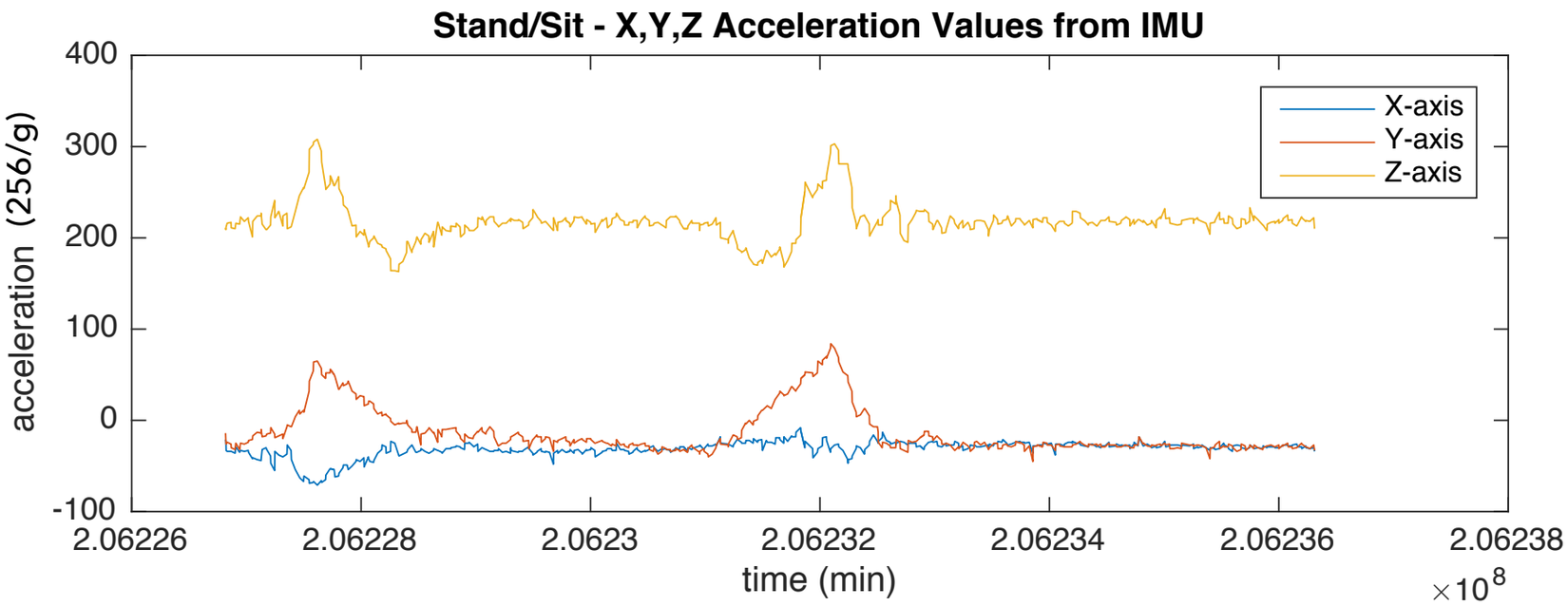
TESTING- WALKING

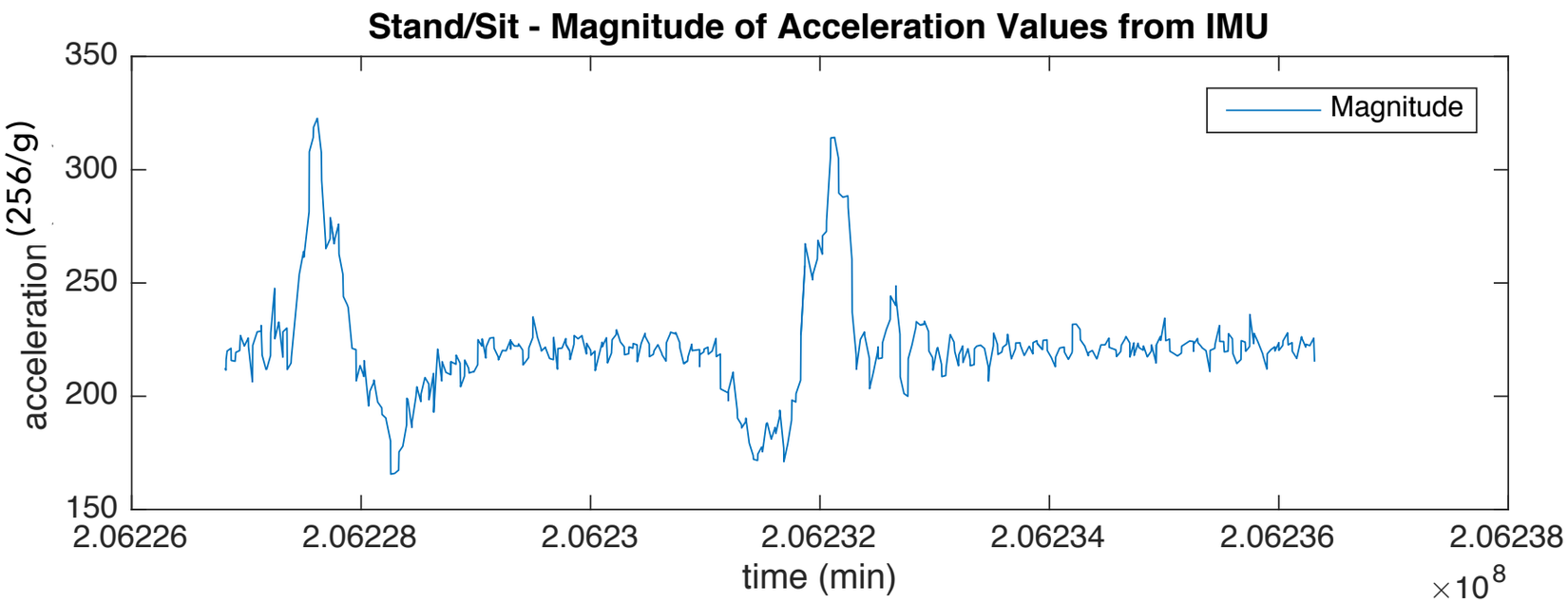




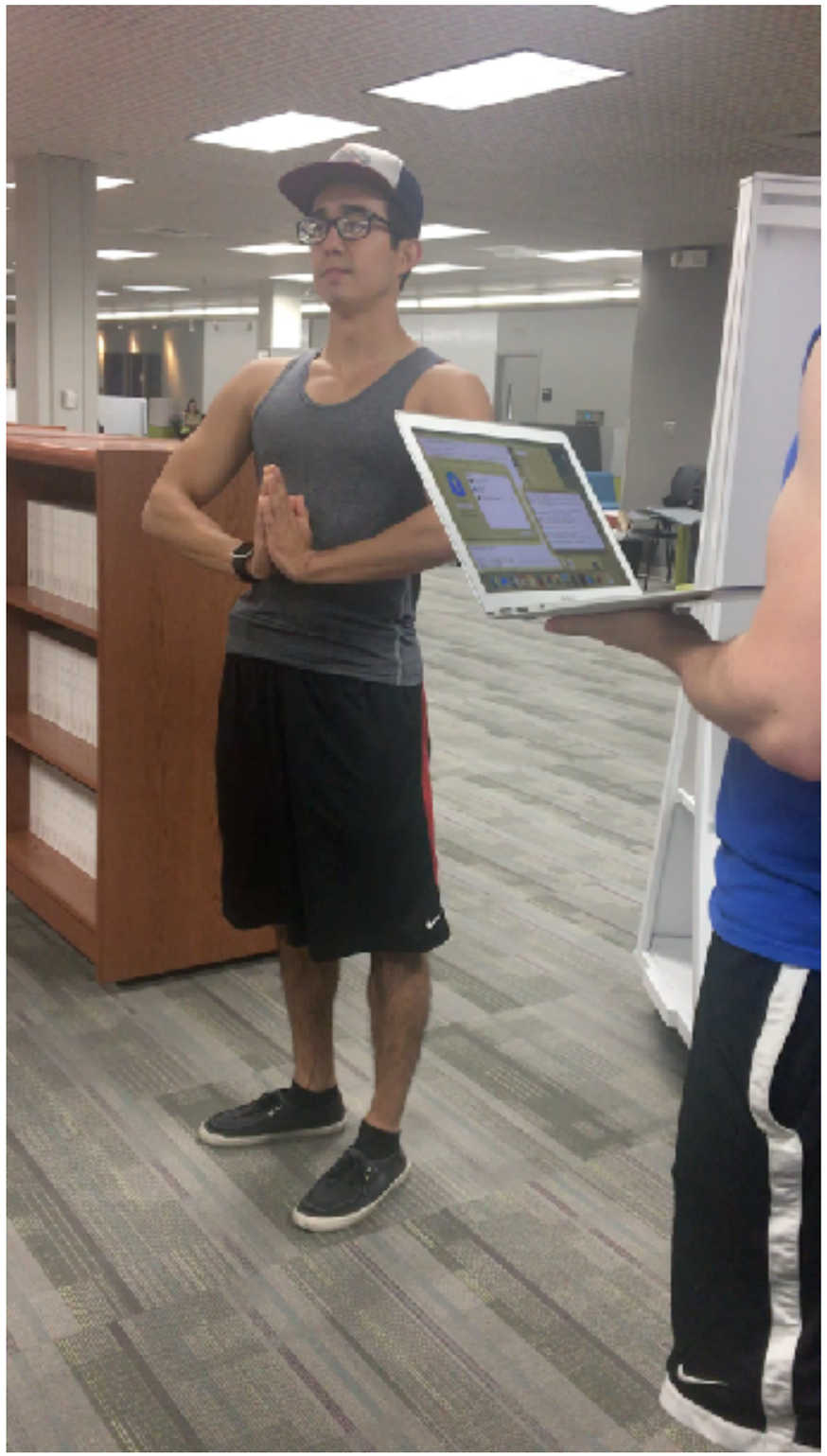
TESTING- STAND/SIT



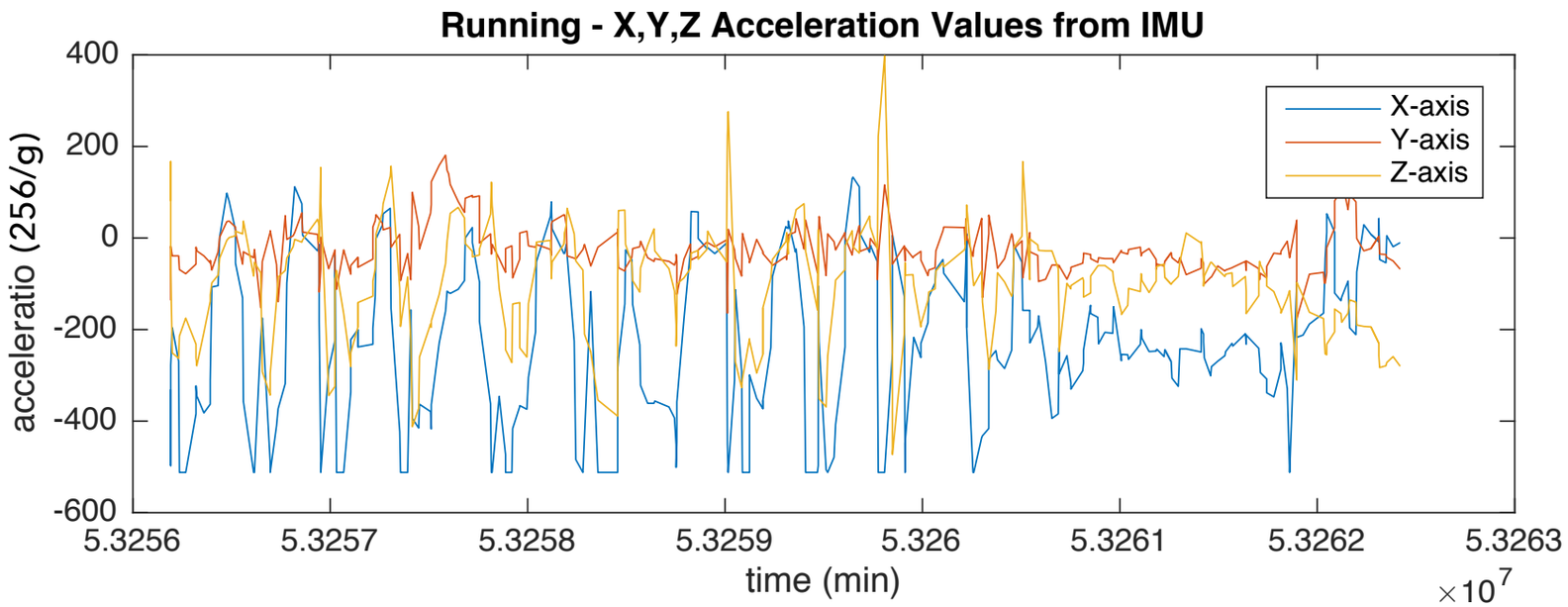


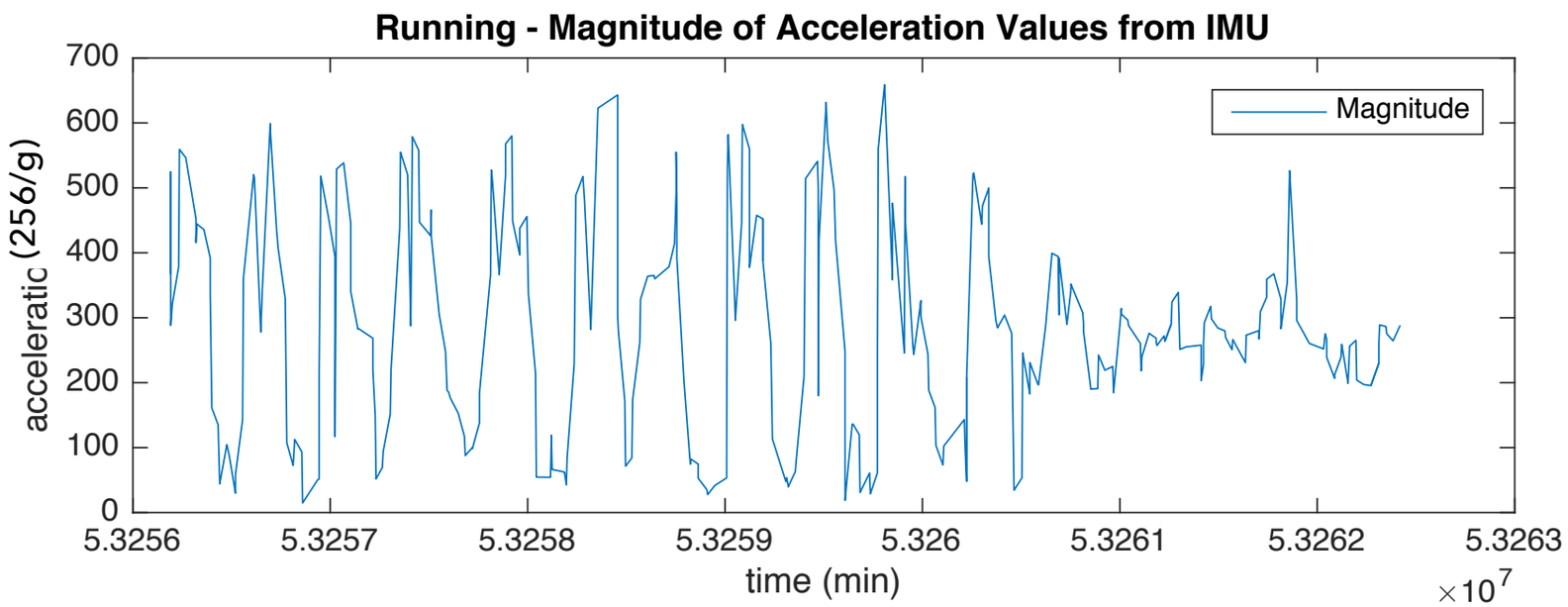


TESTING- RUNNING

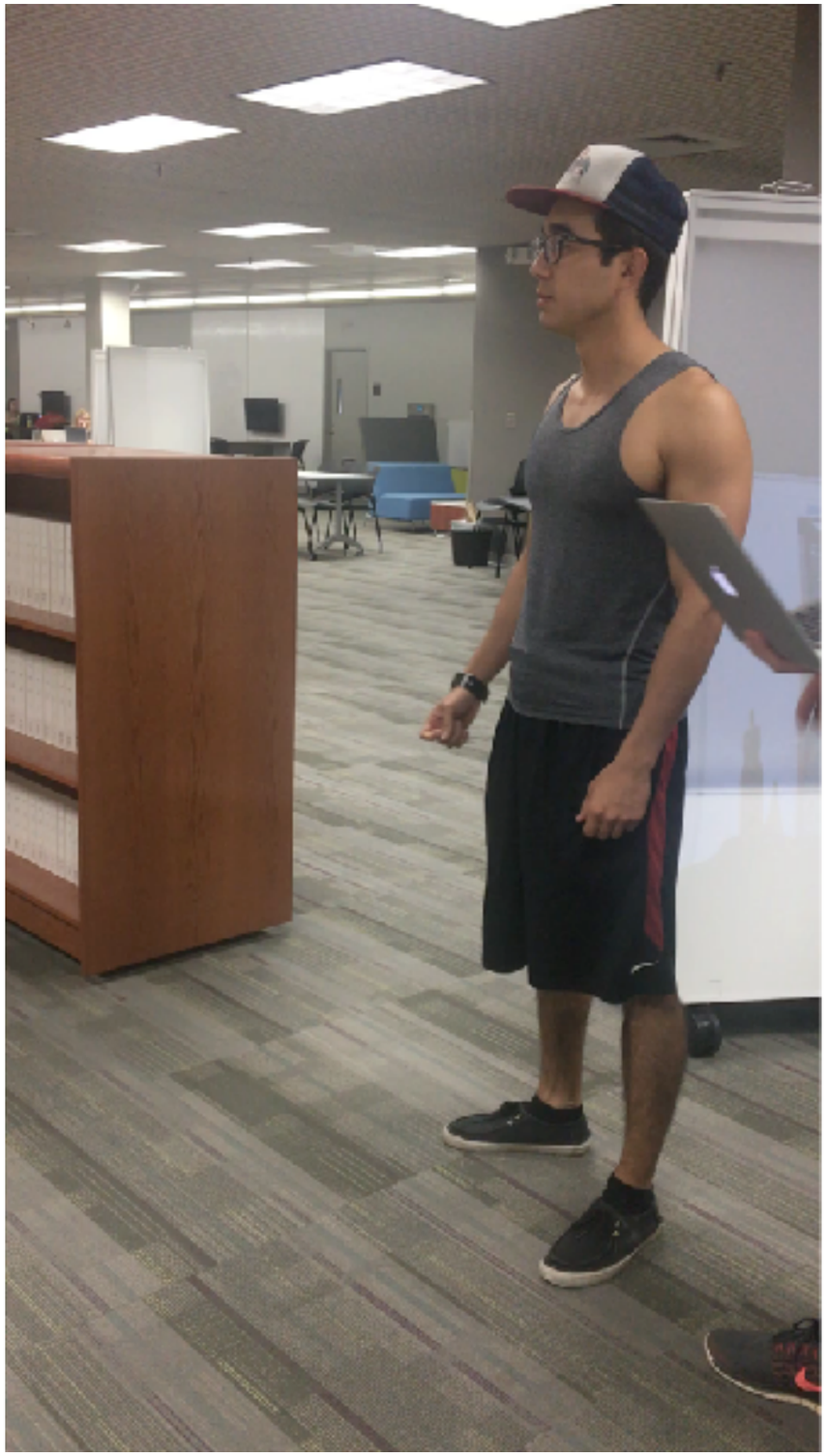


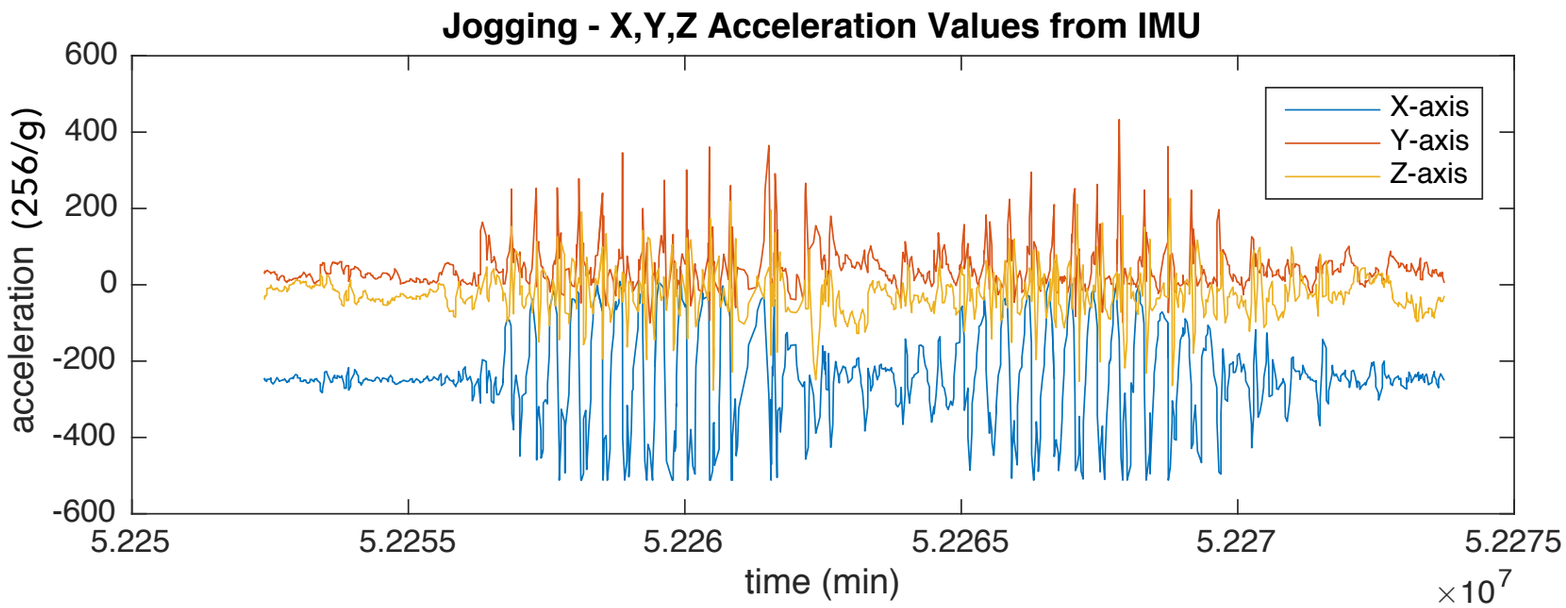
- For this test, we found the device to detect a fall

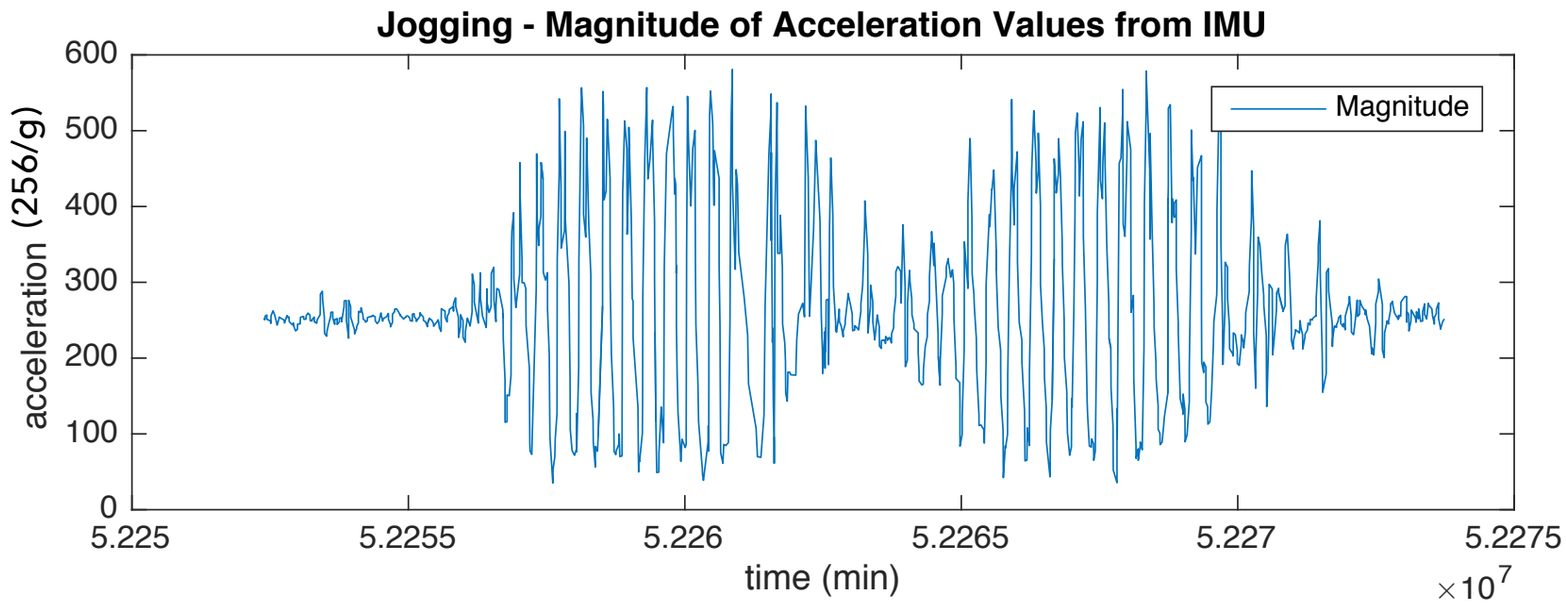




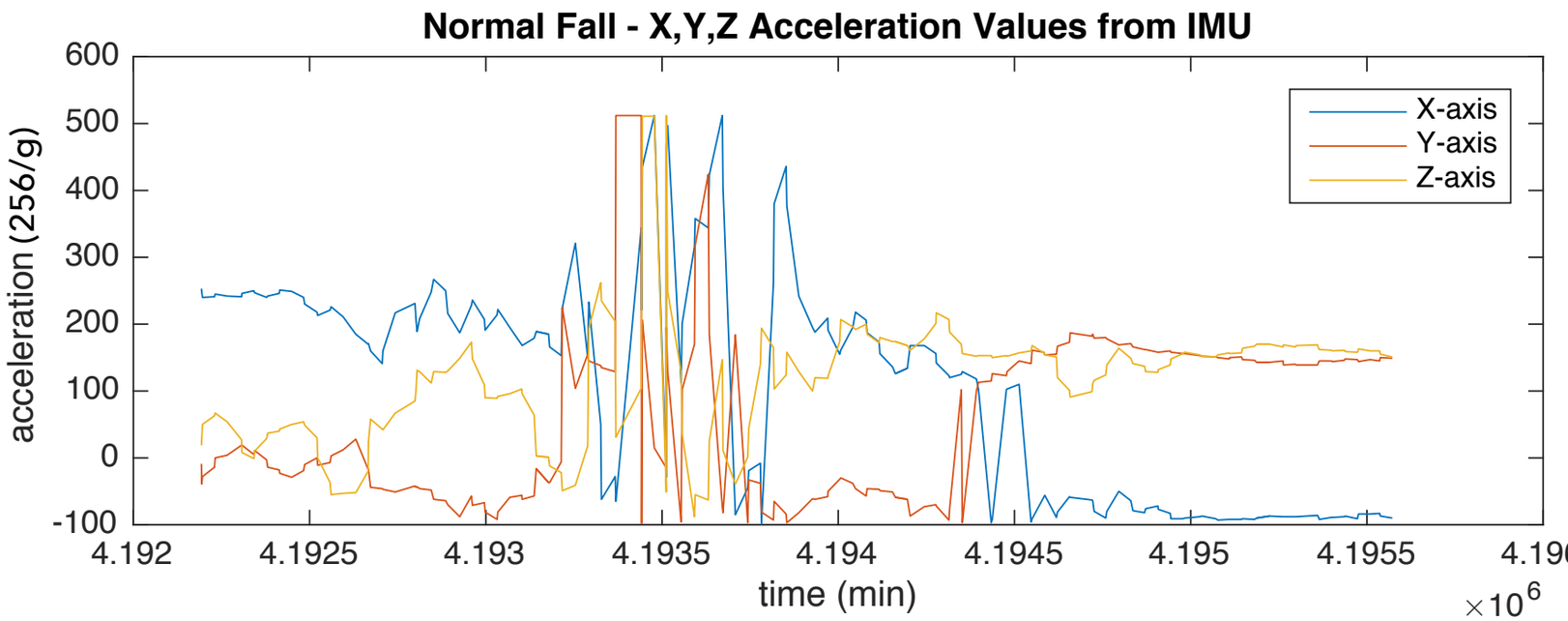
TESTING- LIGHT JOGGING

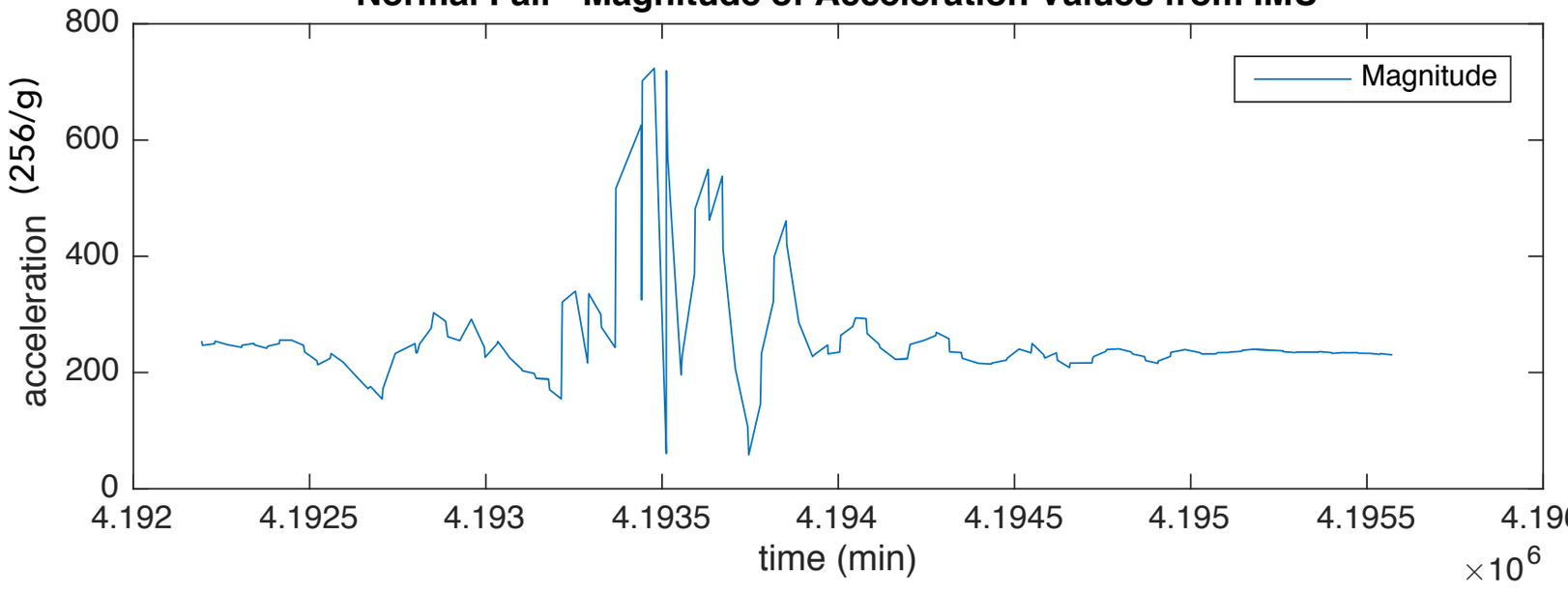




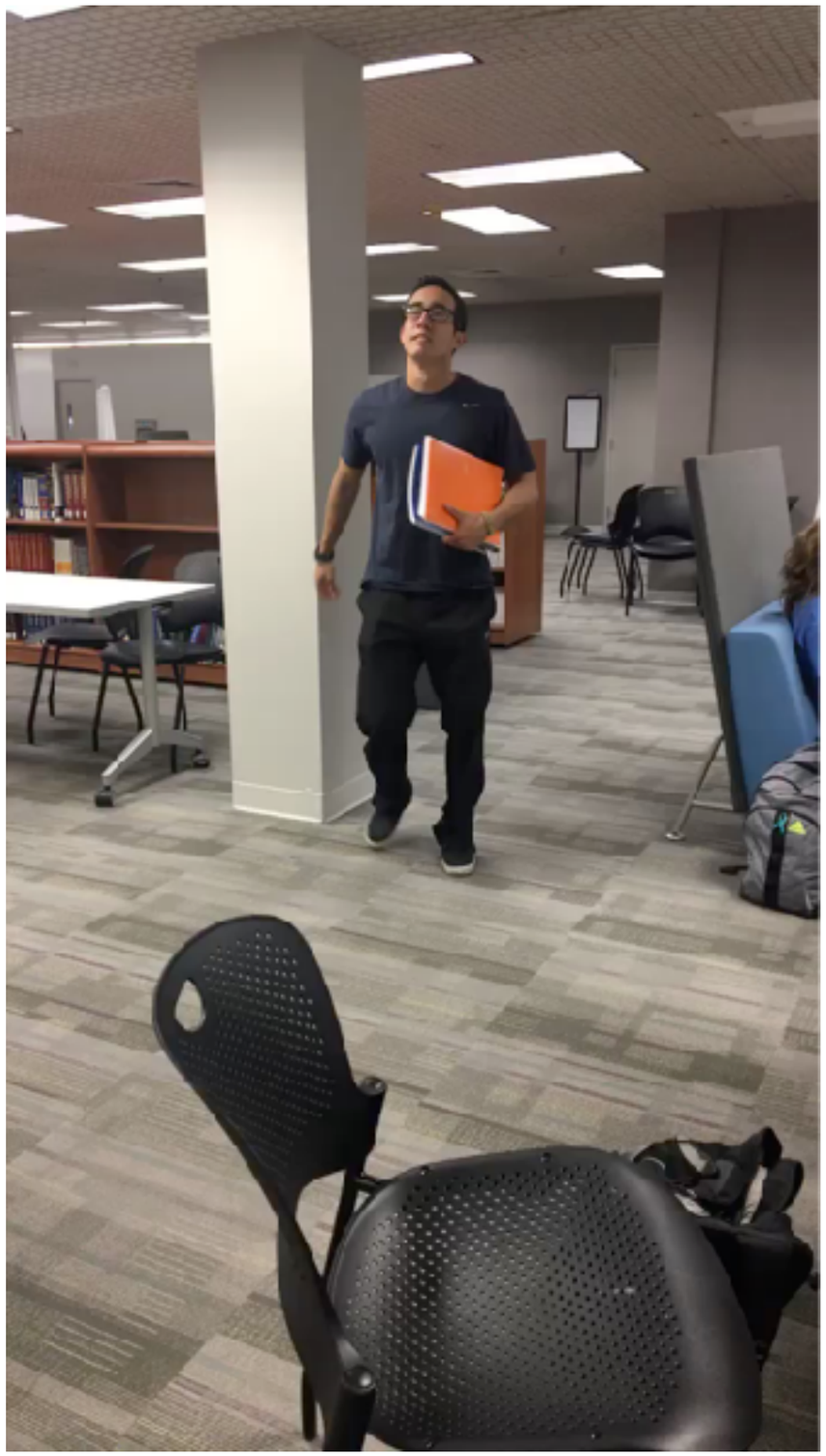


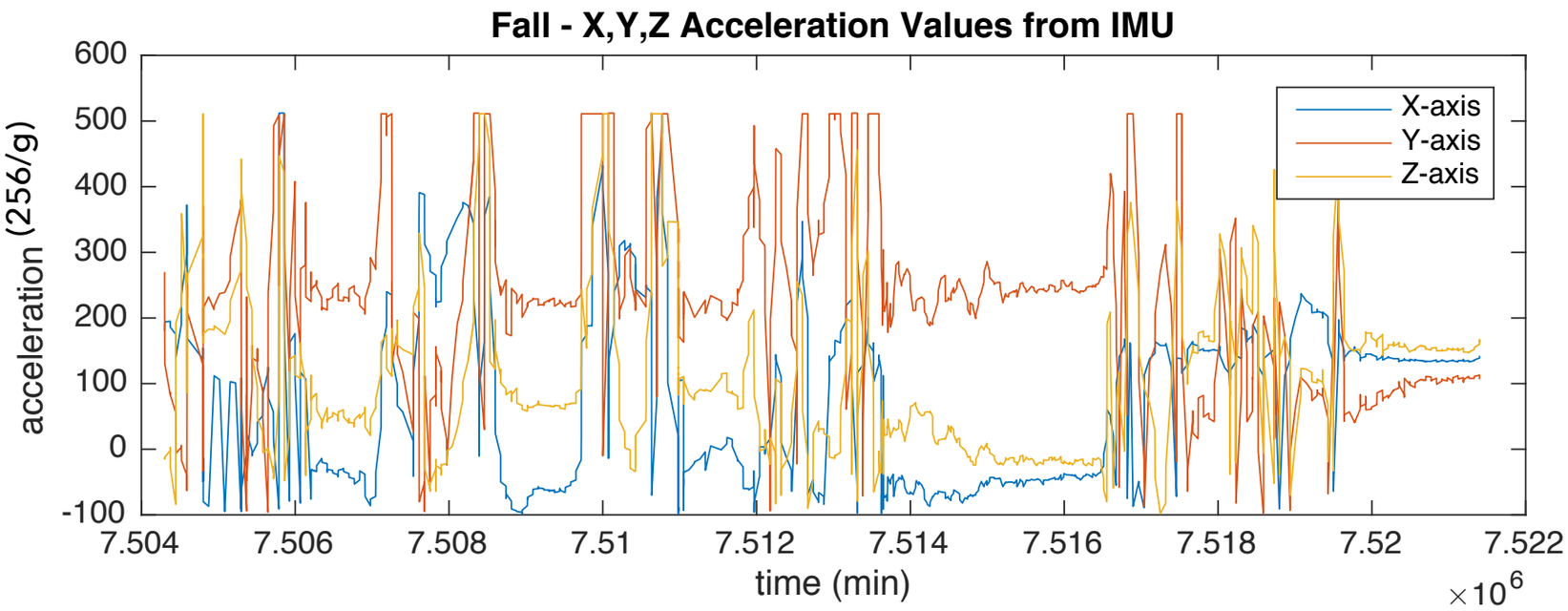
TESTING–NORMAL FALL

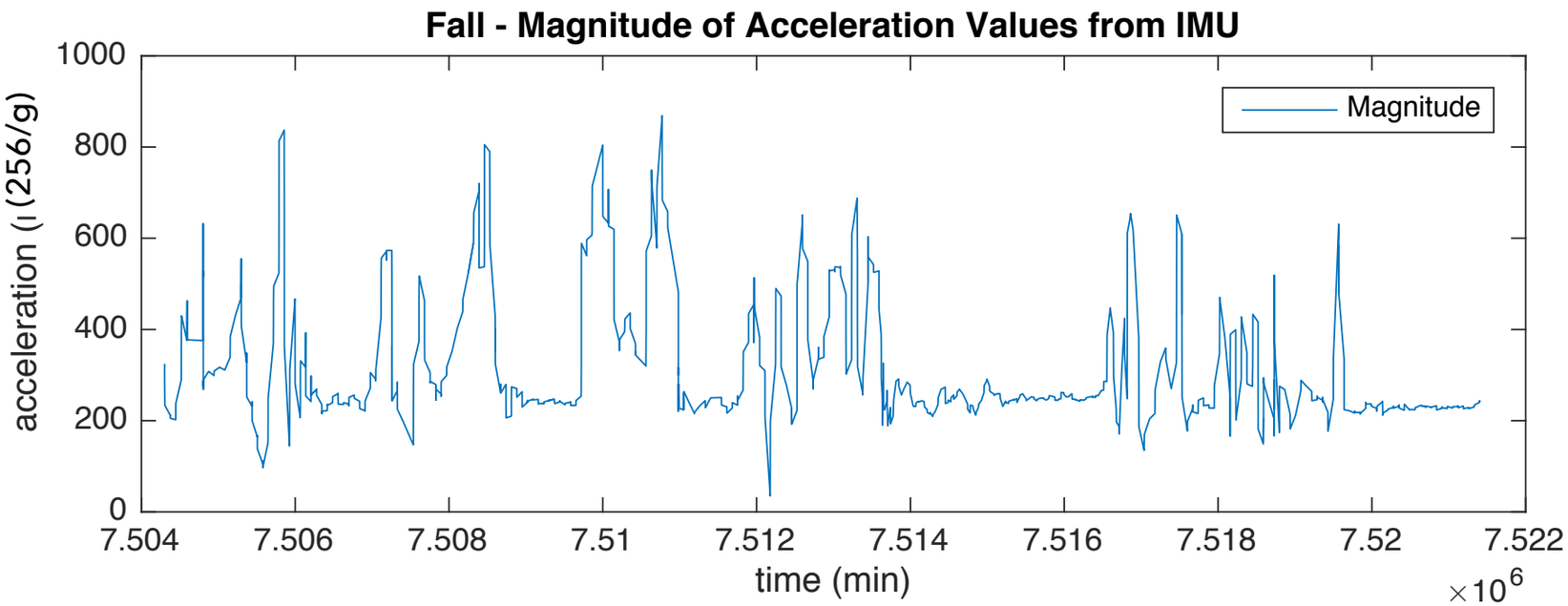




TESTING–FALL

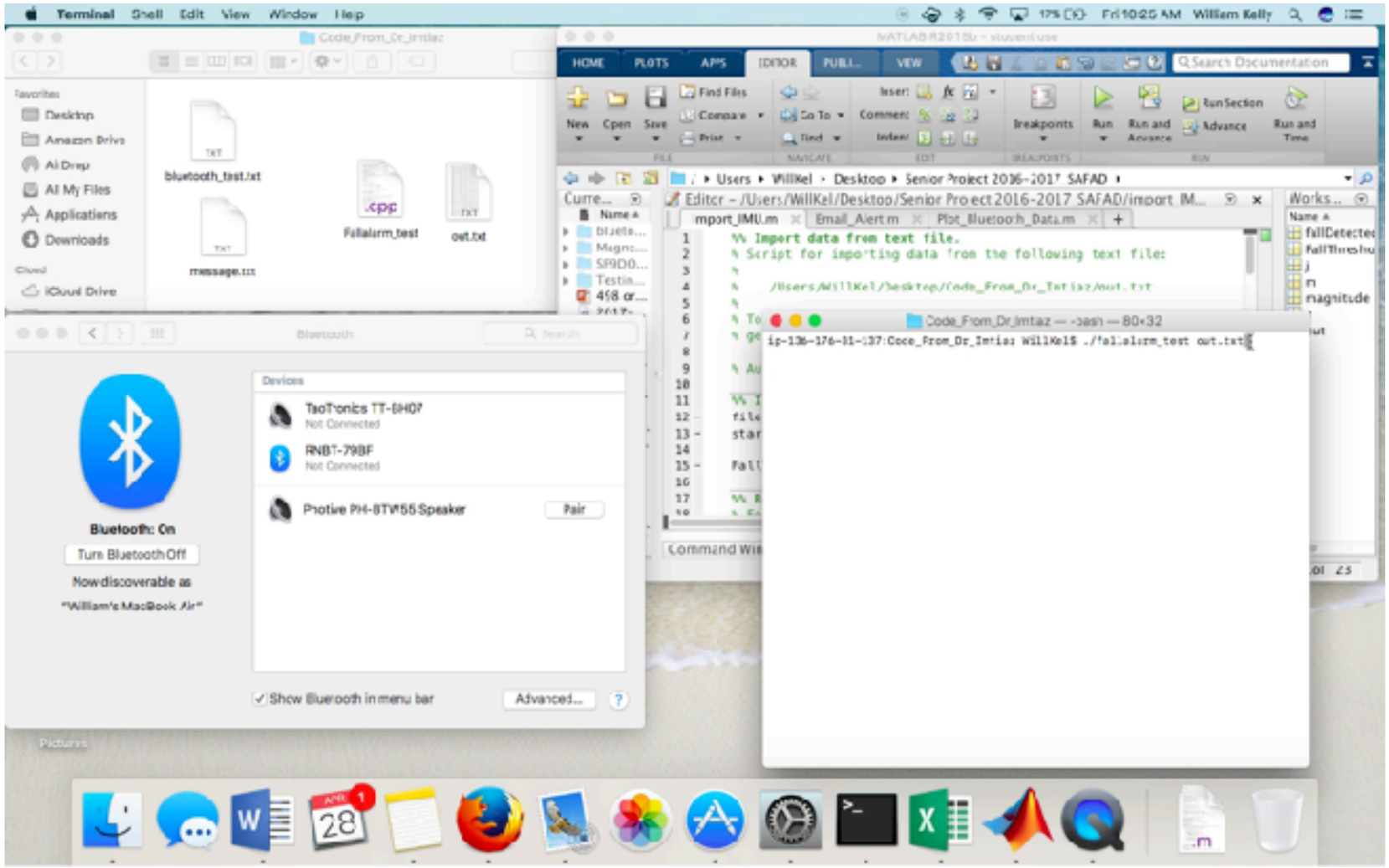






(no group members were harmed in making this video)

DEMO


Terminal Shell Edit View Window Help
Code_From_Dr_Imtiaz
bluetooth_test.txt
message.txt
Fallalarm_test
out.txt
HOME PLOTS APPS EDITOR PUBLI... VIEW
Search Documentation
New Open Save Find Files Compare Print Go To Find Breakpoints Run Run and Advance Run Section Advance Run and Time
Users WillKel Desktop Senior Project 2016-2017 SAFAD
Editor - /Users/WillKel/Desktop/Senior Project 2016-2017 SAFAD/import_IM...
import_IMU.m Email_Alert.m Plot_Bluetooth_Data.m
% Import data from text file.
% Script for importing data from the following text file:
Code_From_Dr_Imtiaz — -bash — 80×32
ip-136-176-81-137:Code_From_Dr_Imtiaz WillKel$ ./fallalarm_test out.txt
Bluetooth
Devices
TaoTronics TT-BH07
Not Connected
RNBT-79BF
Not Connected
Photive PH-BTW55 Speaker
Pair
Bluetooth: On
Turn Bluetooth Off
Now discoverable as
"William's MacBook Air"
Show Bluetooth in menu bar
Advanced...
Pictures

HOW ARE WE DIFFERENT?

- Our main target starting the project was to distinguish ourselves from current medical alerts
- We are different because:
  - we took the user interaction out of the system
  - our device can send texts to multiple caregivers
  - our size is much more compact and worn around waist
  - low cost and no monthly fees
  - our device stores fall data for future analysis
  - can detect inactivity for long period of time

WHAT WE HAVE LEARNED

Team:

- Designating and rotate roles and duties
  - Maisha: “CEO”
    - Aided both software and hardware role
      - reviewed and researched parts that were order
      - schedule meetings, made sure due dates were met
      - poster, final report, presentation
    - Will: Chief Technical Hardware Role
      - final say in what parts should be used
      - aided software trouble shooting
      - final report
    - Mike: Chief Technical Software Role
      - main say in the approach on software
      - website
      - final report
- Helping each other improve on our shortcomings

WHAT WE HAVE LEARNED (CONT.)

Engineering/Industry:

- Reading and understanding data charts
- How to create descriptive block diagrams & flowcharts
- Understanding how to transmit, receive, and collect raw data from an IMU
- Flowcharts- importance and creating them
- The financial aspect of a project
- Creating a business plan
- Documenting work in a professional manner
- If you don’t succeed, keep on trying (and ask for help!)
- Google is your best friend!

PARTS LIST

- **9 Degrees of Freedom - Razor IMU**
  - Cost: $74.95
  - Dimensions: 1.1" x 1.6" (28 x 41mm)
  - 9 Degrees of Freedom on a single, flat board:
    - ITG-3200 - triple-axis digital-output gyroscope
    - ADXL345 - 13-bit resolution, ±16g, triple-axis accelerometer
    - HMC5883L - triple-axis, digital magnetometer
    - On board Atmega328 microcontroller
    - Baudrate 57600 bps
    - 3.3 V, 8 MHz

- **SparkFun Bluetooth Mate Gold**
  - Cost: *$34.95*
  - Dimensions: 13.4mm x 25.88 mm x .2mm
  - Low power consumption: 25mA avg.
  - Operating Voltage: 3.3V-6V
  - Serial communications: 2400-115200 bps
  - Baud rate 1200bps up to 921Kbps
  - Blinks at various colors to imply the state of connections
    - red LED indicates no connection
    - green LED indicates connected

PARTS LIST (CONT.)

- **FTDI Cable**
  - Provided by Mr. Mattus
  - Interface MATLAB to the IMU

- **Lithium Ion Battery**
  - Cost: $4.95
  - Charged by a LiPo charger
  - Small, lightweight battery based on Lithium Ion chemistry
  - Each cell outputs a nominal 3.7V at 400mAh
  - Powers device for ~6 hours

- **LiPo Charger**
  - Cost: $14.95
  - Basic charging circuit that allows you to charge 3.7V LiPo cells at a rate of 500mA or 100mA

- **JST 2-Pin Cable**
  - Cost: $0.75

TOTAL COST

Item	Price
9 Degrees of Freedom Razor IMU	$74.95
Bluetooth Mate Gold	$34.96
Lithium Ion Battery	$4.95
LiPo Charger	$14.95
JST 2-Pin Cable	$0.75
TOTAL	**$130.56**

CONCLUSION

- Falls are successfully detected
- Post-fall alerts delivered effectively (email, SMS)
- Software
  - Matlab was used initially- too slow for real-time application
  - C++ worked well for real-time application
- Designed a cost-effective, highly configurable fall/inactivity detection system
  - User-friendly
  - significant improvement to current solutions

WHAT'S NEXT?

- Improve the fall-detection algorithm:
  - eliminating/minimizing 'false-positive'
  - incorporating gyroscope data to determine orientation of user
  - integrate GPS
- Switch to Wifi for increased range & increased battery life
- Outerwear:
  - reduce size
  - design customized box to contain device- 3D printing
- Replace PC with a Raspberry Pi
- Test on the elderly

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QUESTIONS