WHITMAN COLLEGE

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Smartphone Sensors

Using raw smartphone sensor data in the classroom

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Overview

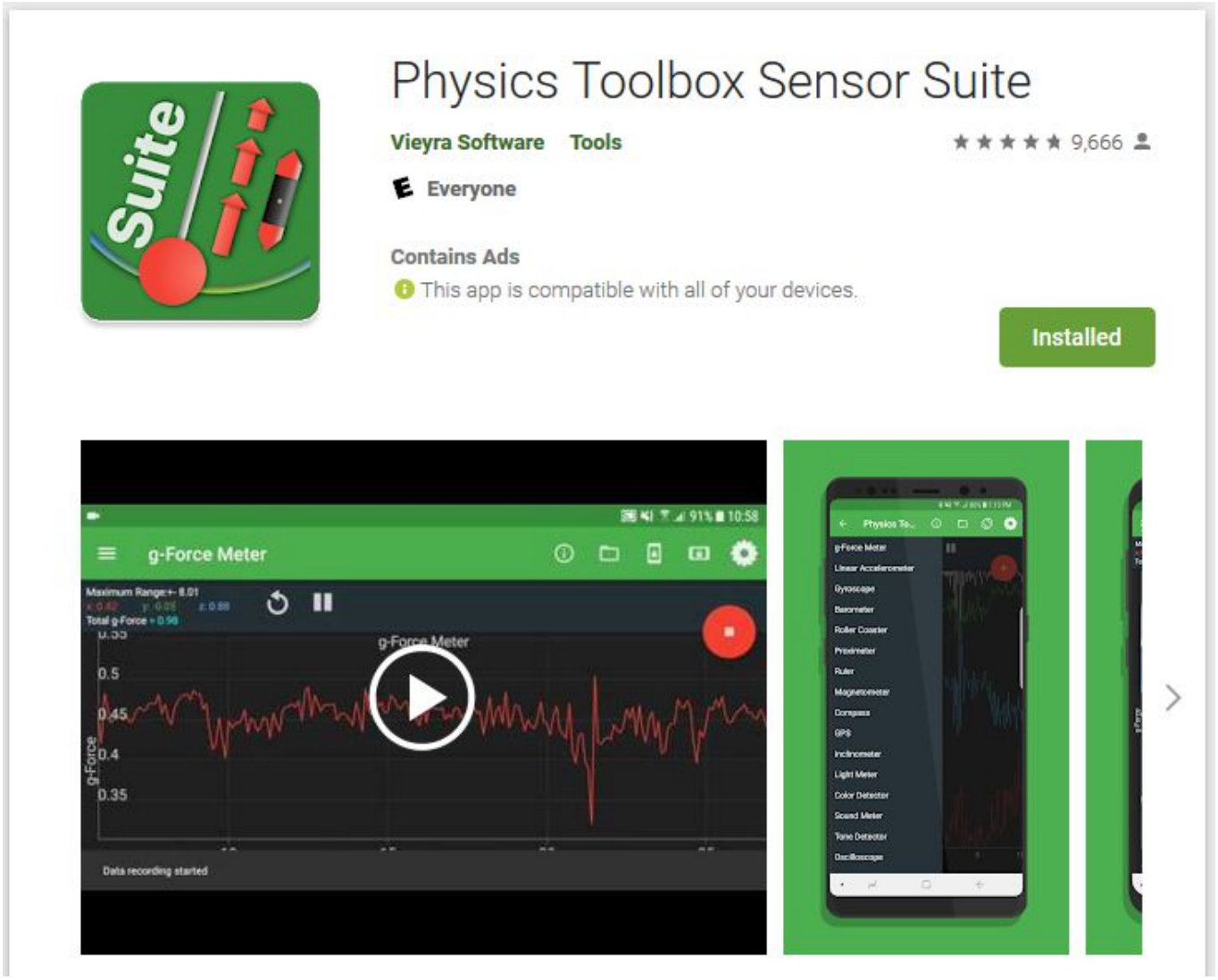
Introduce a collection of useful technologies that have a broad range of applications and that students will find motivating.

- Phone sensors and collecting raw data
- Jupyter/Python for analyzing raw data
- Mapbox, “free” mapping software
- Github, managing and distributing projects

Phone Sensors

From: Majumder, S.; Deen, M.J. Smartphone Sensors for Health Monitoring and Diagnosis. Sensors 2019, 19, 2164.

Raw Sensor Data



Measuring Height

- Use the accelerometer sensor data to measure the height of an object.
- Teaches the relationship between acceleration, velocity, and position.

In [3]:

```
# Compute delta t, (total time)/(number of points)
dt = raw.index[-1]/raw.shape[0]
# Get the z-comp of g-force
az = np.array(raw.gFz)
# Compute the average of the first 100 pts
avg = np.average(az[:100])
# Correct by the average (in case baseline shift), convert to acceleration
az = 9.80665*(az-avg)
# Integrate to get velocity
vz = dt*az
vz = np.cumsum(vz)
# Integrate to get acceleration
pz = dt*vz
pz = np.cumsum(pz)
```

The Fastest Mile: Data Collection

- Use the GPS sensor to record an exercise like walking, running or cycling.
- Teaches about noise, smoothing, average speed, concavity.

The Raw Data

```
In [4]: raw.head()
```

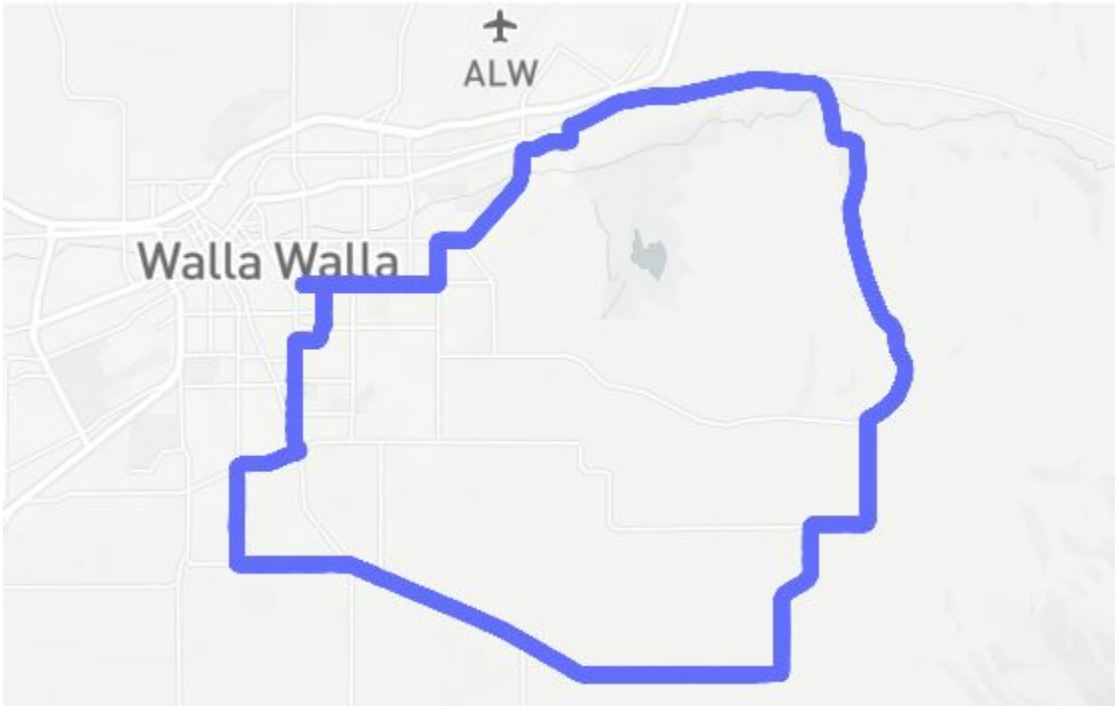
Out[4]:

	time	Latitude	Longitude	Unnamed: 3	Unnamed: 4
0	16:05:56:425	46.062110	-118.323794	NaN	NaN
1	16:05:59:370	46.062103	-118.323783	NaN	NaN
2	16:06:19:366	46.062106	-118.323758	NaN	NaN
3	16:06:20:365	46.062103	-118.323737	NaN	NaN
4	16:06:21:367	46.062094	-118.323729	NaN	NaN

Data Analysis

Visualize the data to make sure you aren't analyzing junk.

- Jupyter, Plotly, Mapbox (all free).
- Plotly on-line visualization of the data.



Data Analysis (cont'd)

Question: Within this longer exercise, which mile-long segment was the fastest?

Answer: brute force approach

Question: Where's the mathematics?

Answer: all over the place

In the math classroom, we must accompany data analysis with abstract mathematical analysis.

Mathematical analysis

Define a time vs. position function:

$$t : [0, D] \to [0, T]$$

Define an average speed function:

$$Q(p) = \frac{t(p + L) - t(p)}{L}$$

Fundamental Theorem of Calculus, concavity

Find fastest and slowest miles by differentiating and setting equal to zero:

$$Q'(p) = \frac{t'(p+L) - t'(p)}{L} = 0$$

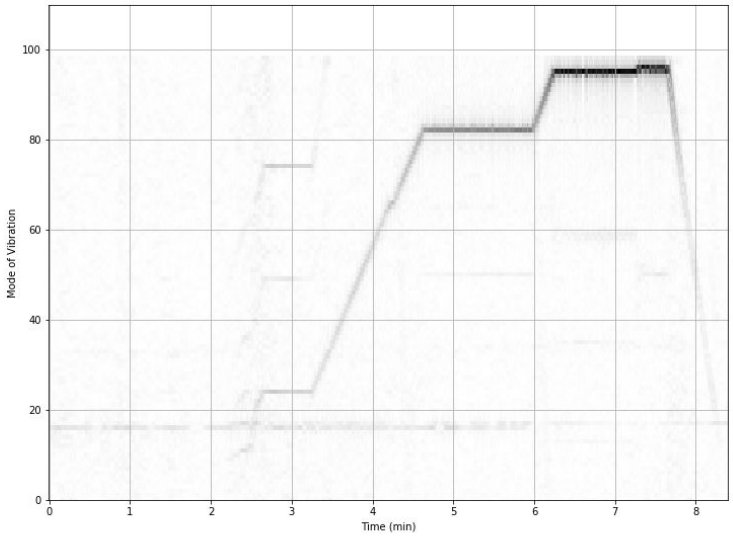
Or, use the FTC and think about concavity:

$$Q'(p) = \frac{1}{L} \int_p^{p+L} t''(v)\, dv = 0$$

Concavity allows student to make some qualitative observations.

Spin Cycle

- Using the accelerometer, we can measure the vibrations of a washing machine.
- A Fourier analysis extracts dominant modes of vibration.
- The dominant modes of vibration tell us how quickly the washing machine spins during its spin cycle.



Other Smartphone Sensor Projects

- Fitness and sleep tracking, accelerometer, GPS
- Respiratory health, cough monitoring, microphone
- Cardiovascular health, camera
- Weather prediction/monitoring, barometer
- Bone density, accelerometer
- Earthquake detection, accelerometer

Learning Resources

How did I figure all of this out?

- Learned to program in Python. There are now many resources: books, on-line courses, videos to help one learn to program.
- Did a lot of DataCamp courses around data science using Python.
- Worked on small, low-stakes data science projects of my own. e.g. crunched data from our office of institutional research.
- Worked on data science projects with students in our senior project course.
- Used (continue to use) Python data science tools to develop course materials and demos in my regular math classes.

Additional Resources

- Recent article by yours truly: *Phone Sensor Data in the Mathematics Classroom* article in PRIMUS (Aug 2019)
- Github Repository: https://github.com/schuelaw/PhoneSensorMath under development, send me your ideas!

Thank you for coming!
Questions?

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