Step Counting and Activity Recognition

CSE 162 – Mobile Computing

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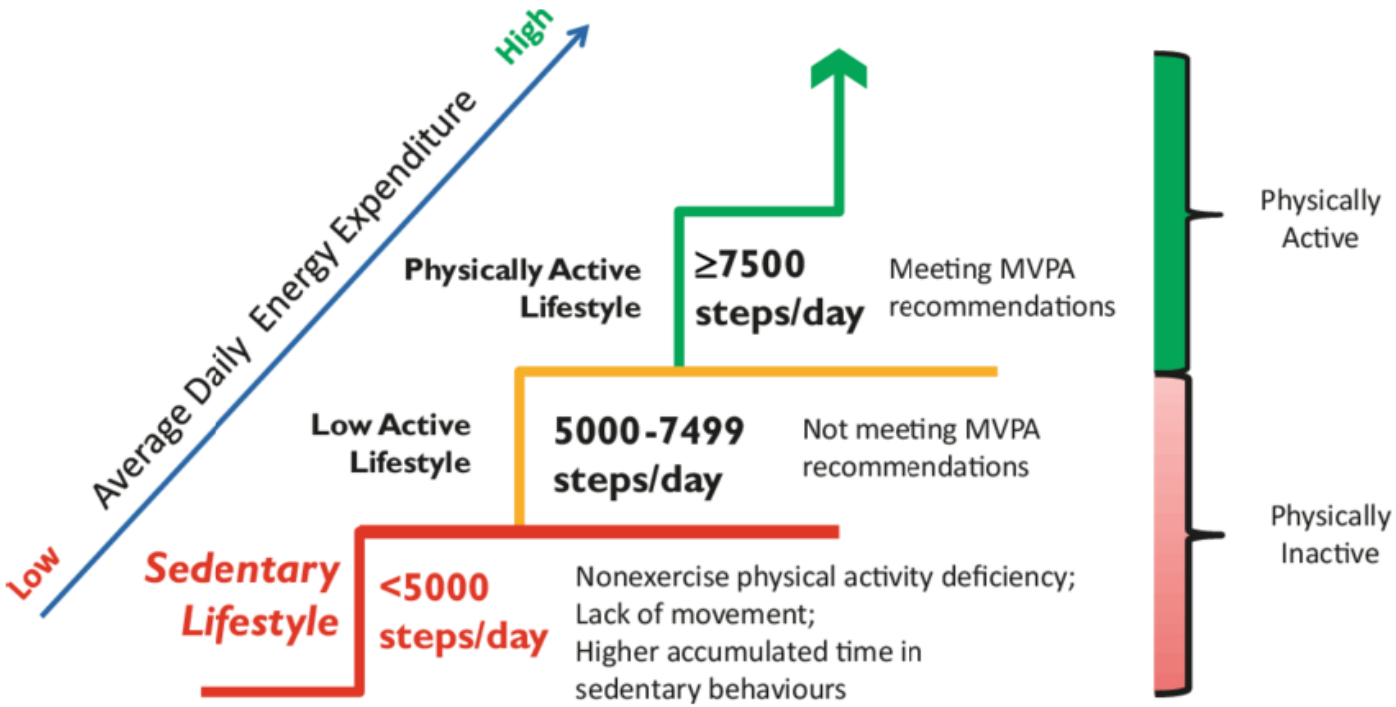
Step Counting

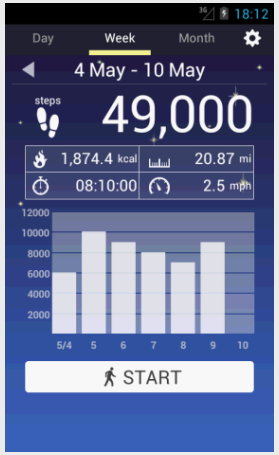
Sedentary Lifestyle

- Sedentary lifestyle
  - Increases risk of diabetes, heart disease, dying earlier, etc
  - Kills more than smoking!!
- Categorization of sedentary lifestyle based on step count:
  - “A step-defined sedentary lifestyle index: < 5000 steps/day” (2013)



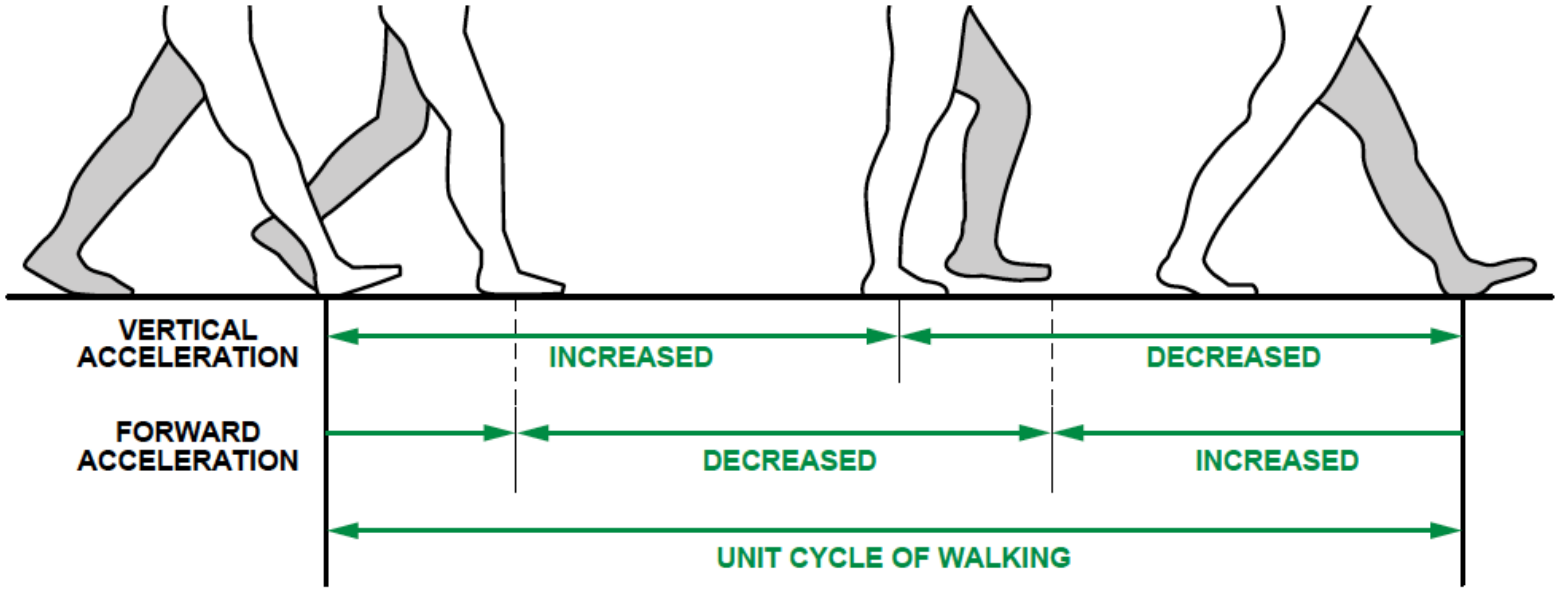
Step Count Mania

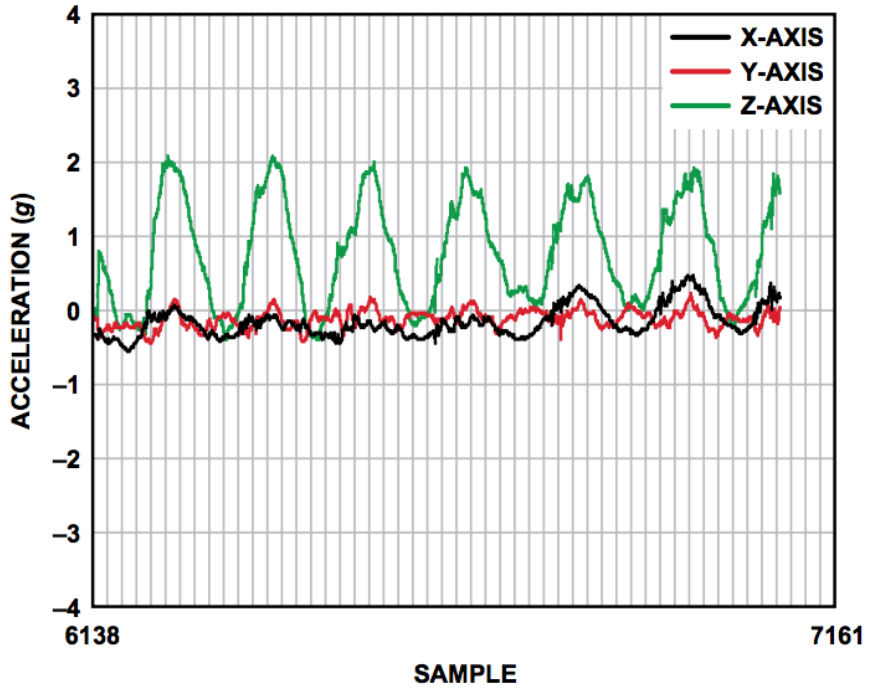
- Everyone is crazy about step count these days
- Pedometer apps, pedometers, fitness trackers, etc
- Tracking makes user aware of activity levels, motivates them to exercise more



The Nature of Walking

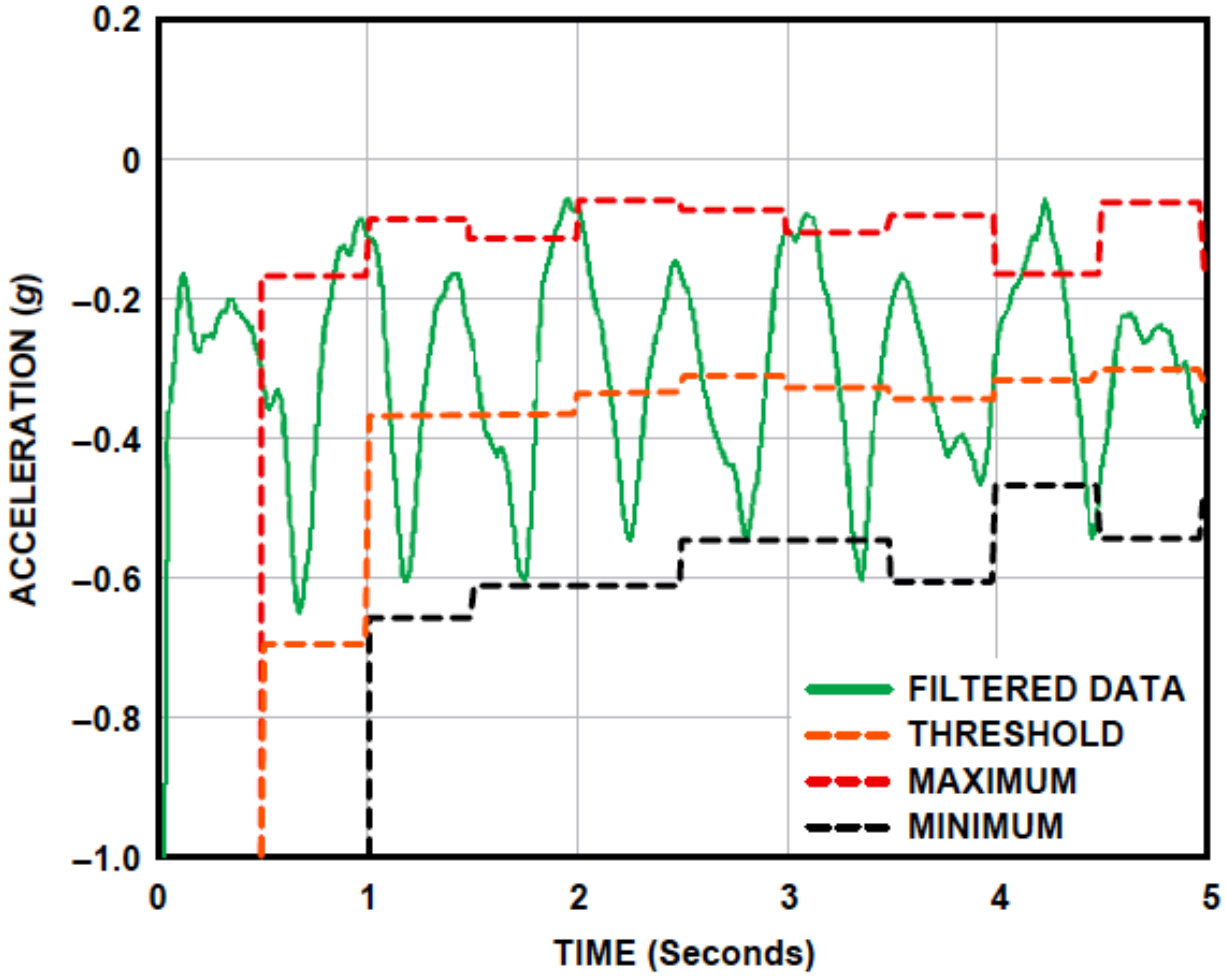
- Vertical and forward acceleration increases/decreases during different phases of walking
- Walking causes a large periodic spike in one of the accelerometer axes
- Which axes (x, y or z) and magnitude depends on phone orientation





Step Detection Algorithm

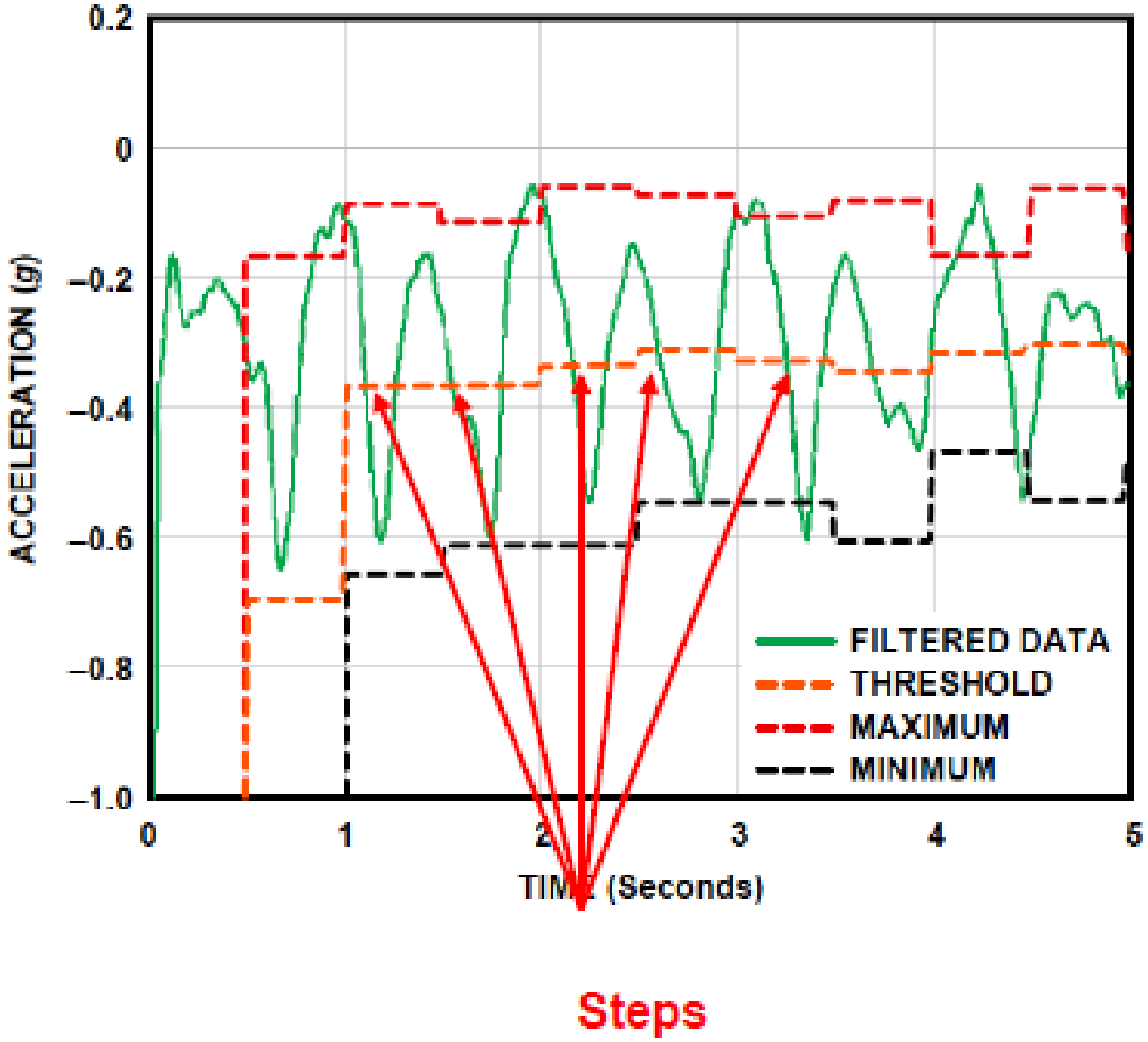
- **Step 1: Smoothing**
  - Signal looks choppy
  - Smooth by replacing each sample with average of current, prior and next sample
- **Step 2: Dynamic Threshold Detection**
  - Focus on accelerometer axis with largest peak
  - Would like a threshold such that each crossing is a step
  - But cannot assume fixed threshold (magnitude depends on phone orientation)
  - Track min, max values observed every 50 samples
  - Compute ***dynamic threshold: (Max + Min)/2***



Step Detection Algorithm

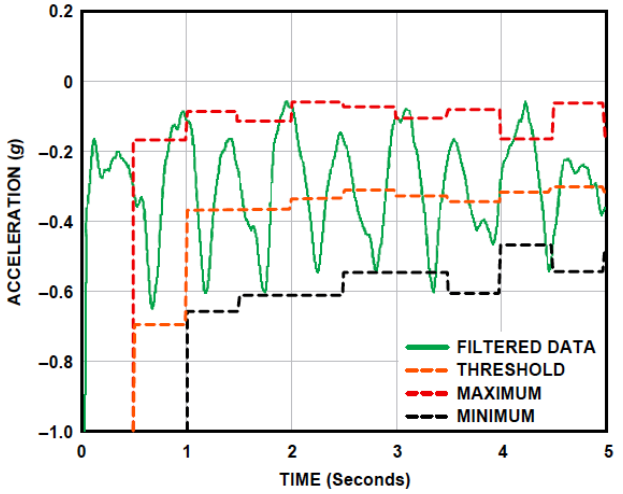
A step is

- Indicated by crossings of dynamic threshold
- Defined as negative slope (sample_new < sample_old) when smoothed waveform crosses dynamic threshold



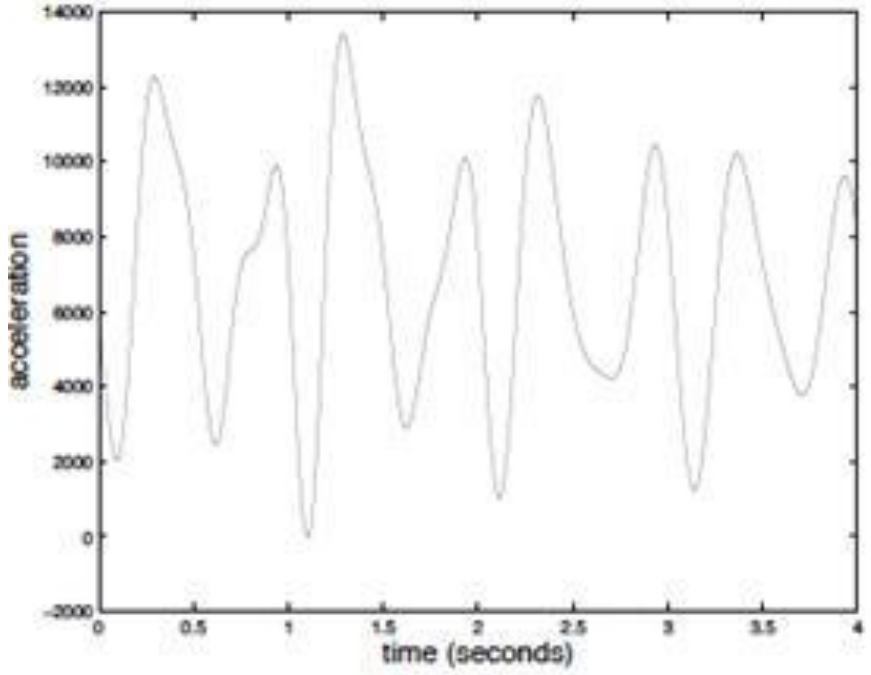
Improvements

- **Problem:** vibrations (e.g. mowing lawn, plane taking off) could be counted as a step
- **Optimization:** Fix by exploiting periodicity of walking/running
- Assume people can:
  - **Run:**5 steps per second => 0.2 seconds per step
  - **Walk:**1 step every 2 seconds => 2 seconds per step
- So, eliminate “negative crossings” that occur outside period [0.2 –2 seconds] (e.g. vibrations)

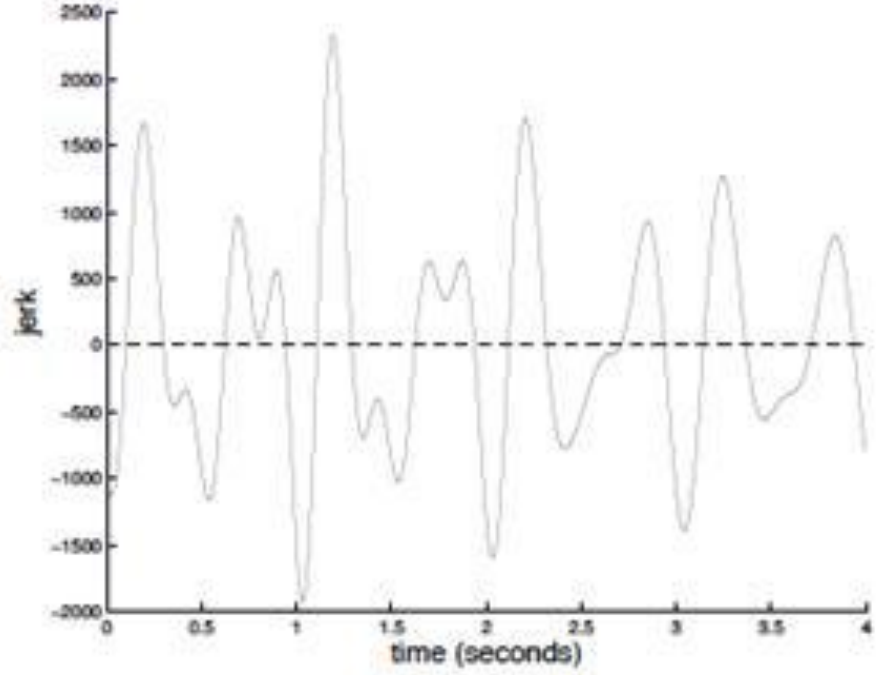


Improvements

- Use more frequency domain processing algorithms for smoothing
- Poll: are you familiar with time-series signal processing algorithms, such as band-pass filtering, Fourier transform



(c) Output of the low-pass filter.



(d) Derivative of the low-pass filter.

Distance Estimation

- Calculate distance covered based on number of steps taken
  - *Distance = number of steps ×distance per step*
- Distance per step (stride) depends on user's height (taller people, longer strides), and step frequency
- Using person's height, can estimate their stride, then number of steps taken per 2 seconds

Steps per 2 s	Stride (m/s)
0~2	Height/5
2~3	Height/4
3~4	Height/3
4~5	Height/2
5~6	Height/1.2
6~8	Height
>=8	1.2 × Height

Calorie Estimation

- To estimate speed, remember that speed = distance/time. Thus,
  - *Speed (in m/s) = (no. steps per 2 s ×stride (in meters))/2s*
- Calorie expenditure, which depends on many factors
  - Body weight, workout intensity, fitness level, etc
- Empirical simplified equation:
  - *Calories (C/kg/h) = 1.25 ×speed (m/s) ×3600/1000 = 4.5 ×speed (m/s)*

Discussion and Future Work

- Strong assumptions on how the users walk. What happens if:
  - Short-interval, high intensity exercise?
  - What about the other calorie expenditures? Standing vs sitting
- Currently, dedicated system for each activities. General activity recognition is still under research.

Mobile Activity Recognition

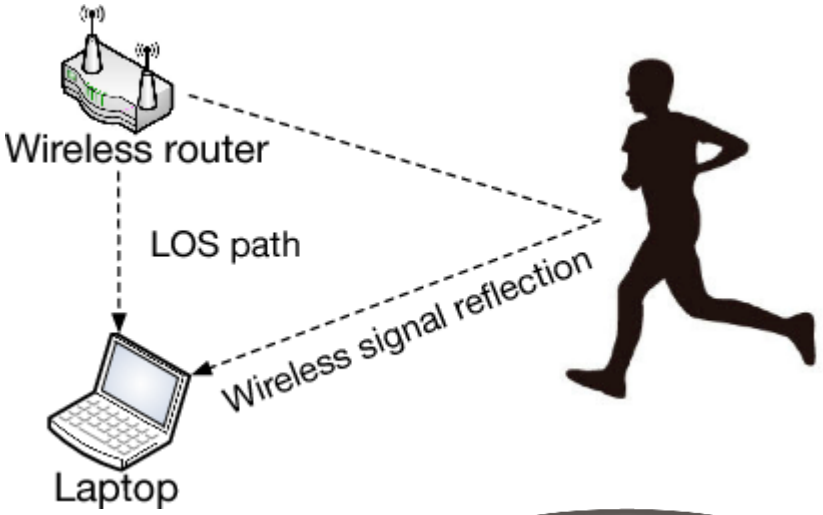
Activity Recognition

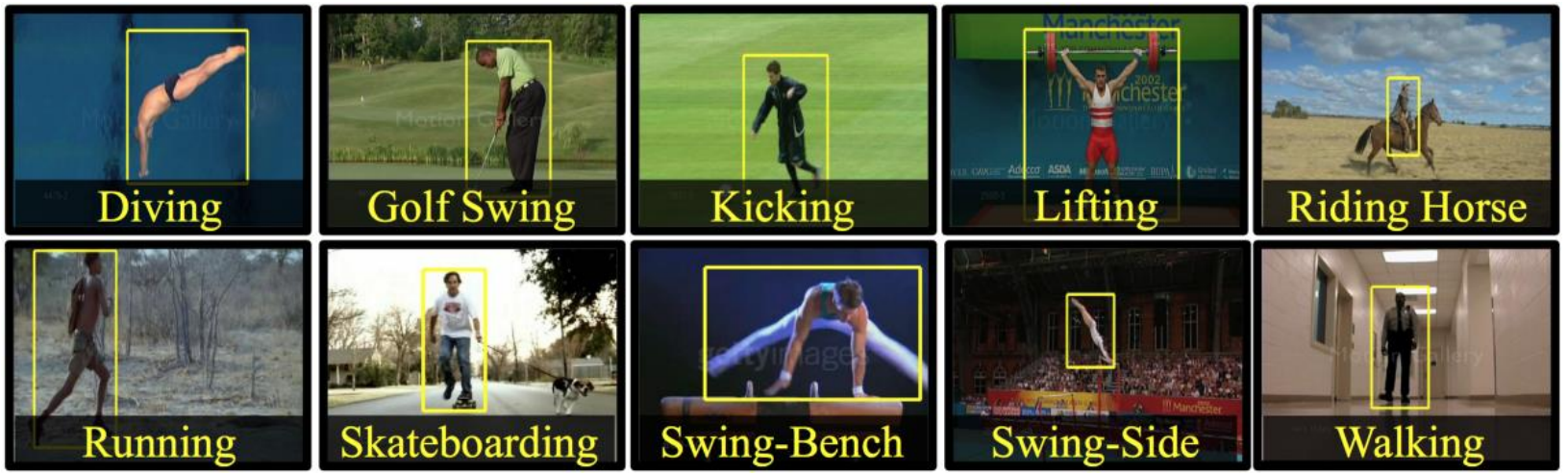
- Goal: know what the subject is doing

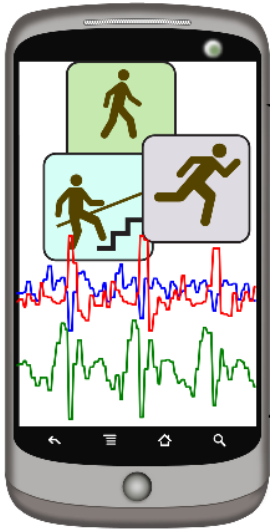
- **Classification task:** which of these 6 activities is user doing?
  - Walking,
  - Jogging,
  - Ascending stairs,
  - Descending stairs,
  - Sitting,
  - Standing

Activity Recognition Systems

- Computer vision based
- Environmental sensor based
- Mobile sensor based





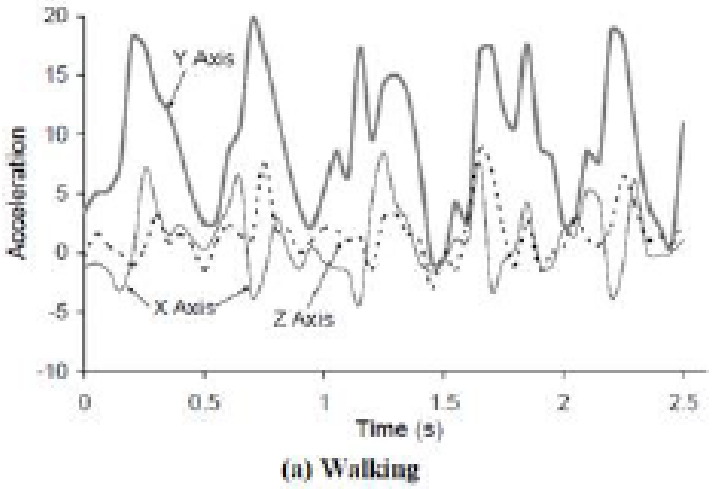


Discussion: pros and cons

	Cost	Privacy	Accuracy
Computer Vision			
Environmental Sensors			
Mobile Sensors			

Mobile Activity Recognition Architecture

Gather Accelerometer data



(a) Walking

Machine Learning Classifier

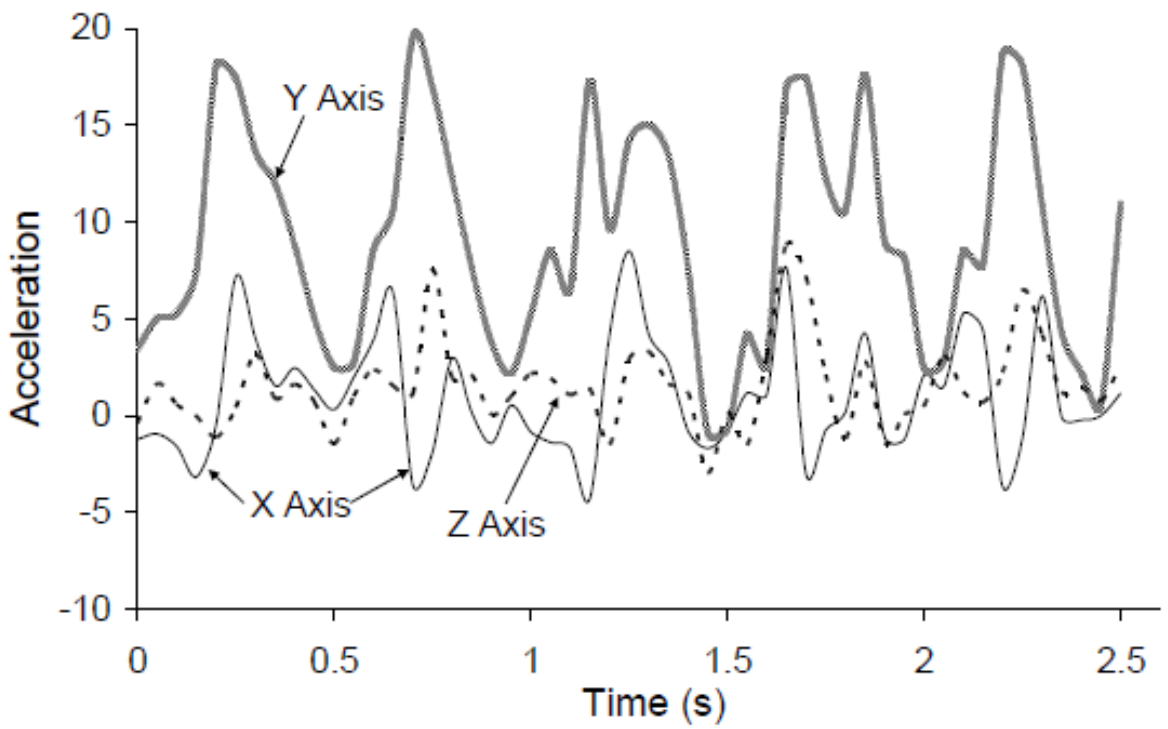
Walking

Running

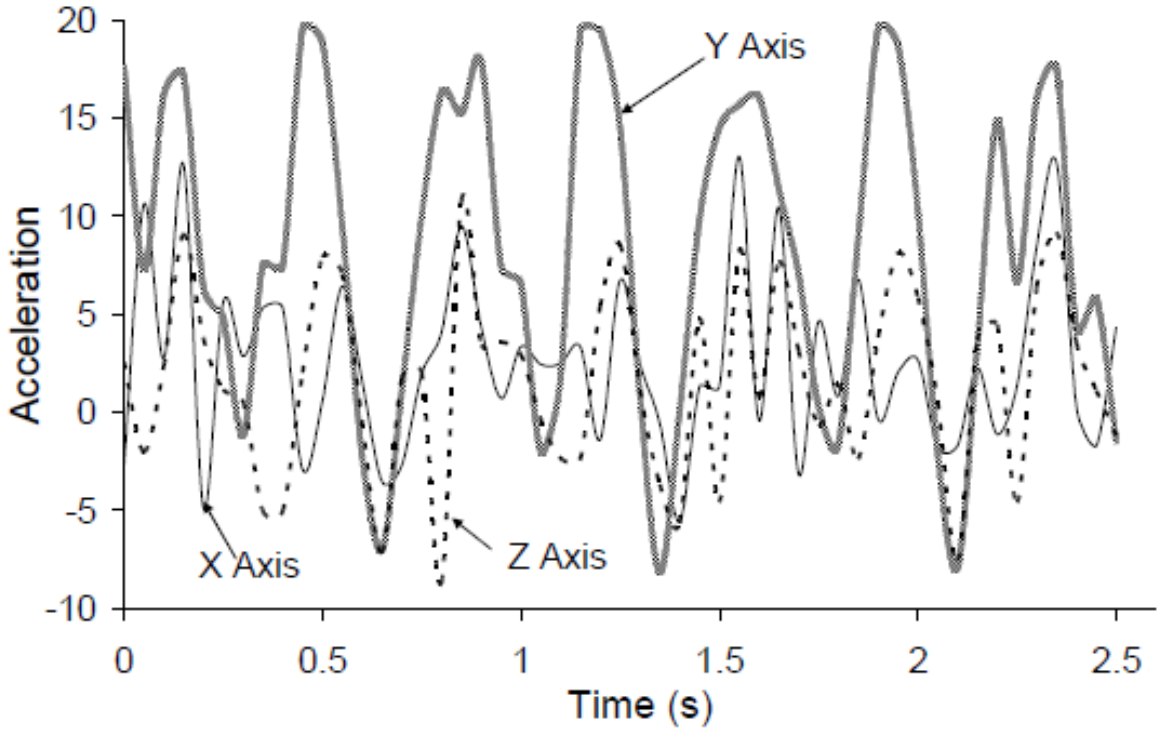
Climbing Stairs

Classify Accelerometer data

Sample Accelerometer during activities

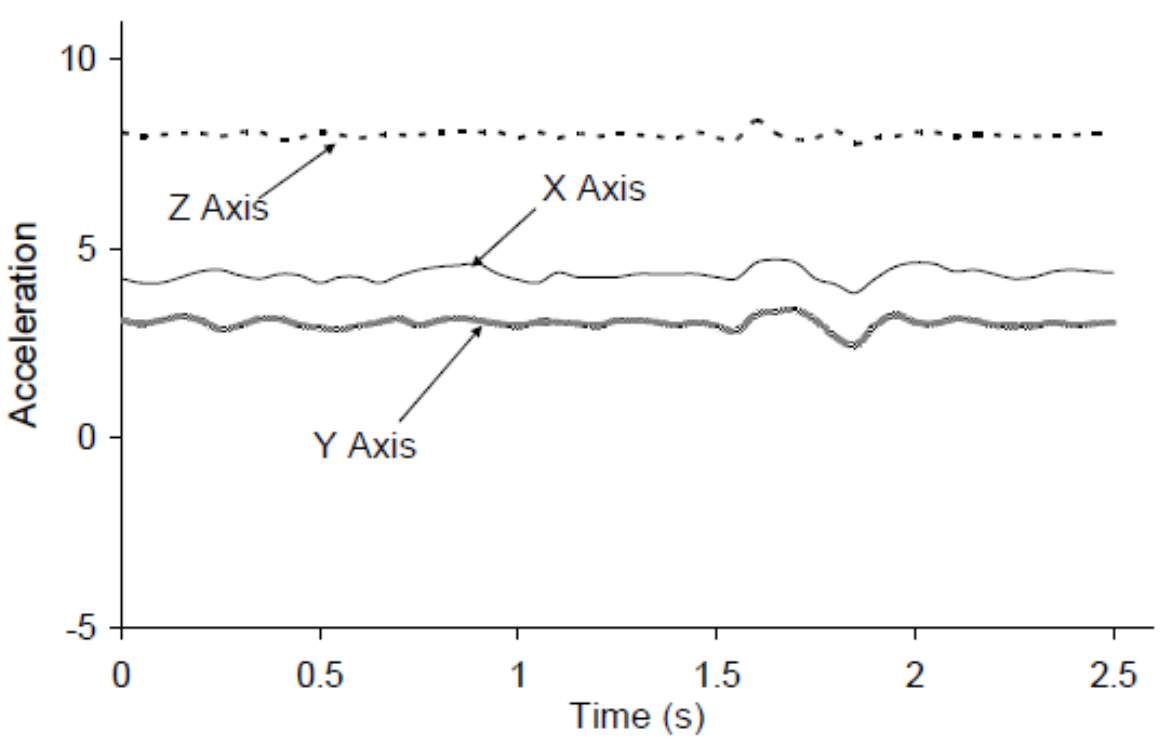


(a) Walking

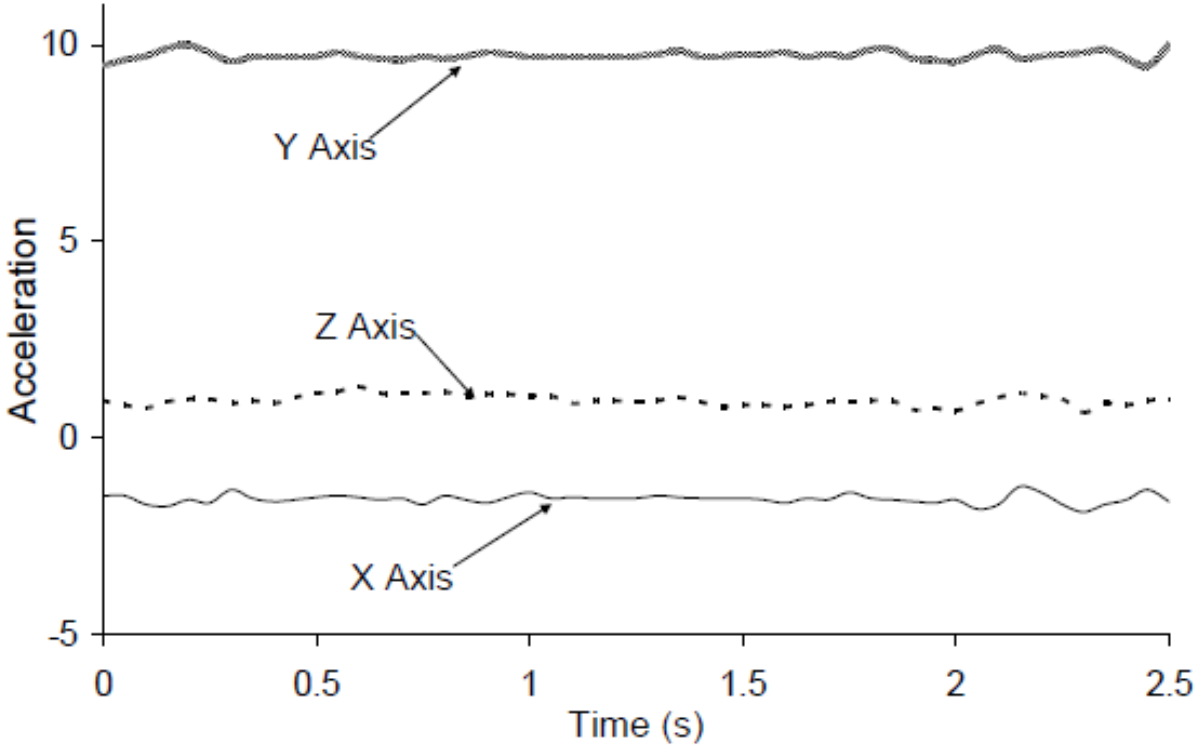


(b) Jogging

Sample Accelerometer during activities



(e) Sitting

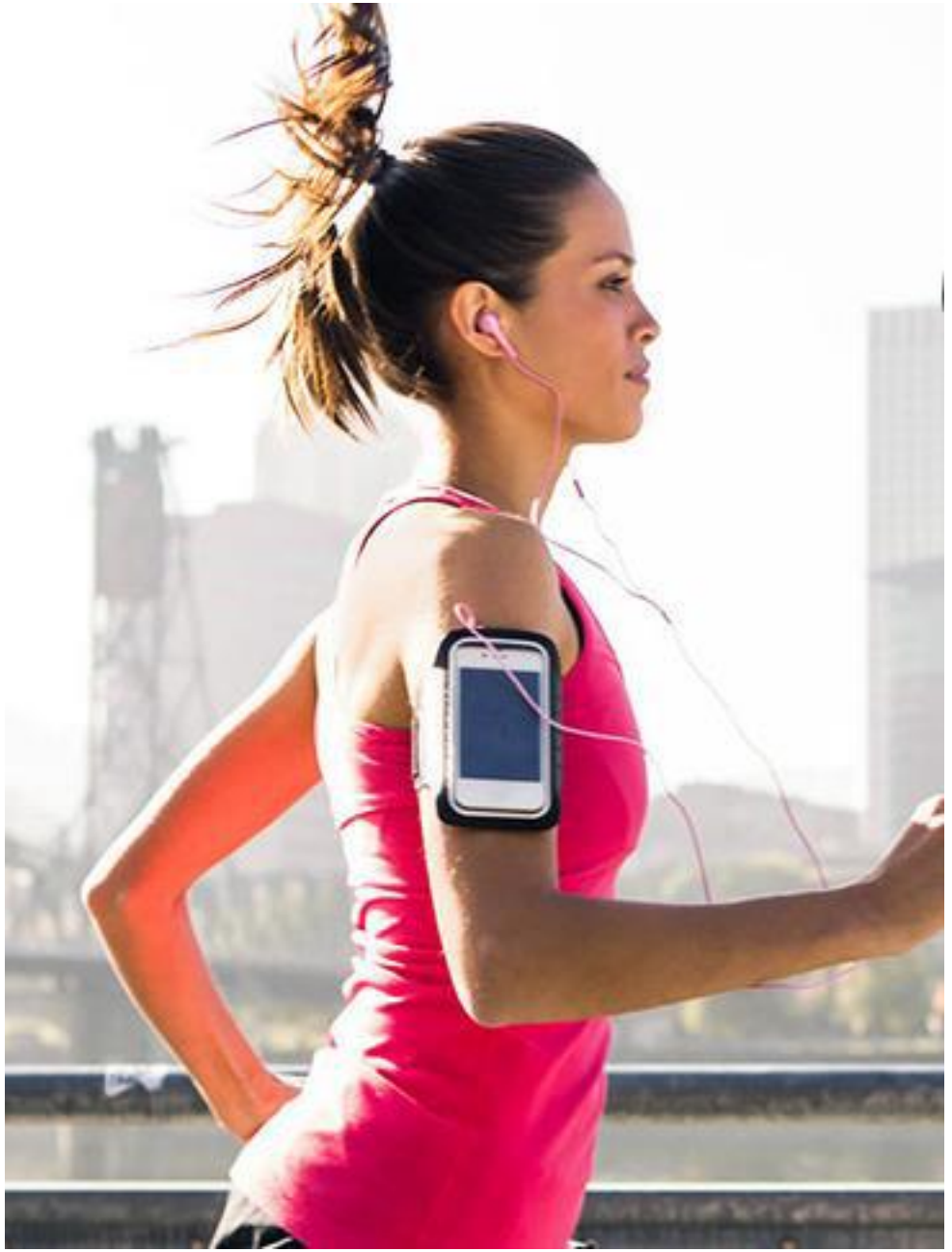


(f) Standing

Activity Recognition Applications

Fitness Tracking

- **Initially:**
  - Physical activity type,
  - Distance travelled,
  - Calories burned
- **Newer features:**
  - Stairs climbed,
  - Physical activity (duration + intensity)
  - Activity type logging + context
  - Sleep tracking
  - Activity history



Health Monitoring

- Make clinical monitoring pervasive, continuous, real world!!
  - Gather context information (e.g. what makes condition worse/better?)
  - E.g. timed up and go test
- Show patient contexts that worsen condition => Change behavior
  - E.g. walking in narrow hallways worsens gait freeze

Gait Freezing

Question: What data would you need to build PD gait classifier? From what types of subjects?

Fall Detection

- A leading cause of death for seniors
- Smartphone/watch, wearable detects senior who has fallen, alert family
  - Text message, email, call relative

Context-aware Behavior

- Study found that messages delivered when transitioning between activities better received
  - In-meeting? => Phone switches to silent mode
  - Exercising? => Play song from playlist, use larger font sizes for text
  - Arrived at work? => download email

- Adaptive Systems to Improve User Experience:
  - Walking, running, riding bike? => Turn off Bluetooth, WiFi (save energy)
  - an increase battery life up to 5x

Smart Home

- Smart Thermostat
  - Determines if the users are at home
  - Recognize where the users are and adjust temperature accordingly

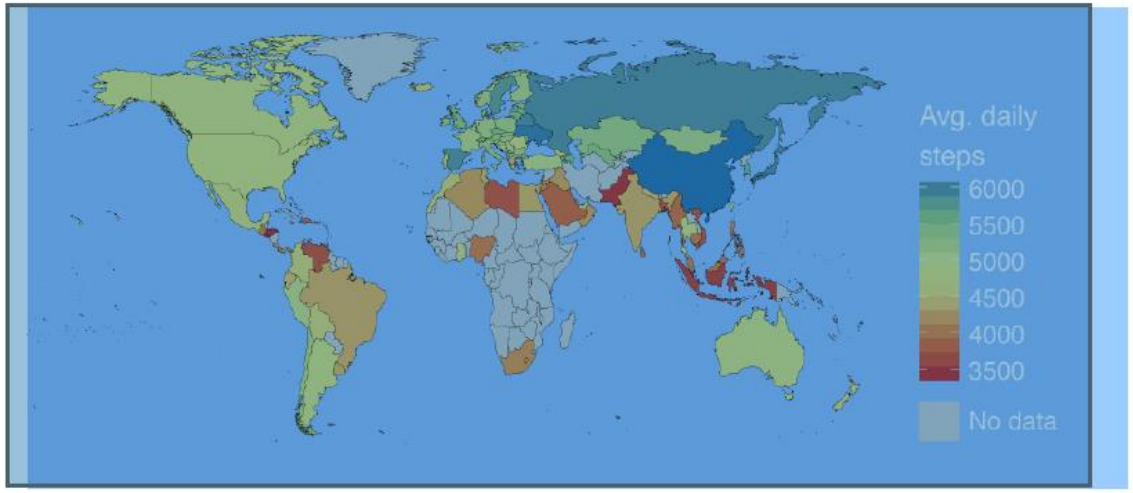
- Smart TV
  - Turns on TV when the user is at the couch

Targeted Advertisements

- User runs a lot => Get exercise clothing ads
- Goes to pizza places often + sits there => Get pizza ads

Research Platforms for Data Collection

- E.g. public health officials want to know how much time various people (e.g. students) spend sleeping, walking, exercising, etc
- Mobile AR: inexpensive, automated data collection
- E.g. Stanford Inequality project: Analyzed physical activity of 700k users in 111 countries using smartphone AR data
  - http://activityinequality.stanford.edu/

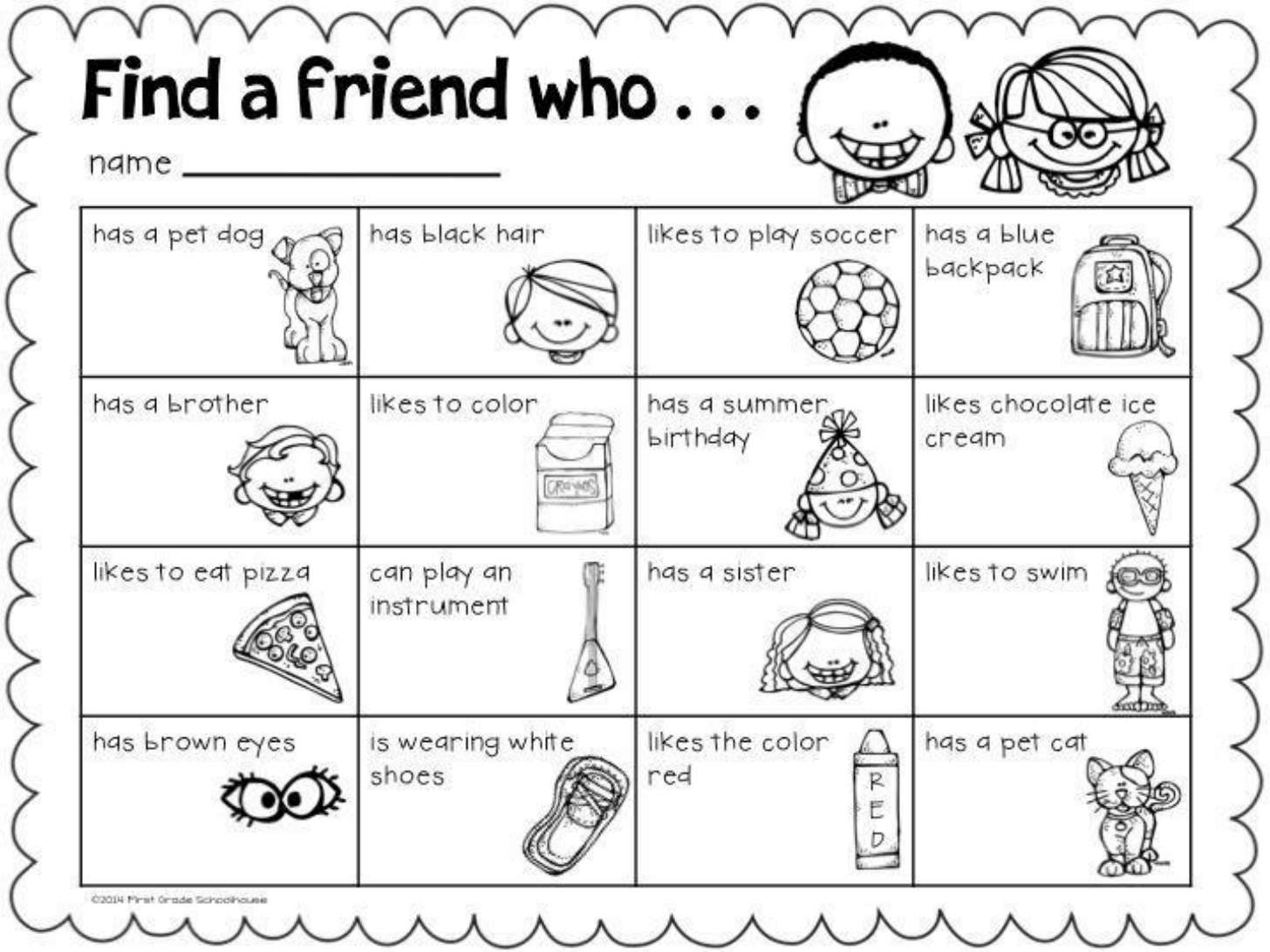


Track, manage staff on-demand

- E.g. at hospital, determine “availability of nurses”, assign them to new jobs/patients/surgeries/cases

Activity-Based Social Networking

- Automatically connect users who do same activities + live close together



Activity Recognition using Google API

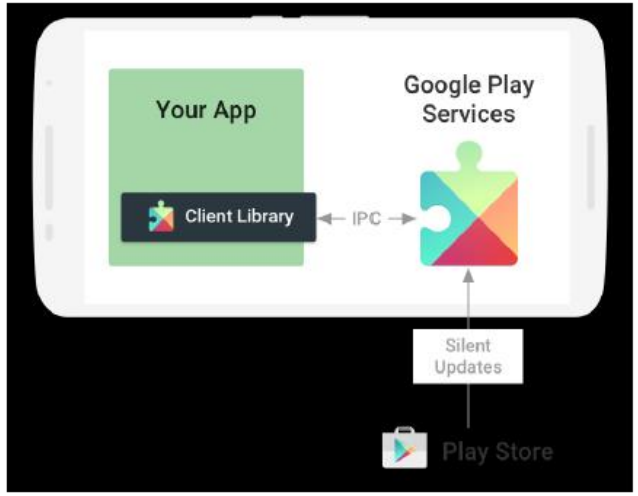
- We can adapt the mobile behaviors based on the user's behaviors
  - E.g., If the user is driving, don't send notifications

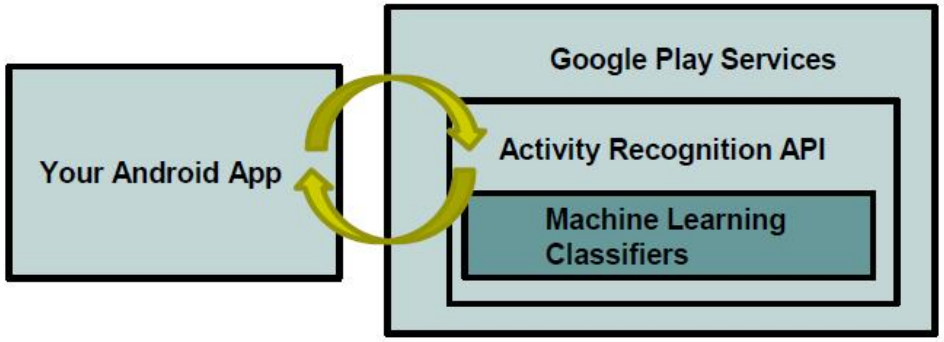
Google Activity Recognition API

- API to detect smartphone user’s current activity
- Programmable, can be used by your Android app
- Currently detects 8 states:
  - In vehicle
  - On Bicycle
  - On Foot
  - Running
  - Walking
  - Still
  - Tilting
  - Unknown

Google Activity Recognition API

- Deployed as part of Google Play Services





Awareness API

- Enable your app to intelligently react to the user's current situation.
- Benefits
  - Ease of implementation
  - Better context data
  - Optimal system health

Awareness API

- Available Context types:

Time	Current local time
Location	Latitude and longitude
Activity	Detected user activity, like walking, running, or biking
Beacons	Nearby beacons that match the specified namespace
Headphones	Status of whether headphones are plugged in, or not