Lecture 01

Smart Phone Sensing

- Instructor
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- Lectures
  - Monday: 08:30 – 10:30
  - Wednesday: 15:30 – 17:30
- Lab (not mandatory, mainly for advice and Q&A)
  - Wednesday: 13:30 – 17:30 [Starting May 13th]

WHY CARE?

Why care?
It is a good skill to have (LinkedIn)

2013

1. Social Media Market
2. Mobile Developmen
3. Cloud and Distribute
4. Perl/Python/Ruby
5. Statistical Analysis ar
6. User Interface Desig
7. Digital and Online M
8. Recruiting
9. Business Developme
10. Retail Payment and I
11. Business Intelligence
12. Data Engineering an

2014

1. Statistical Analysis and Data Mining
2. Middleware and Integration Softwar
3. Storage Systems and Management
4. Network and Information Security
5. SEO/SEM Marketing
6. Business Intelligence
7. Mobile Development
8. Web Architecture and Development
9. Algorithm Design
10. Perl/Python/Ruby
11. Data Engineering and Data Wareho
12. Marketing Campaign Management

2015

1. Cloud and Distributed Computing
2. Statistical Analysis and Data Mining
3. Marketing Campaign Management
4. SEO/SEM Marketing
5. Middleware and Integration Software
6. Mobile Development
7. Network and Information Security
8. Storage Systems and Management
9. Web Architecture and Development Frameworks
10. User Interface Design
11. Data Engineering and Data Warehousing
12. Algorithm Design
13. Perl/Python/Ruby

* NR (Not recorded in 2014)

2016

1. Cloud and Distributed Computing
2. Statistical Analysis and Data Mining
3. Web Architecture and Development Framework
4. Middleware and Integration Software
5. User Interface Design
6. Network and Information Security
7. Mobile Development
8. Data Presentation

2019

1. Cloud Computing

Recommended Courses: Learning Cloud Computing: Networking, Learning Amazon Web Services (AWS) for Developers, AWS for Architects: Advanced Security

Why it matters, in one sentence: As the world rushes toward the cloud, companies are desperately searching for engineers who have the skills to accommodate this demand.

2. Artificial Intelligence

Recommended Courses: Artificial Intelligence Foundations: Neural Networks, Artificial Intelligence Foundations: Machine Learning, Machine Learning and AI Foundations: Classification Modeling

Why it matters, in one sentence: Its official — the Age of AI is here.

3. Analytical Reasoning

Recommended Courses: Making Decisions, Decision Making Strategies, Executive Decision Making

Why it matters, in one sentence: As they collect more data than ever before, companies are hungry for professionals who can make smart decisions based off of it.

4. People Management

Recommended Courses: Motivating and Engaging Employees, Managing Team Conflict, Leading with Purpose

Why it matters, in one sentence: The world has changed from a "command-and-control" model toward leaders who can coach and empower, a difficult skillset few professionals possess.

5. UX Design

Recommended Courses: UX Foundations: Multidevice Design, UX Design: 01 Overview, UX Research for Agile Teams

Why it matters, in one sentence: UX design is the key to making a digital world work for humans.

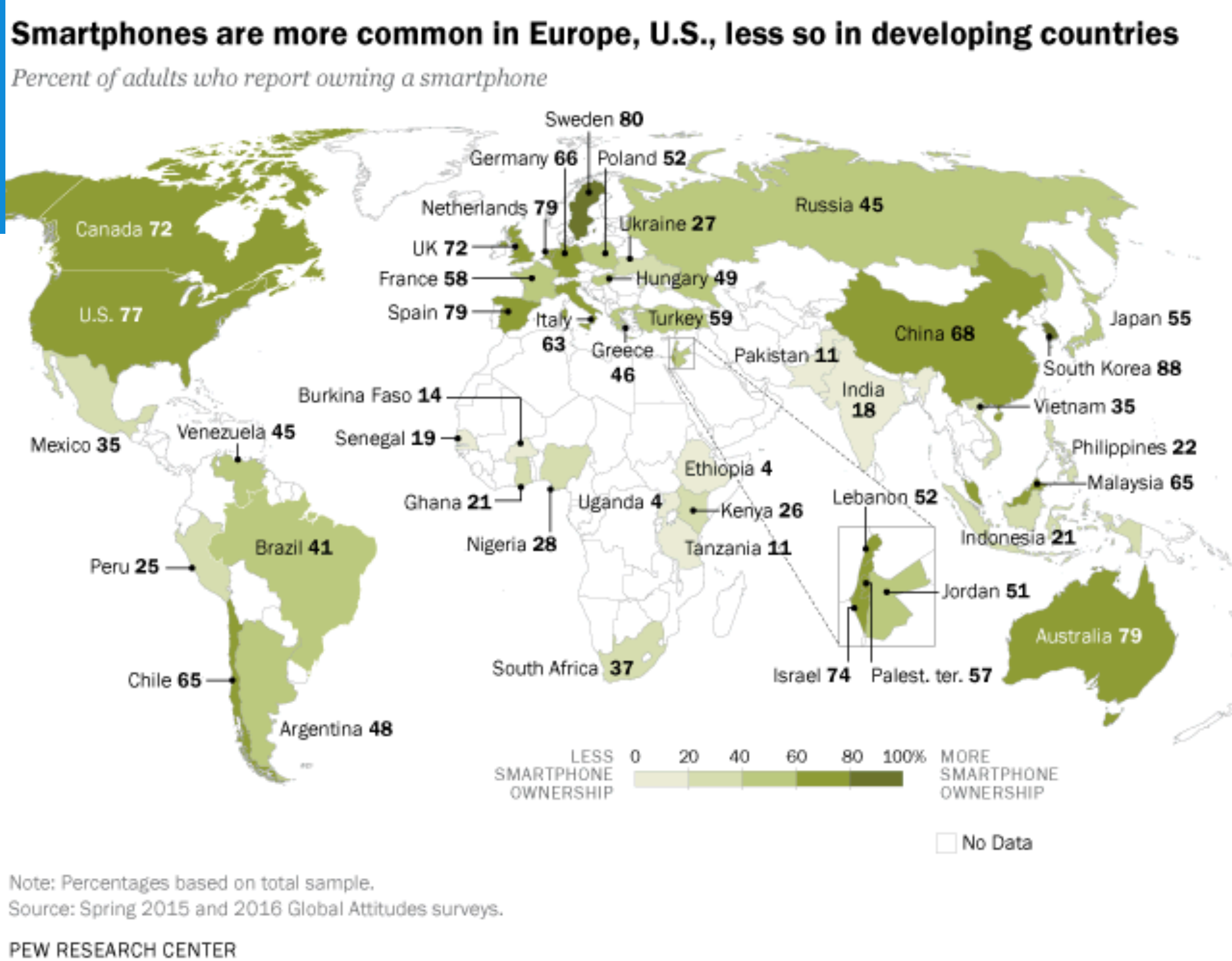
6. Mobile Application Development

Recommended Courses: React Native Essential Training, iOS 12 Development Essential Training: 1 Fundamental, UI, and Architecture, iOS 12 Development Essential Training: 2 Web Content, Views, and Distribution

Why it matters, in one sentence: A skill that's been in-demand for several years as companies continue to design mobile-first platforms.

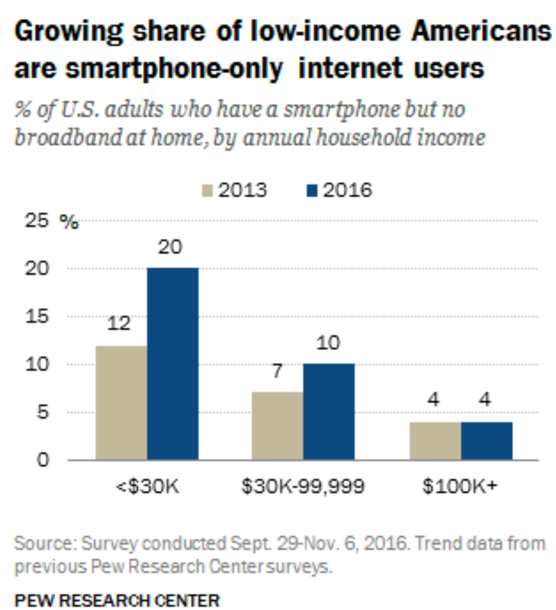
Source:LinkedIn

Why is it a good skill? Planet of the phones



45% of people in the world have a smartphone (by April 2020) [Source: statista.com]

Smartphones are far more popular than tablets and PCs

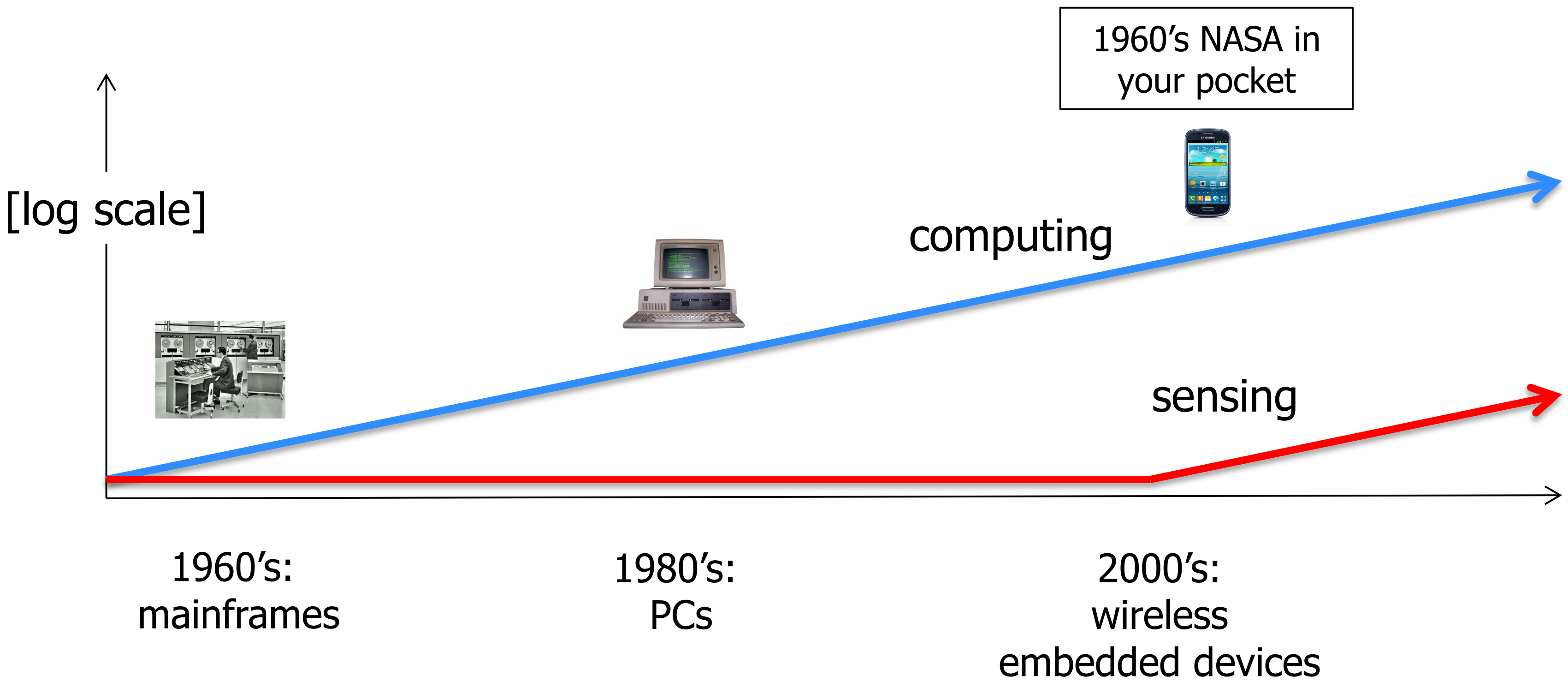


By 2019, US: 81, India: 24

TECHNICALLY, WHY ARE SMARTPHONES CREATING SUCH A REVOLUTION?

Why is it a good skill?

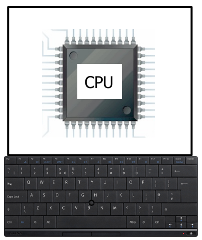
Tackles a major technological change



For the first time in history we have plenty of computing and sensing capabilities

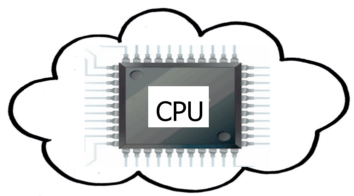
Computation & Sensing

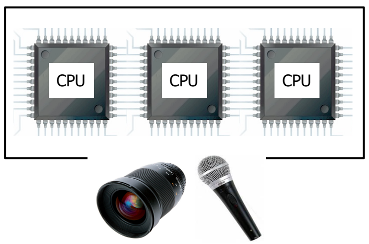
~until 2000



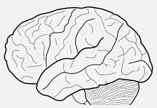
data

now





still missing



tools

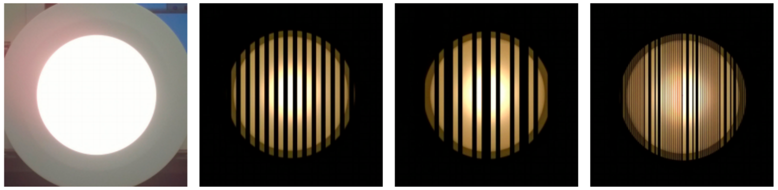
creativity

sensing	implies we can now gather tons of DATA
computing	implies we can process these tons of DATA

Research example 1: Indoor localization

Problem
- GPS does not work inside
- We spend almost 90% of our time indoors

Solutions
- sensor: many, but let's look at a very recent one based on LEDs
- tool: Visible Light Communication
- output: information



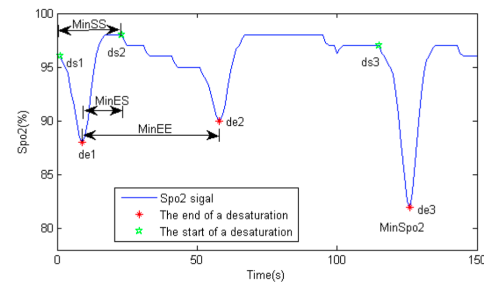
Paper: "Luxapose: Indoor Positioning with Mobile Phones and Visible Light", ACM Mobicom 2014

Research example 2: Sleep Apnea

Problem
- treat sleep apnea at home

Solution
- sensor: pulsoximeter
- tools: machine learning
- actuation: adjustable pillow


photo courtesy of http://sleepapneadisorder.info



Paper:
"A real-time auto-adjustable smart pillow system for sleep apnea detection and treatment",
IEEE/ACM IPSN 2013
http://dl.acm.org/citation.cfm?id=2461405

Reason to care

There are lots of *smartphones* out there …
… collecting lots of **data**
… and enabling lots of *applications*

It is a good idea to know about them

WHAT APP WILL YOU DEVELOP?

Project (individual)

if there are too many students registered the project will be done in groups

Option 1: Indoor Localization

1) Localization:
   - RSS + KNN
   - RSS + Filters
   - IMU + Sensors
2) Innovation (beyond class):
   - Light Sensors
   - Your own ideas
3) GUI

Option 2: Your own

Your own project
- Requires prior approval

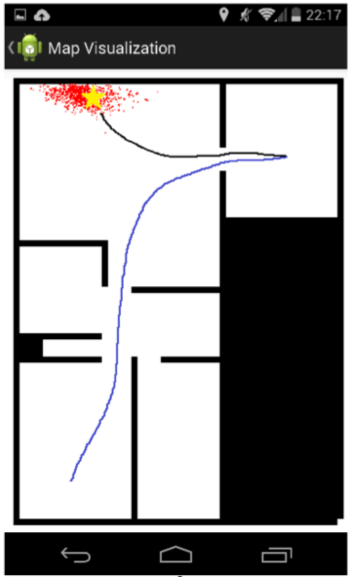
Evaluation criteria
- Technical depth & creativity

Other Options:
- COVID-19 tracker

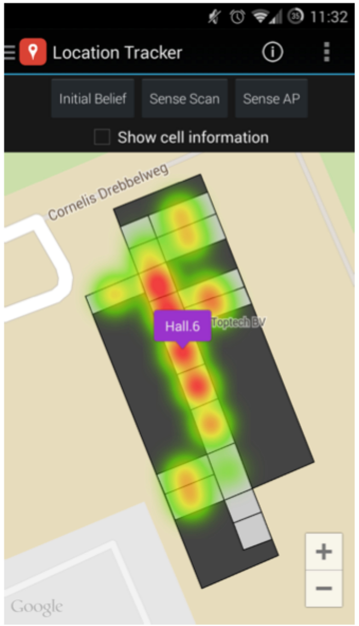
All code must be on the phone itselft!

If you want to go for option 2, please contact me asap.

Last years



TrackMe@Home:
a student tracking his location at his place



TrackMe@Work:
a student tracking his location at EWI, 9^{th} floor

Shazam:
a scaled-down version

What this course is about: learning objectives

- Smartphone + data + math = Awesome Apps

- You need to be familiar with
  - (1) the signals smartphones can gather,
  - (2) the math tools to process those signals

- We use techniques from algorithms, signal processing and machine learning to develop some exciting apps!

$$p(X_k \mid Z_{1:k-1}) = \int p(X_k \mid X_{k-1})\, p(X_{k-1} \mid Z_{1:k-1})\, dX_{k-1}$$

What this course is about: approach

Theory

- (2) tools: math & algorithms

Practice (pointers)

- (1) Sensors: data acquisition
- (4) Cloud: communication

Practice (pointers)

- (3) GUI & Actuation

LOGISTICS

Got a smartphone?

- If yes, please use your own
- If no, we have some smartphones available but we need to time-share them.
- If you need a smartphone, send an email to the TA.

Grading

- Option 1
  - First Report (max 1 page text + figures) 10% week 3
  - Second Report (max 1 page text + figures) 10% week 6
  - Final online evaluation 80% week 9-10
    - Novel Twists 20%

- Option 2 (weekly mentoring)
  - First report (2 pages) 10% week 3
  - Second Report (5 pages), 10% week 6
  - App Evaluation 80% week 9-10

- There is NO resit

ACTIVITY MONITORING & LOCALIZATION

Option 1

Indoor Localization

1) Localization
   - RSS + KNN
   - RSS + Filters
   - IMU + Filters

Steps for classification: get raw signal

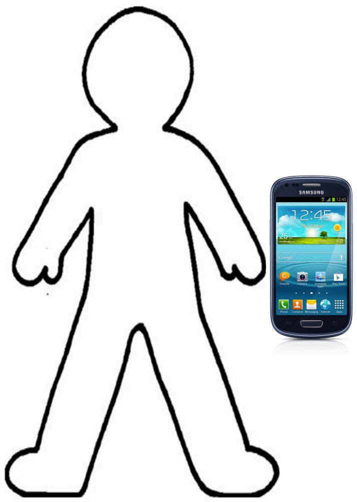
(1) Raw signal (sensor information)

(2) Feature extraction (art and science)

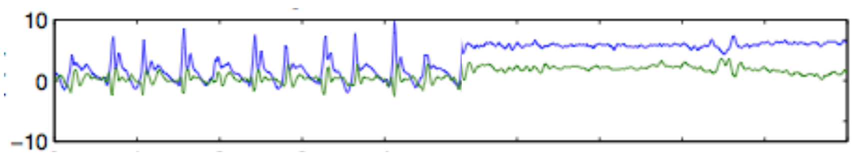
(3) Classification method (art and science)

Problem

- What am I doing?



walking



still

Steps for classification: train your system

(1) Raw signal

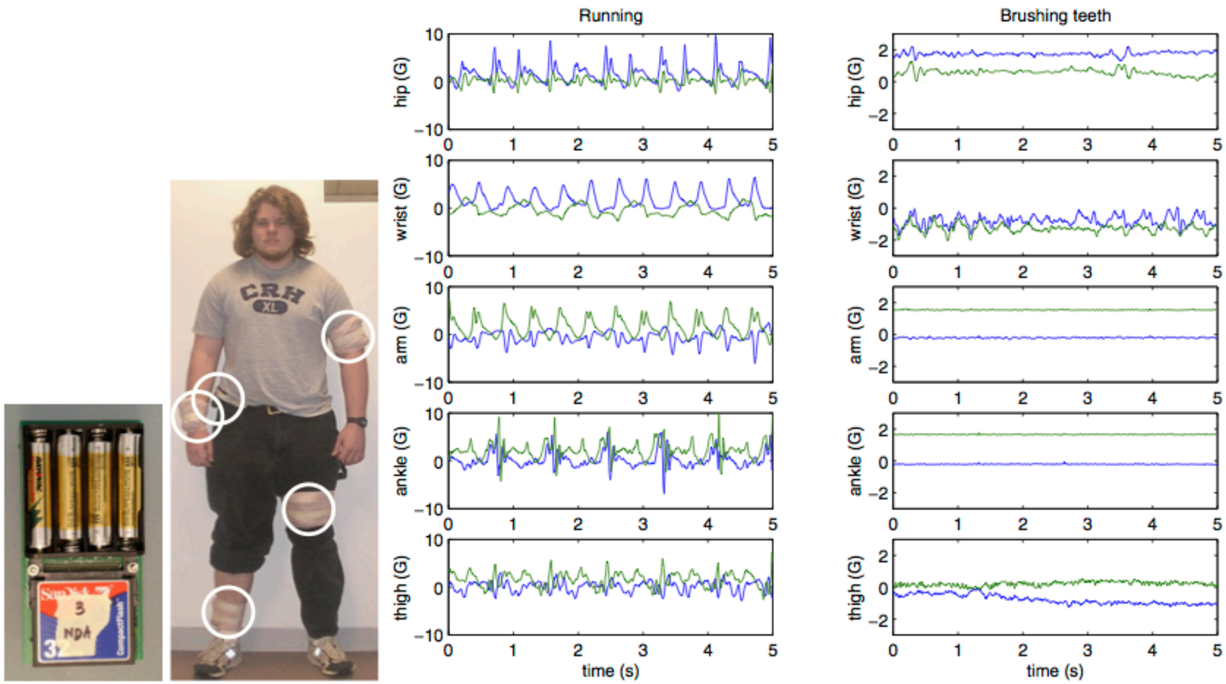
(2) Feature extraction (art and science)

Training

(3) Classification method (science)

Activity recognition

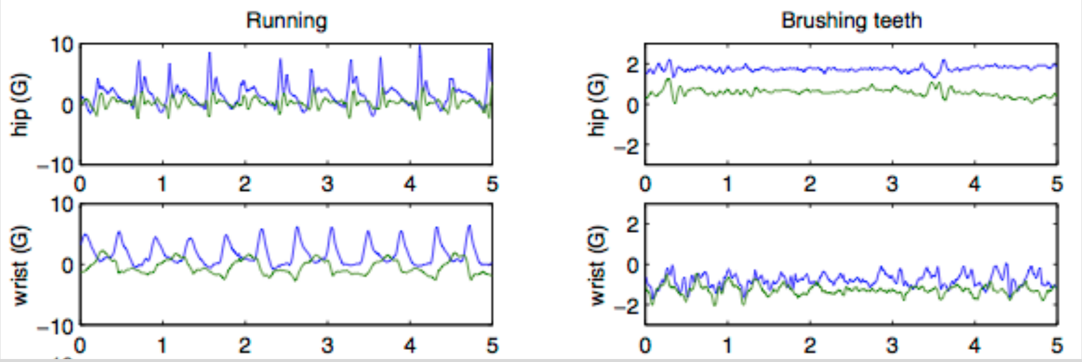
- Most smartphones have 3-axis accelerometers.
- Accelerometers can provide a lot of information.



Paper: "Activity Recognition from User-Annotated Acceleration Data", Pervasive 2004

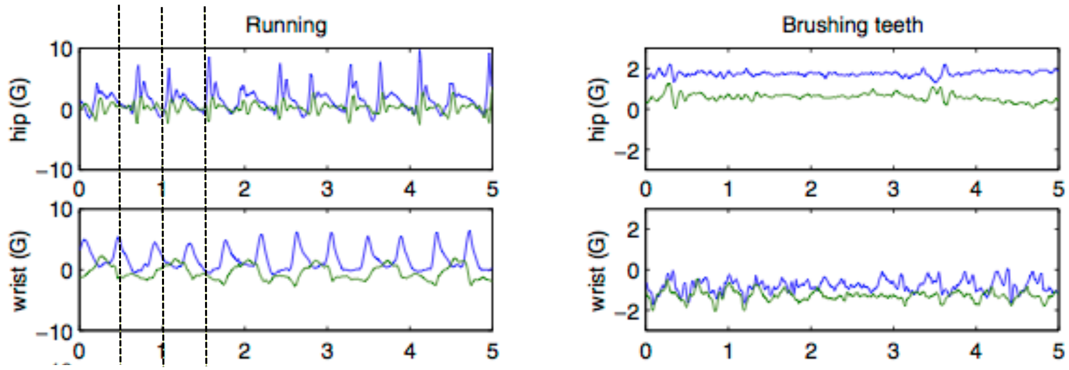
Identifying Features

- How would you describe a signal statistically?



Features: Training Data

- Choose a window size
  - 20 samples
  - 500 ms
- Then select features
  - Mean
  - Max Min
  - Variance
  - Fourier Transforms
  - Autocorrelation



Steps for classification: test your system

(1) Raw signal

(2) Feature extraction (art and science)

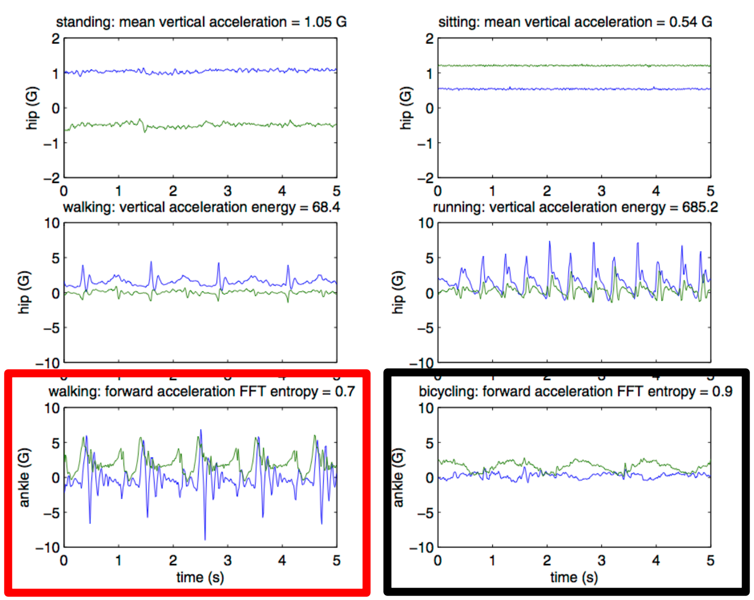
Training Phase

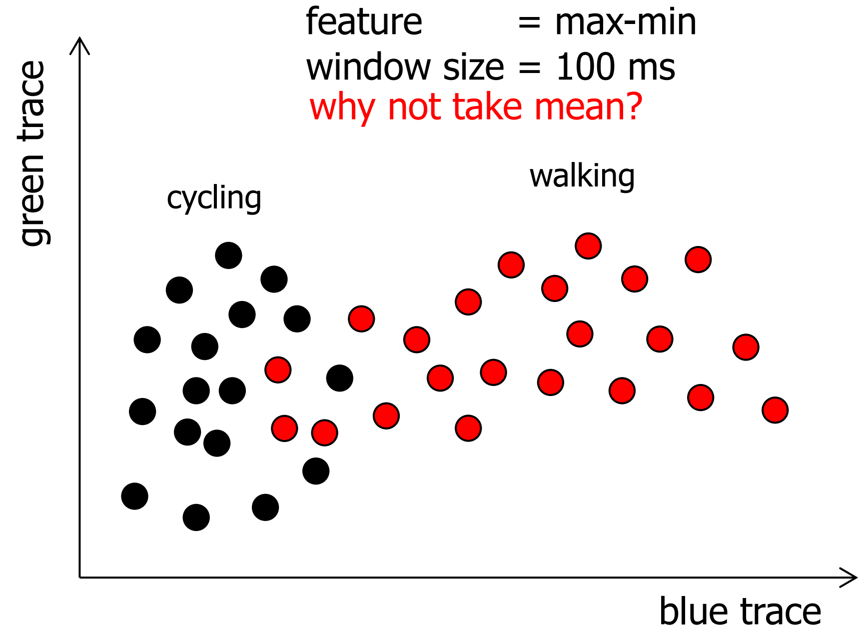
(3) Classification method (art and science)

Testing Phase

Classification

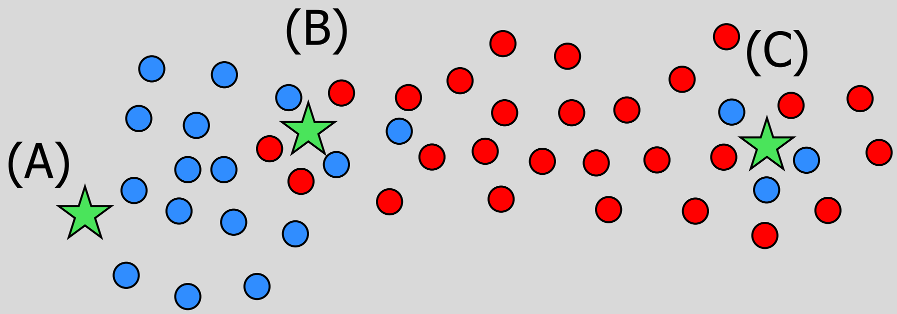
- Let's get some features and plot them
- There is going to be an overlap depending on the window's size





Paper: "Activity Recognition from User-Annotated Acceleration Data", Pervasive 2004

Classify points: Testing Data



k-NN in one slide

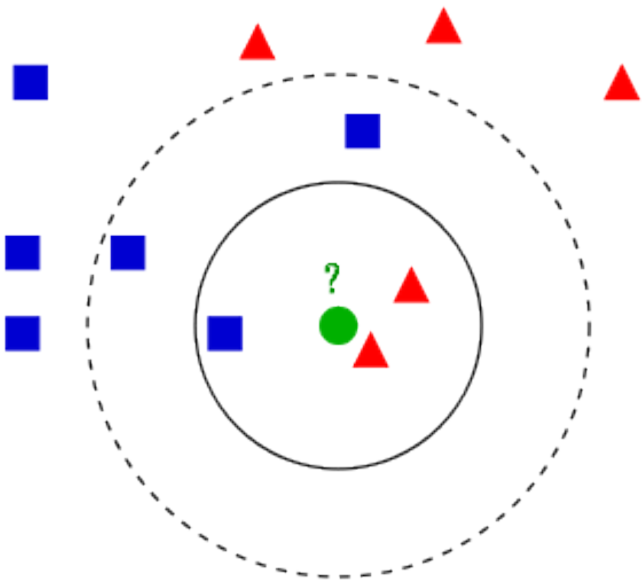
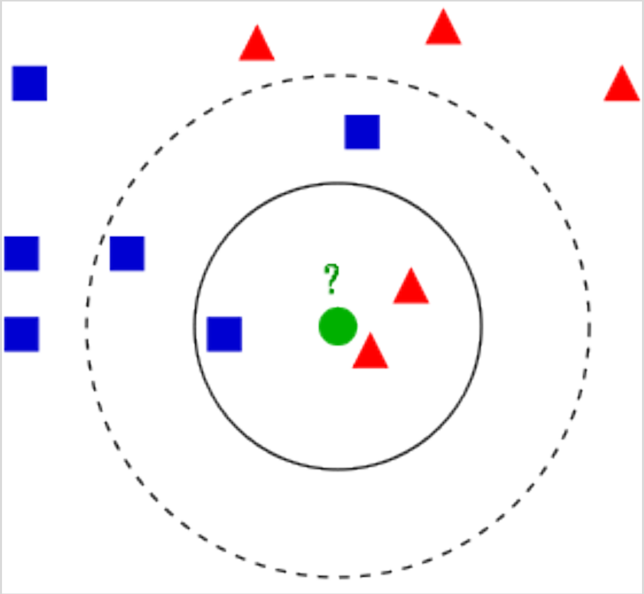


image from wikipedia: http://en.wikipedia.org/wiki/K-nearest_neighbor_algorithm

What is the best value for k?

What happens if k=1?
What happens if k =n?
    n is the total number of training points
What is the best value of k?



What K? What distance?

- Value of K:
  - Odd number
  - $\sqrt{n}$

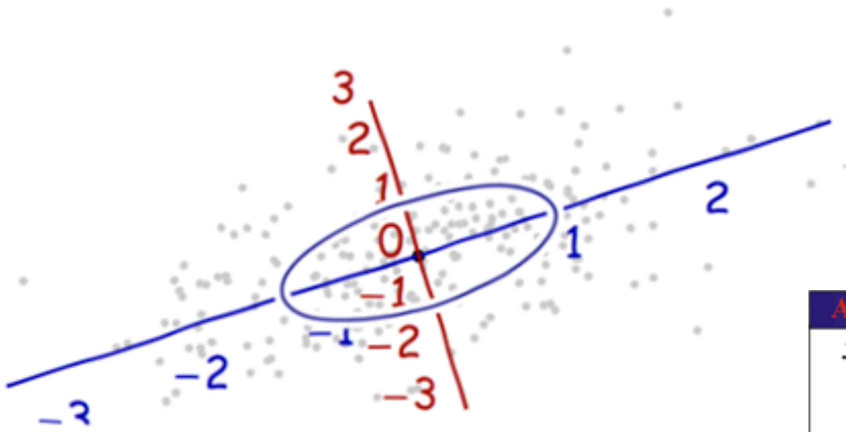
- Distance:
  - Euclidean: $D(\mathbf{w}_i,\mathbf{v}_i) = \sqrt{\Sigma\,(\mathbf{w}_i-\mathbf{v}_i)^2}$
  - Manhattan: $D(\mathbf{w}_i,\mathbf{v}_i) = \Sigma\,|\mathbf{w}_i-\mathbf{v}_i|$
  - Hamming: $D(\mathbf{w}_i,\mathbf{v}_i) = \Sigma\,I(\mathbf{w}_i,\mathbf{v}_i)$
  - Mahalanobis: $D(\mathbf{w}_i,\mathbf{v}_i) = \sqrt{(\mathbf{w}-\mathbf{v})^T S^{-1}(\mathbf{w}-\mathbf{v})}$

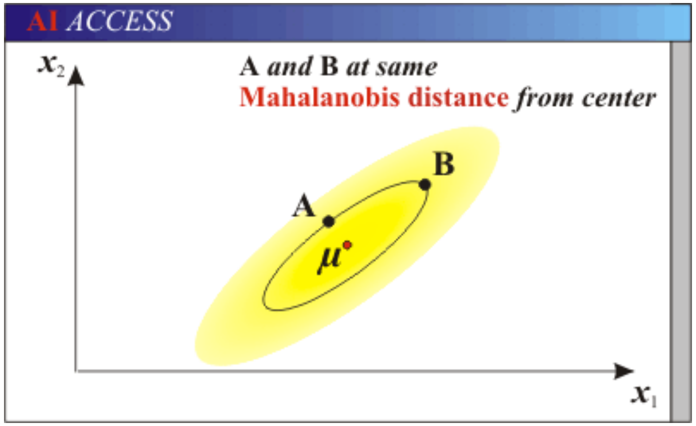
Mahalanobis distance: $D(\mathbf{w}_i, \mathbf{v}_j) = \sqrt{(\mathbf{w}-\mathbf{v})^T S^{-1} (\mathbf{w}-\mathbf{v})}$

S: covariance metric. $S_{wv} = E[(w-u_w)(v-u_v)]$

Intuition = $(\mathbf{x}-u)/\sigma$

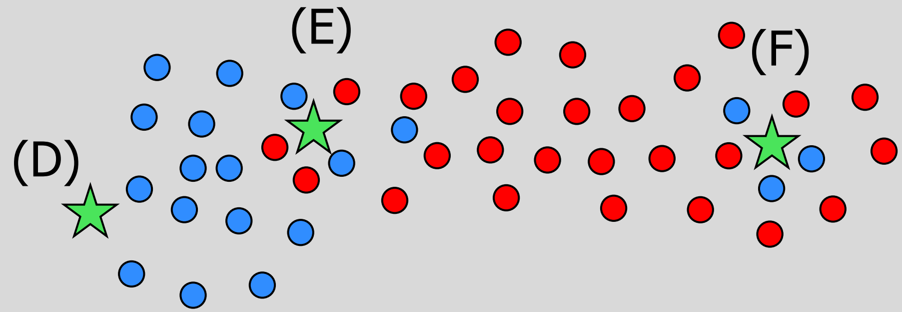
- unit-less measure
- If S=identity matrix, then mahalanobis = euclidean





Images taken from:
http://stats.stackexchange.com/questions/62092/bottom-to-top-explanation-of-the-mahalanobis-distance
http://blog.csdn.net/lovelyloulou/article/details/6339976
Localization paper using mahalanobis distance:
"Paper Lightweight Map Matching for Indoor Localisation Using Conditional Random Fields", IEEE/ACM IPSN 2014.

Classify the points below
Assume k=5 and Euclidean distance



K-NN is a top-10 machine learning tool

- A formal definition:
  - A supervised method: training & testing.
  - **x** features, Y label: (xi, xj, …., Y)
- KNN is non parametric
  - does not make any assumption on underlying data distribution. This is very useful!
- Simple training, costly testing (in time and memory)
- Data (features) are in a metric space.
- Very good for being that simple:

  for K=1: $P^* \leq P \leq P^* (2 - c/(c-1)\, P^*$

  where "P" is the 1-NN error, "P*" is the Bayes error and c is the number of classes

More theory of KNN: https://www.cs.rit.edu/~rlaz/PatternRecognition/slides/kNearestNeighbor.pdf

POINTERS

Pointers: theory (1)

- K-NN:
  - http://en.wikipedia.org/wiki/K-nearest_neighbor_algorithm
  - http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-034-artificial-intelligence-fall-2010/tutorials/MIT6_034F10_tutor03.pdf
  - http://saravananthirumuruganathan.wordpress.com/2010/05/17/a-detailed-introduction-to-k-nearest-neighbor-knn-algorithm/
- Mahalanobis distance:
  - http://en.wikipedia.org/wiki/Mahalanobis_distance
  - http://stats.stackexchange.com/questions/62092/bottom-to-top-explanation-of-the-mahalanobis-distance

Pointers theory (2)

- What’s going on in other schools
  - UIUC: http://www.ece.illinois.edu/mediacenter/article.asp?id=1274
  - Darmouth: http://www.cs.dartmouth.edu/~campbell/smartphonesensing.html