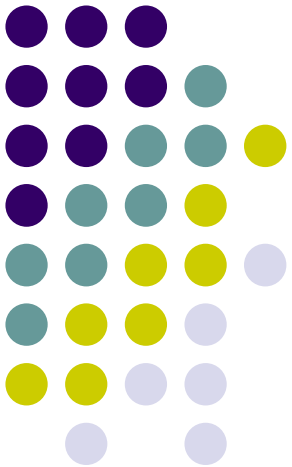
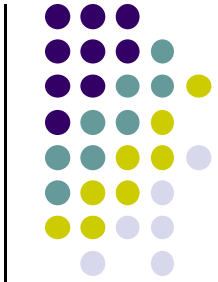
CS 528 Mobile and Ubiquitous Computing

Lecture 8: Making Apps Intelligent/Machine Learning

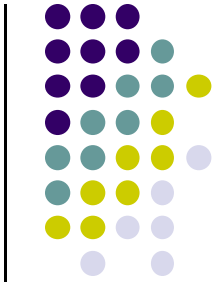
Emmanuel Agu



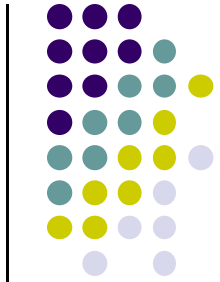


Making Apps Intelligent (Sensors Inference & Machine Learning)

My Goals in this Section

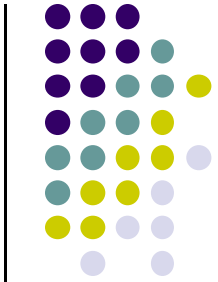


- If you know machine learning
  - Set off light bulb
  - Projects involving ML?
- If you don’t know machine learning
  - Get general idea, how it’s used
- Knowledge will also make papers easier to read/understand

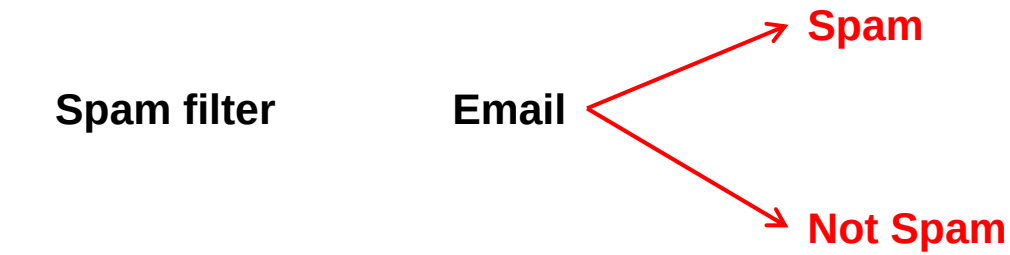


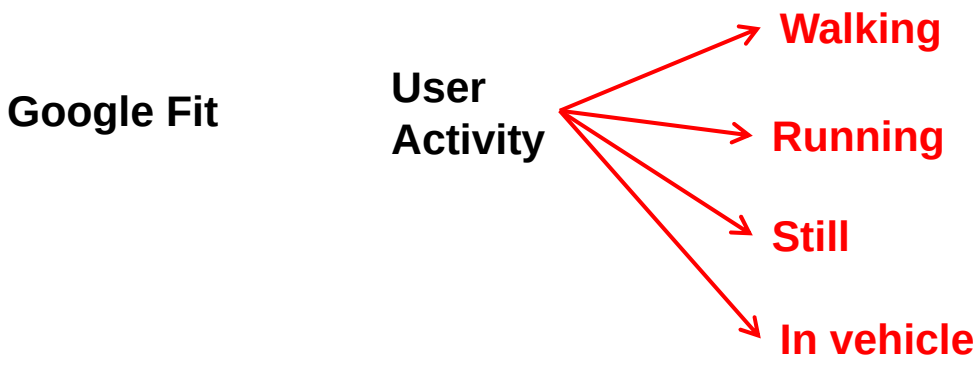
Intuitive Introduction to Classification/Supervised Machine Learning

Classification

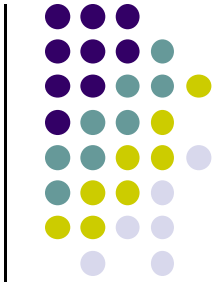


- Classification is type of machine learning used a lot in Ubicomp
- Classification? determine which class a sample belongs to
- Examples:

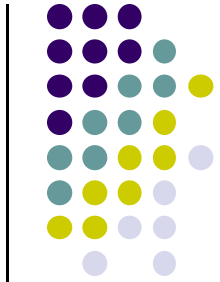




Classifier



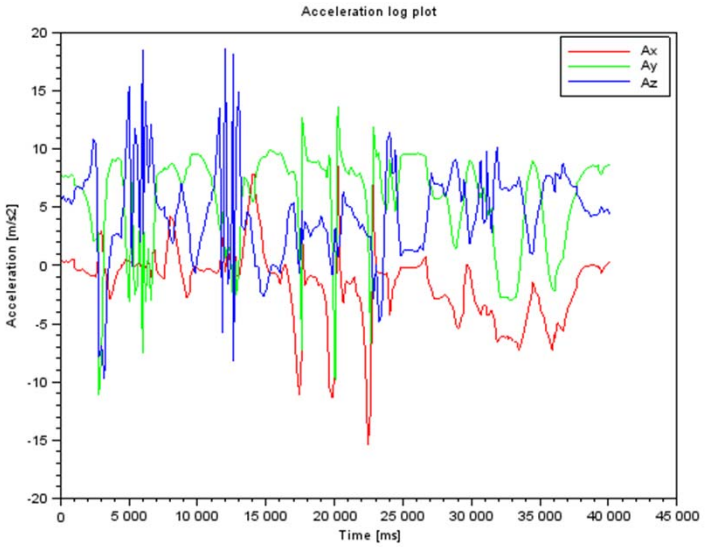
- Spam filter, Google Fit run a classifier
- Classifier:
  - Inspects new sample, decides which class
  - Created using example-based approach
- Classifier created using supervised machine learning
  - Supervised: labelled data as input
  - Examples of each class => generate rules to categorize new samples
  - **E.g:** Examples of spam email, non-spam email => generate rules to categorize new email



Explaining Classification/Supervised Learning using Activity Recognition

Activity Recognition

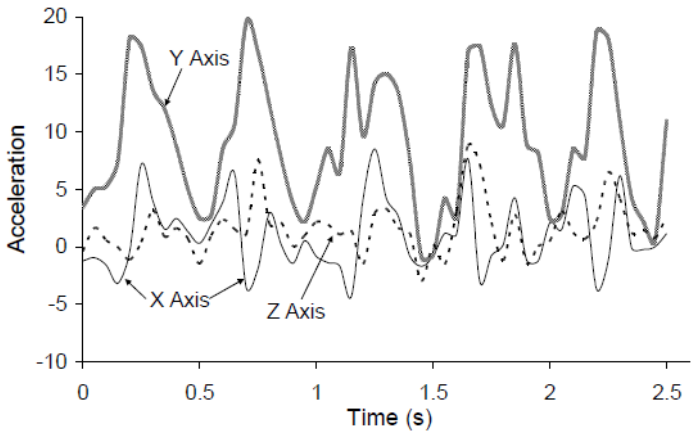
- Want app to detect when user is performing any of the following 6 activities
  - Walking,
  - Jogging,
  - Ascending stairs,
  - Descending stairs,
  - Sitting,
  - Standing



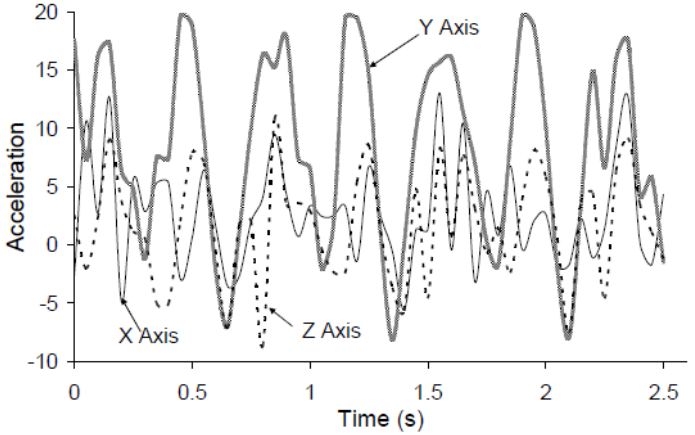
- **Approach:** Classifier to decide user activity based on accelerometer readings

Example Accelerometer Data for Activities

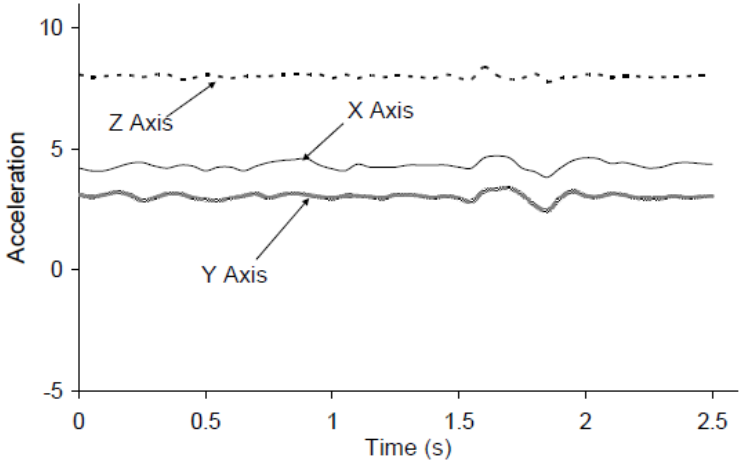
Step 1: Gather lots of example accelerometer data for each activity type



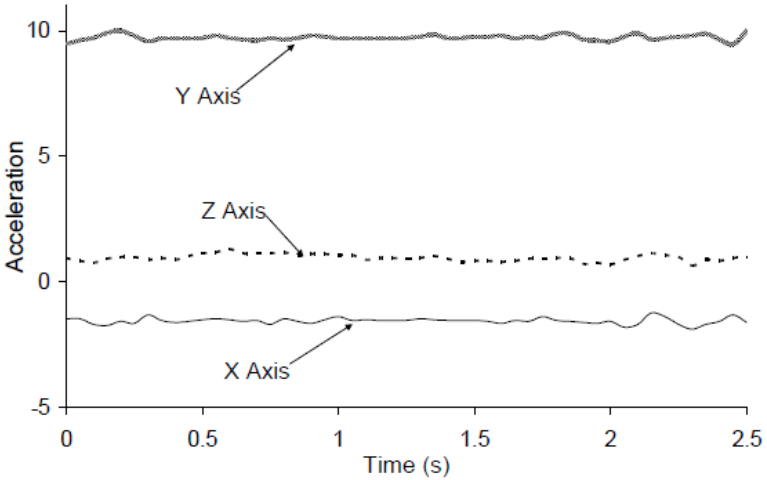
(a) Walking



(b) Jogging

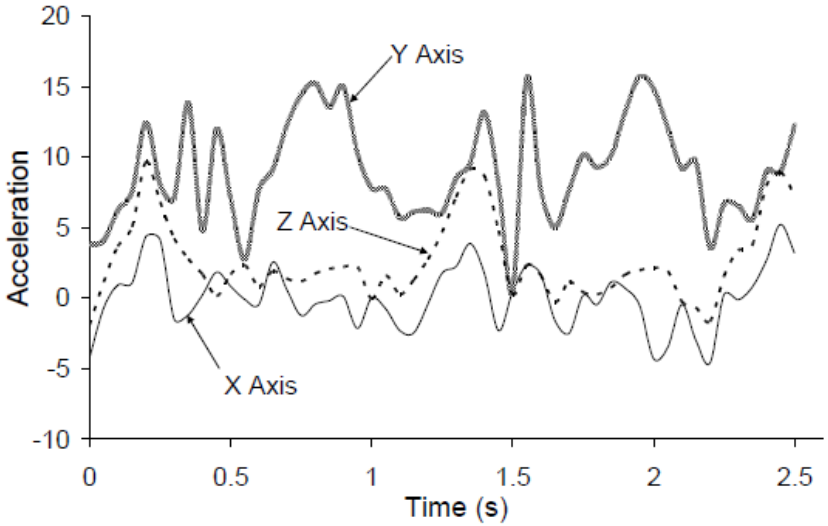


(e) Sitting

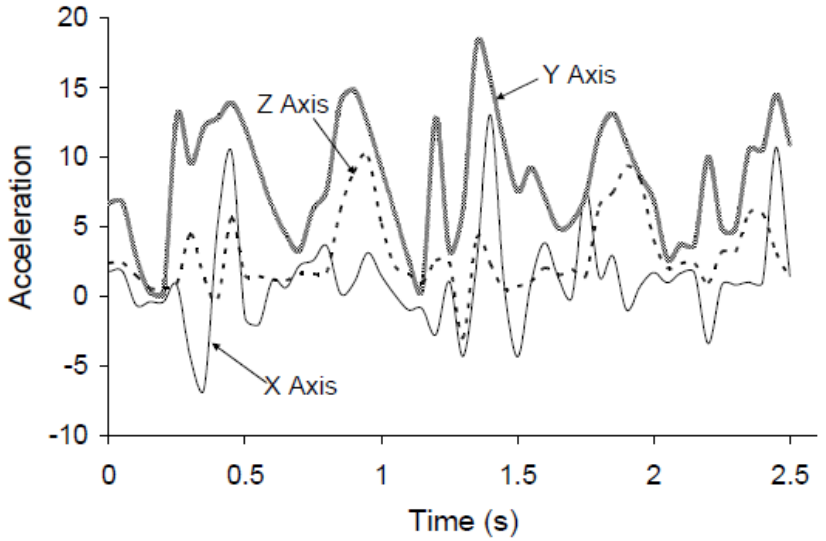


(f) Standing

Example Accelerometer Data for Activities

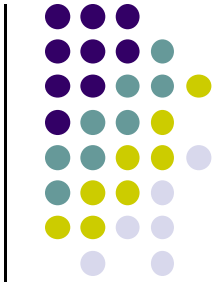


(c) Ascending Stairs



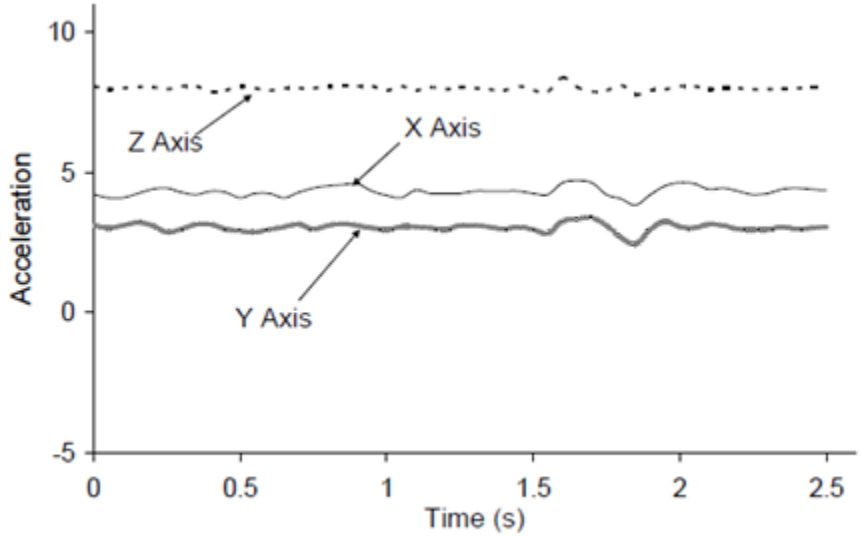
(d) Descending Stairs

Gathering Accelerometer Data



- Can write simple app that retrieves accelerometer data while user is doing each of 6 activities (1 at a time)

- Label each data with activity performed.
  - E.g. label the following data as sitting



(e) Sitting

Funf (funf.org)

- Can also download, FUNF app from MIT to gather data
- Continuously collects user data in background:
  - Accelerometer readings
  - Phone calls
  - SMS messages, etc
- Simple to use:
  - Download app,
  - Check off sensors to log (e.g. accelerometer)

Step 2: Run Study to Gather Example Data

- Data collected from many (e.g. 30) subjects
- Users run Funf in their phones while performing each activity
  - Perform each of 6 activities (walking, sitting,.. Etc)
- Accelerometer data collected every 50ms
- Funf pushes data to dropbox, download data
- Now have 30 examples of each activity

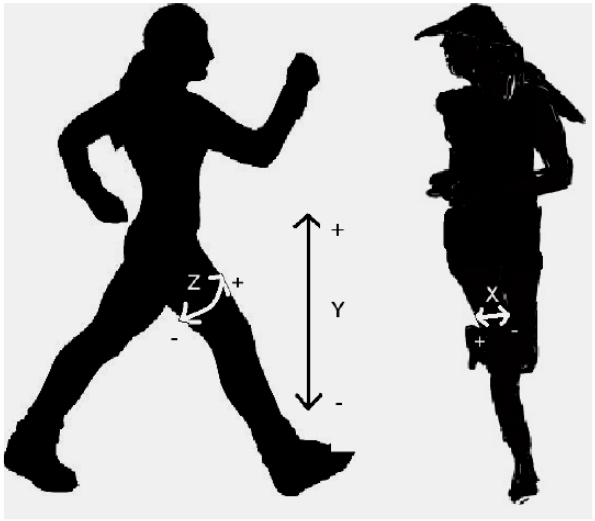
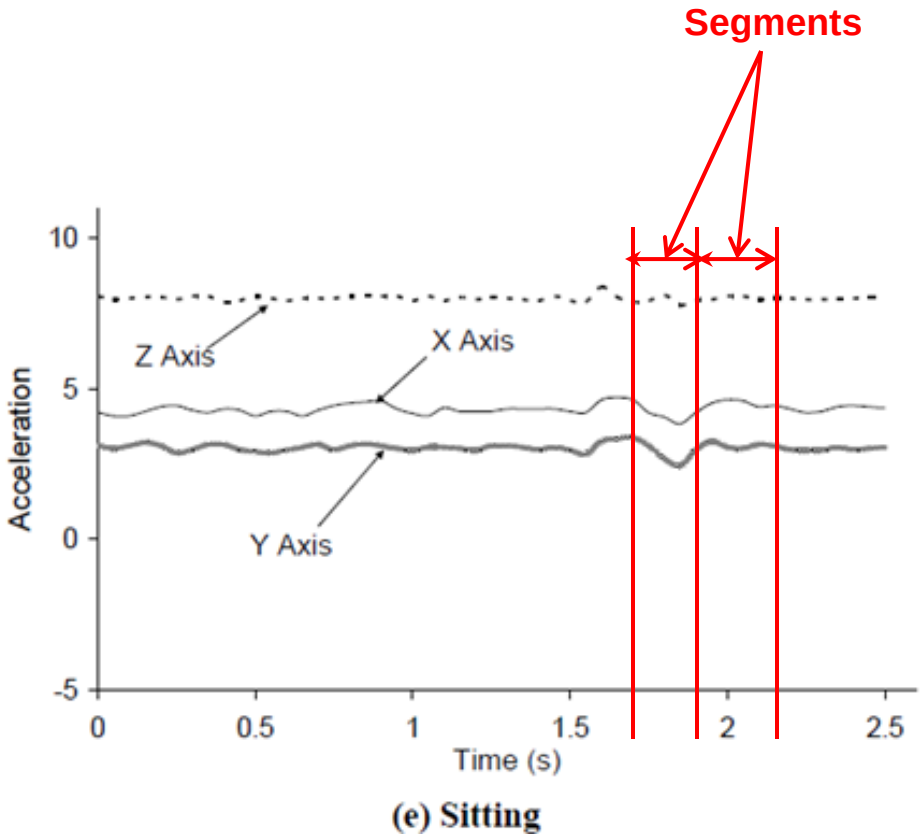


Figure 1: Axes of Motion Relative to User

Segment Data (Windows)

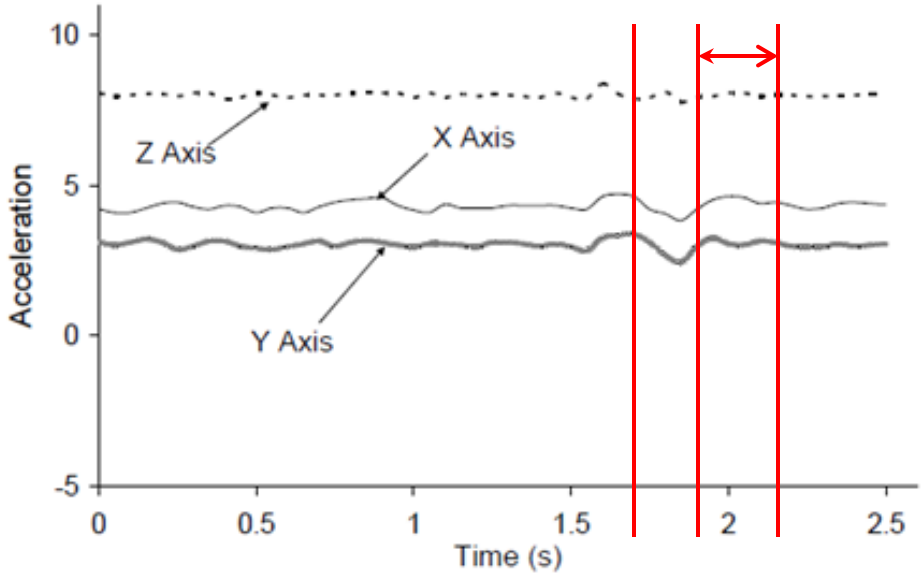
- Divide raw time-series data divided into segments (e.g. 10 seconds)



(e) Sitting

Compute Features

- Within segments, compute features
- **Features:** Functions computed on accelerometer data, captures important accelerometer characteristics
- **Examples:** min-max values within segment, magnitude within segment, standard deviation, moving average

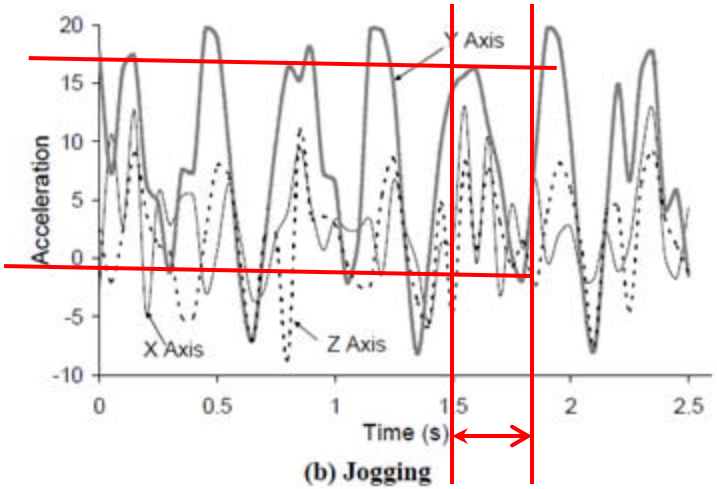


(e) Sitting

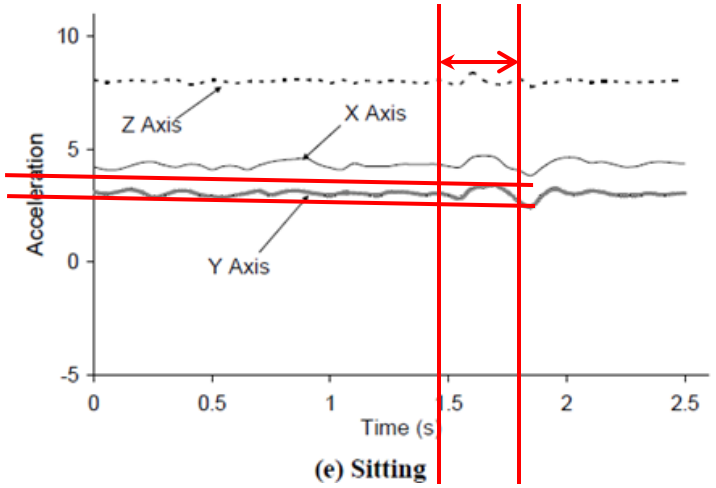
Compute Features

- **Important:** For given feature formula, each of activities should yield a different range of values
- **E.g:** Min-max Y axis range feature

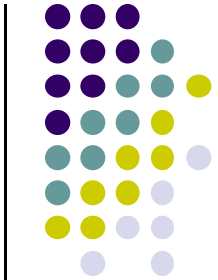
Large min-max for jogging



Small min-max for jogging



Feature Computation

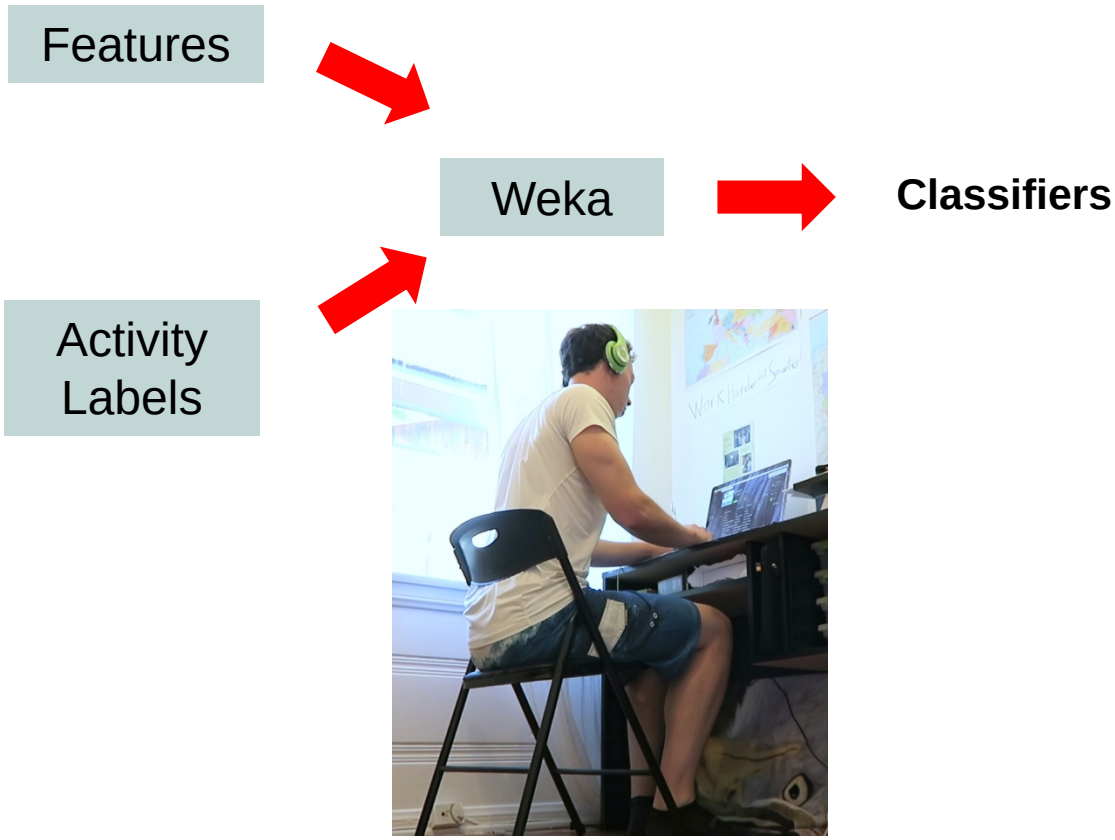


Calculate many different features

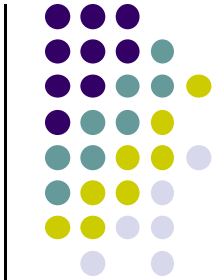
- Average[3]: Average acceleration (for each axis)
- Standard Deviation[3]: Standard deviation (for each axis)
- Average Absolute Difference[3]: Average absolute difference between the value of each of the 200 readings within the ED and the mean value over those 200 values (for each axis)
- Average Resultant Acceleration[1]: Average of the square roots of the sum of the values of each axis squared $\sqrt{(x_i^2 + y_i^2 + z_i^2)}$ over the ED
- Time Between Peaks[3]: Time in milliseconds between peaks in the sinusoidal waves associated with most activities (for each axis)
- Binned Distribution[30]: We determine the range of values for each axis (maximum – minimum), divide this range into 10 equal sized bins, and then record what fraction of the 200 values fell within each of the bins.

Machine Learning

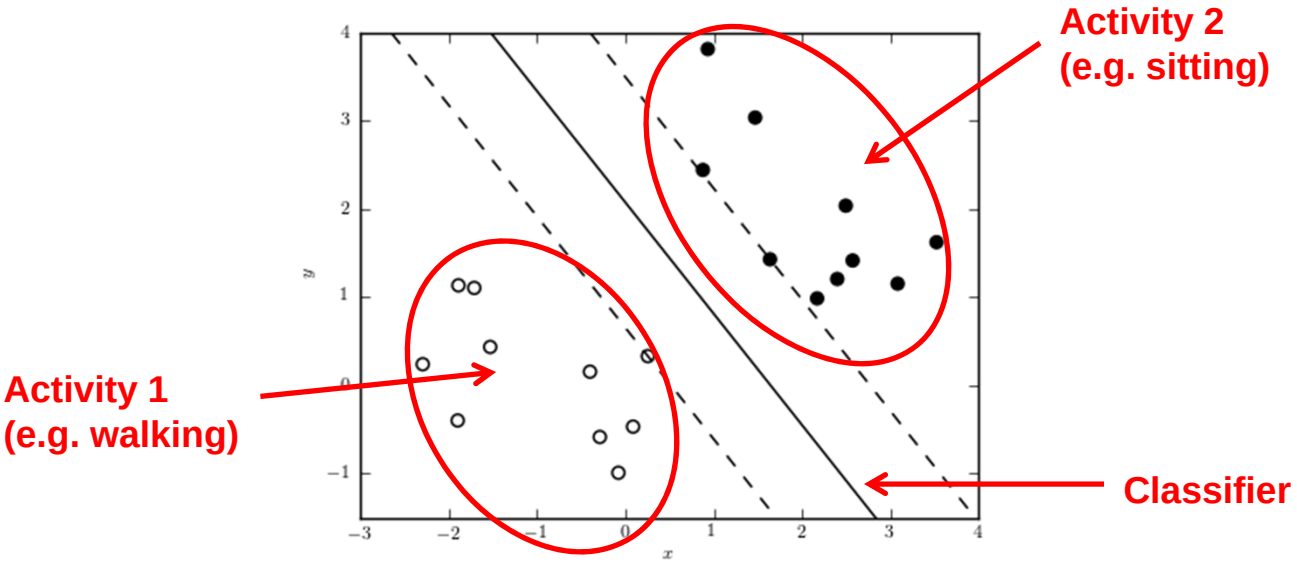
- Pull calculated features + activity labels into Weka (or other Machine learning Framework)



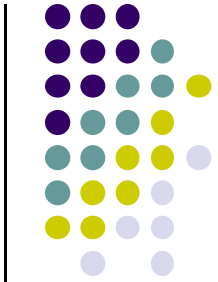
What does Weka do?



- Features are just numbers
- Different values for different activities
- Weka figures out ranges corresponding to each activity
- Tries different classifier algorithms (SVM, Naïve Bayes, Random Forest, J48, etc)
- SVM example



Accuracy of Classifiers



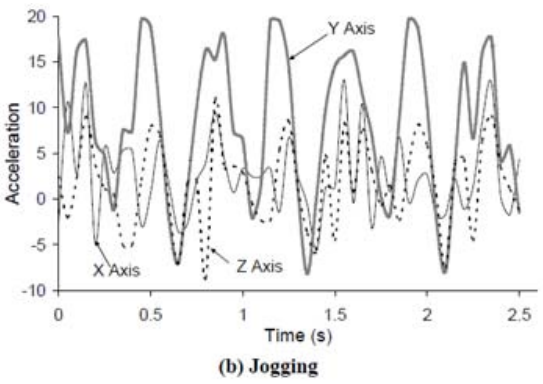
- Weka also reports accuracy of each classifier type

Table 2: Accuracies of Activity Recognition

	% of Records Correctly Predicted			
	J48	**Logistic Regression**	**Multilayer Perceptron**	**Straw Man**
Walking	89.9	**93.6**	91.7	37.2
Jogging	96.5	98.0	**98.3**	29.2
Upstairs	59.3	27.5	**61.5**	12.2
Downstairs	**55.5**	12.3	44.3	10.0
Sitting	**95.7**	92.2	95.0	6.4
Standing	**93.3**	87.0	91.9	5.0
Overall	85.1	78.1	**91.7**	37.2

Export Classifier from Weka

- Export classifiers as Java JAR file
- Run classifier in Android app
- Classifies new accelerometer patterns while user is performing activity => Guess (infer) what activity

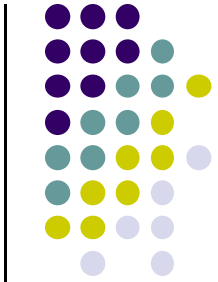


New accelerometer Sample in real time

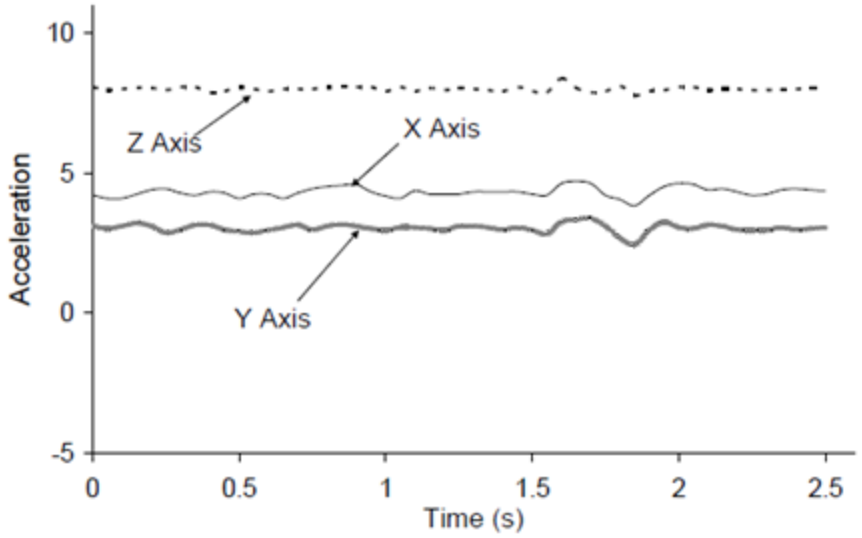
Classifier in Android app

Activity (e.g. Jogging)

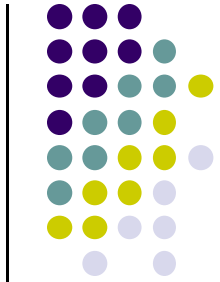
What if you don't know Machine Learning



- Visually inspect accelerometer waveform, come up with rules by trial and error
- E.g. If (min-max range < threshold), activity = sitting



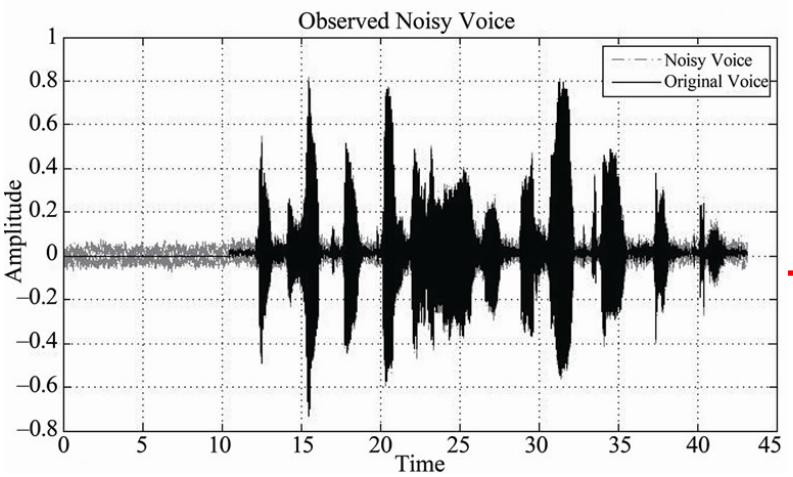
(e) Sitting



Concrete Examples of Classification

Voice Classification

- Voice input from Phone microphone



Voice Featues → Classifier → Stressed, Nervous, Depressed, Drunk

Facial Expression Classification

- Most of computer vision uses machine learning
- Classify camera images, to infer mood