# 180D Motion Classification Project Midterm Presentation

Corbett Cappon, Anthony Nguyen, Jincheng Zhou, Zhe Wan

# Design Overview: Objectives Summary

- Problem
  - There is a need for classifying human motion in clinical trials, energy expenditure monitoring, and user activity management
  - Advancements in motion sensor technology make it an increasingly usable tool for classifying human motion
- Objective
  - Accurately and cheaply classify human motions using state of the art motion sensor technology.

# Design Overview: Approach Summary

- Detailed Problem Statement
  - Design Constraints:
    - Our motion classification needs to be completed using data from only two motion sensors, measured using bluetooth wireless communication.
  - Challenges to be detailed in System Implementation and Testing sections
- Detailed Approach
  - It's difficult to predict in advance which parameters of our motion sensor will best differentiate the different types of motion. As a result, our general methodology is to methodically measure the human motion in question, and use the sensor fusion toolkit to compare all feature effectiveness, and find the features that work best for classification.

# Background

- Background integrated into System Implementation and Testing sections

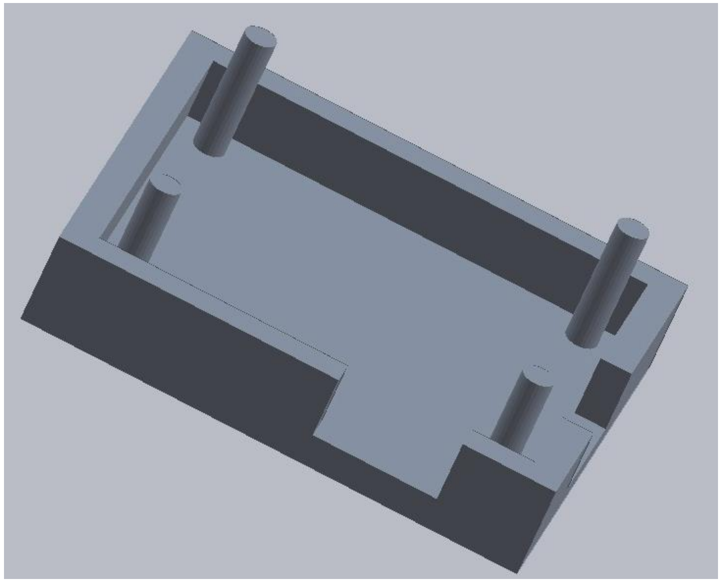
# Pre-Collection Considerations

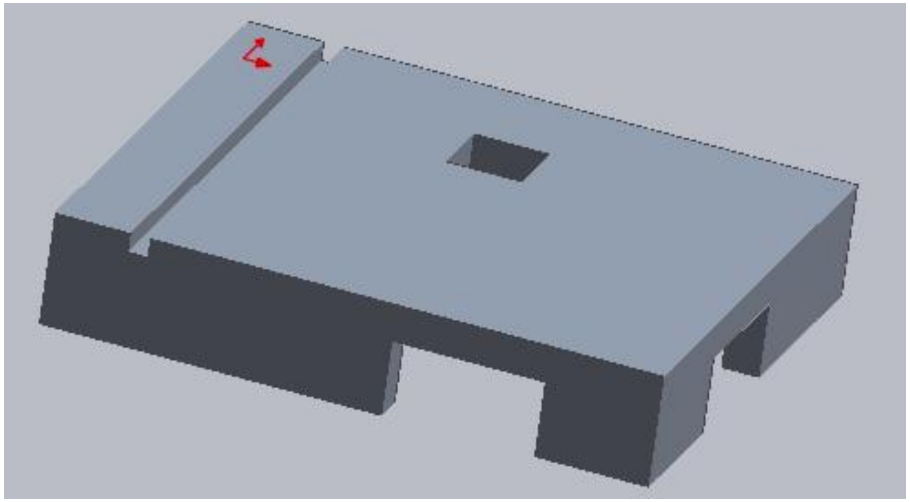
- Electronics are fragile and easily broken

# Rapid Design of Enclosure

- Examined original device dimensions
- Created CAD design using Autodesk Inventor
- Exported model to .STL file format
- Printed with Makerbot Replicator 2
- ~5 hours from conception to completion

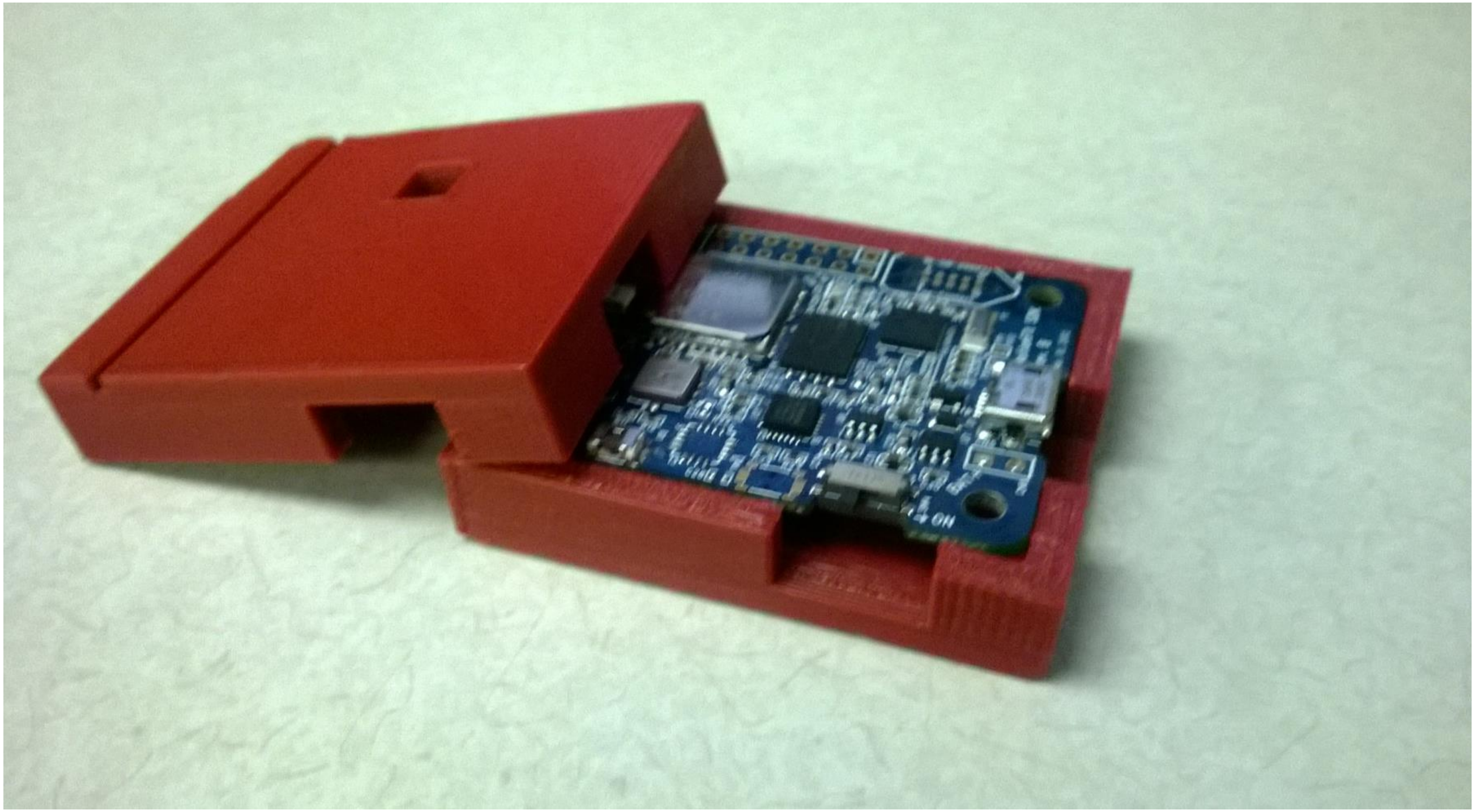
# WHS Shell 1.0





UCLA

# Use of Actual Device



# Data Collection

- Locations Choosing
  - Level 1: Walking
    - Hallway Outside the Classroom
  - Level 2: Stair Climbing
    - Drake Stadium
  - Level 3: Ramp Climbing
    - Sloped Ramp/Hill Next to the Dashew Center
- Difficulties
  - Stairs Too Short, Ramp Not Good
  - Sensors Not Functioning Well

# Collecting Good Data

- Choose Good Locations
  - From Engr 4 Stairs To Drake Stadium
  - From Bruin Walk to Dashew Center
- Avoid Sensor Disfunction
  - Keep Sensor Close Enough to Laptop
  - Make sure the signal is not blocked
- Consistent Position of Sensors
  - FFE8AB Tie On Thigh and FFEA55 On Foot All The Time

# Collecting Good Data Cont.

- Make Obvious Separation Between Sections
  - Add **Jump** Between Sections
- Use Metronome To Vary Different Speeds
  - 105 beats per minute for walk up slow
  - 130 beats per minute for walk up fast
  - 120 beats per minute for going down stairs

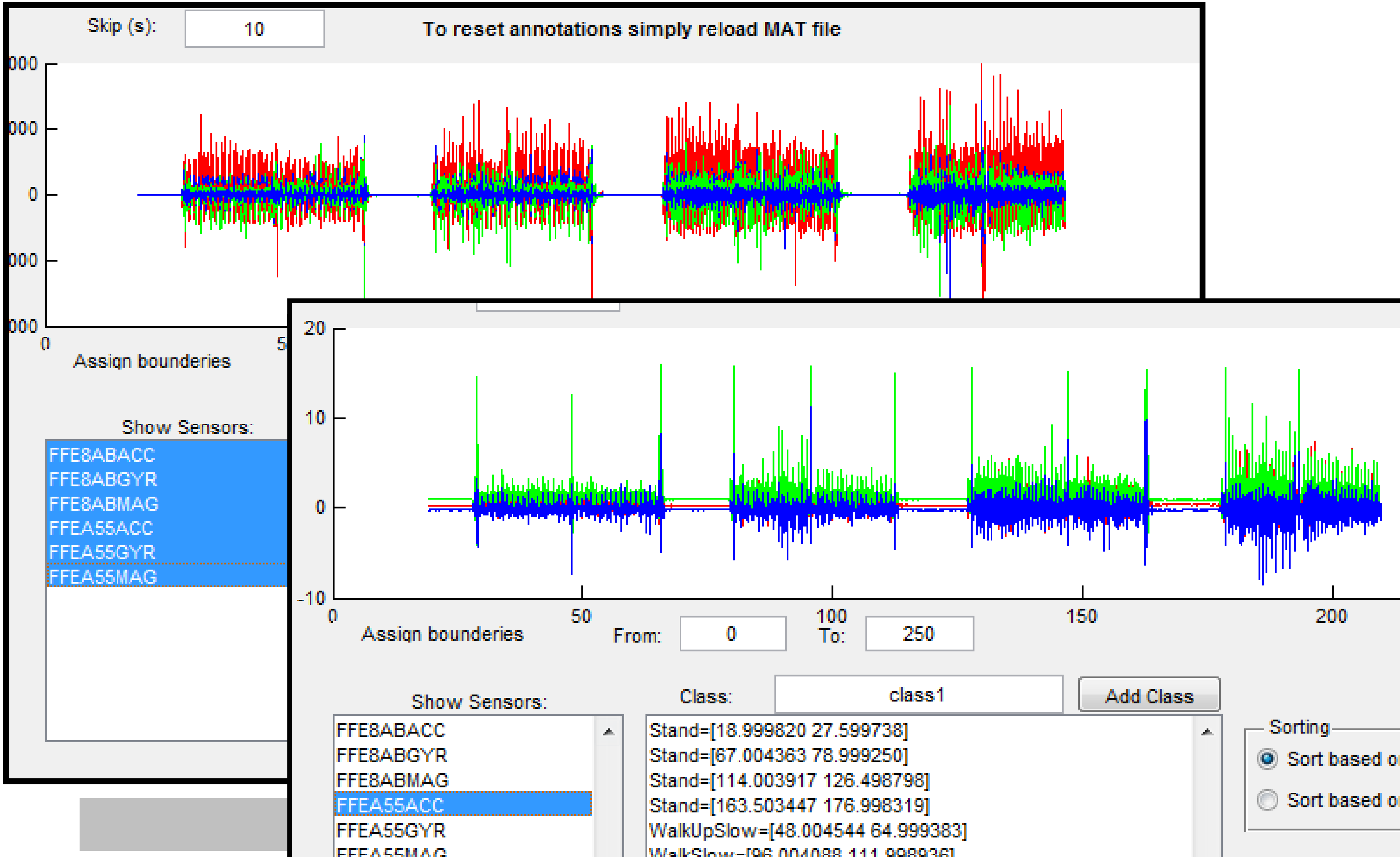
# System Implementation

- Data Collection
- Merge, Align
- Label
- Structure (Branch)
- Feature Finding
- Testing

# Labeling

- Give the ground truth to the dataset
  - Recognize the transition of different motion (use specific sensor’s data)
  - Avoid bad data for training, but accept them in testing for robustness

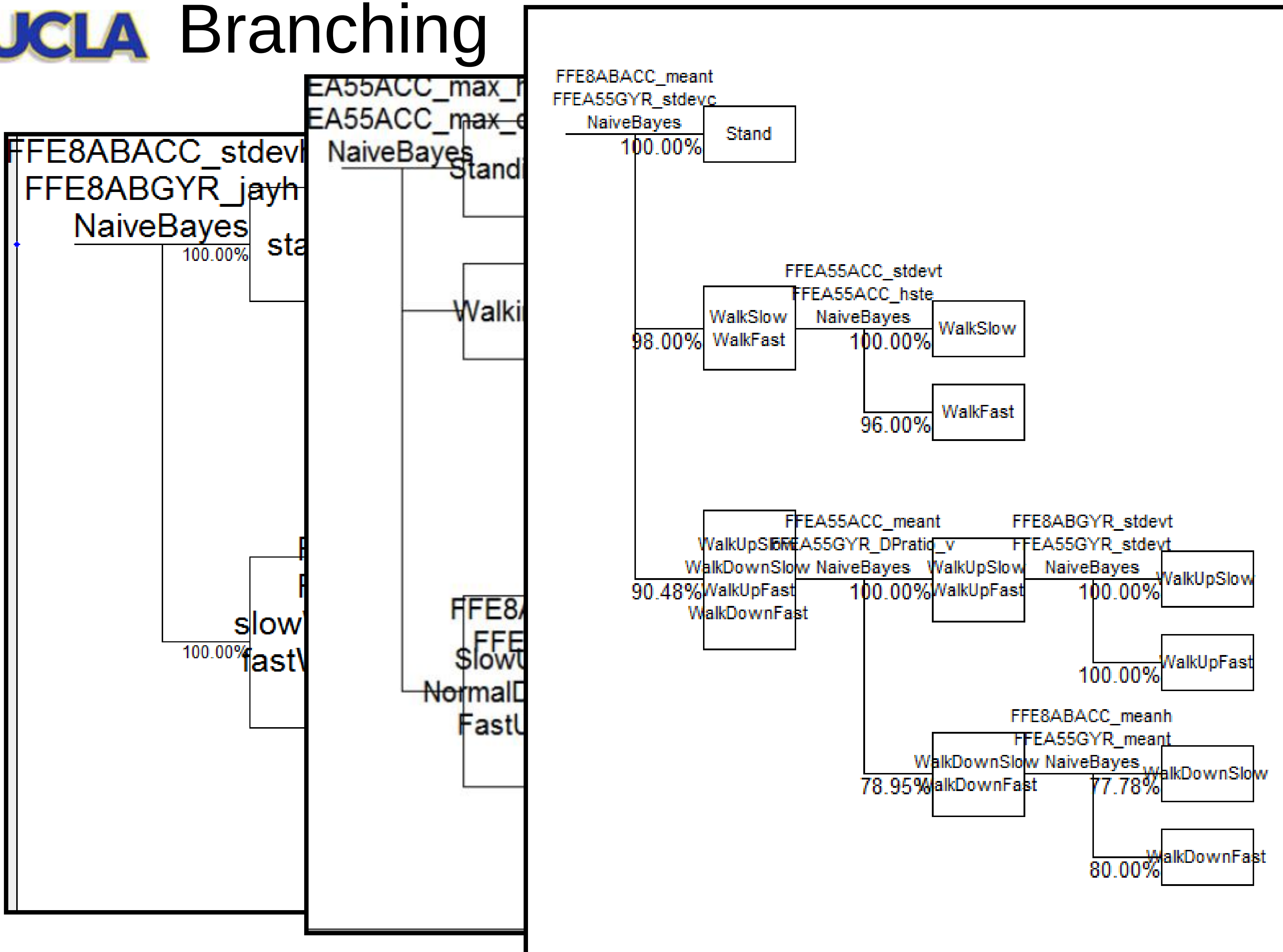
# Labeling


Skip (s):
10
To reset annotations simply reload MAT file
Assign bounderies
Show Sensors:
FFE8ABACC
FFE8ABGYR
FFE8ABMAG
FFEA55ACC
FFEA55GYR
FFEA55MAG
20
10
0
-10
0
50
100
150
200
Assign bounderies
From:
0
To:
250
Class:
class1
Add Class
Show Sensors:
FFE8ABACC
FFE8ABGYR
FFE8ABMAG
FFEA55ACC
FFEA55GYR
Stand=[18.999820 27.599738]
Stand=[67.004363 78.999250]
Stand=[114.003917 126.498798]
Stand=[163.503447 176.998319]
WalkUpSlow=[48.004544 64.999383]
Sorting

# Branching

- Structure the “tree” for classification
  - An important aspect prior to feature finding and testing
  - Number of sub-branch affects performance
  - Branching philosophy (speed/acceleration oriented or direction oriented)

# Branching


FFE8ABACC_meant
FFEA55GYR_stdevc
NaiveBayes
100.00%
Stand
98.00%
WalkSlow
WalkFast
FFEA55ACC_stdevt
FFEA55ACC_hste
NaiveBayes
100.00%
WalkSlow
96.00%
WalkFast
90.48%
WalkUpSlow
WalkDownSlow
WalkUpFast
WalkDownFast
FFEA55ACC_meant
FFEA55GYR_DPratio_v
NaiveBayes
100.00%
WalkUpSlow
WalkUpFast
FFE8ABGYR_stdevt
FFEA55GYR_stdevt
NaiveBayes
100.00%
WalkUpSlow
100.00%
WalkUpFast
78.95%
WalkDownSlow
WalkDownFast
FFE8ABACC_meanh
FFEA55GYR_meant
NaiveBayes
77.78%
WalkDownSlow
80.00%
WalkDownFast
FFE8ABACC_stdev
FFE8ABGYR_jayh
NaiveBayes
100.00%
100.00%
slow
fast
EA55ACC_max_
EA55ACC_max_
NaiveBayes
Standi
Walki
Slow
NormalD
FastU

# Feature Finding

- Find features to tell the difference among distinct motions
  - Filter out less useful sensor/parameter
  - Start with one feature to find the “good” feature
  - Testing for very consistent data (in the future)

# Testing and Verification

- Training more than one dataset
  - A feedback to the training system
  - A smarter machine with memory

# Used features

- Level 1:
  - Stand vs. Walk: Thigh_ACC_stdevh & ThighGYR_jayh
  - slowWalk vs. fastWalk: ThighACC_stdevh & ThighGYR_max_c

Accuracy 100%

# Used features

- Level 2:
  - Stand vs. walking vs. UpAndDown: Foot_ACC_max_h & Foot_ACC_max_c
  - Down vs. Up: Thigh_GYR_DPration & Foot_GYR_max_v
  - SlowUp vs. FastUp: Thigh_GYR_vste & Foot_GYR_cste

  Accuracy 97.059%

# Used features

- Level 3:
  - Stand vs. WalkFlat vs. WalkUpDown: Foot_GYR_stdevc & Thigh_ACC_meant
  - WalkSlow vs. WalkFast: Foot_ACC_stdevt & Foot_ACC_hste
  - WalkUp vs. WalkDown: Foot_ACC_meant & Foot_GYR_Dpratio_v

# Used features

- Level 3 (con’t):
  – WalkUpSlow vs. WalkUpFast: Thigh_GYR_stdevt & Foot_GYR_stdevt
  – WalkDownSlow vs. WalkDownFast: Thigh_ACC_meanh & Foot_GYR_meant

  – Accuracy: 89.216%

# What does it mean? (Background on Emphasis of Specific Features)

Level 1 primary features used

- For walking slow vs walking fast
  - Standard deviation of thigh accelerometer in y direction
    - Why the y direction?
      - The Y direction is the direction that gravity faces when one is standing still, hence change in the y accelerometer results from changing the direction that gravity is applied at.
    - Why the accelerometer standard deviation?
      - Walking faster means the “jerk” you apply to your leg when lifting it while walking forward will be stronger in magnitude, due to propelling yourself further and faster. In addition, you are taking more strides, meaning more of your time is taken making the “jerk” motions of starting a stride versus the slow acceleration involved in being mid step. Both of these increase standard deviation in the forward direction, making this variable a sensible one for differentiating motion.
    - Why the thigh?
      - The foot accelerator had more sudden motions involved in walking, potentially making its measurements more subject to variability and irregularity, which may explain why the thigh performed more consistently in differentiating different motions.
  - Maximum energy of thigh gyroscope
    - Why the maximum energy?
      - As mentioned above, walking faster involves a stronger “jerk” in starting each step. In addition, walking faster will cause the footfalls to be heavier as a result of our steps containing more kinetic energy. Both of these phenomena will cause increased vibrations throughout the leg, causing both the gyroscope and accelerators to oscillate more with each step initiation and step ending.
      - The oscillations increase both the standard deviation and the energy of the accelerometer and the gyroscope, but the standard deviation only reflects increased vibrations in one axis while the energy reflects increased vibrations in all three axes, making energy the more reliable of the two variables.
    - Why the gyroscope?
      - While energy is increased in both the accelerometer and the gyroscope from the oscillation increase, the accelerator has more factors that could potentially obfuscate the measurement of vibrations. The accelerometer has a mean acceleration forward, along with many different types of acceleration oscillations involved in walking, both of which would affect the . The gyroscope on the other hand theoretically only has a single type of oscillating change in pitch, potentially with some changes in yaw due to turning, with the mean changes of both being around zero. As a result, the energy of the gyroscope will more closely be proportional to the vibrations of the leg than the accelerator.
    - Why the thigh?
      - Like the accelerometer, the thigh gyroscope is less subject to variability and irregularity, making it a more consistent variable in differentiating human motions.

# What does it mean? (Background on Emphasis of Specific Features)

Level 2 primary features used

- For climbing stairs up vs down:
  - Max foot pitch change
    - Why the foot pitch change?
      - In climbing up stairs, one's foot stays relatively flat the entire time, whereas in climbing down stairs, one typically angles their foot down to cause their landing to be more gradual.
    - Why the maximum?
      - Both the mean and standard deviation are susceptible to error due to the vibrations that occur when one finishes a step.
      - The maximum, on the other hand, can theoretically remain uncahnged despite these vibrations if the gyroscopic changes in changing the foot pitch are much larger than the gyroscopic changes due to vibrations.
  - DP ratio for thigh roll
    - Why the roll DP ratio?
      - DP ratio appears to be a measure of how spread out the frequencies are, with a higher DP ratio corresponding to a less spread out frequency distribution, and vice versa.
      - Since theoretically our thigh should be only changing in pitch, not in roll or yaw, this is probably more related to the vibrations in the thigh than the regular movements.
      - If we are trying to observe trends in the vibration of the thigh, the pitch's vibrations trends are obfuscated by the pitch's general variation in climbing stairs, and the yaw's vibration trans are obfuscated by small turns in the course of climbing stairs.
      - As a result of the above three points, we could see roll DP ratio as a plausible best variable if we are looking for regular trends in the vibrations incurred by walking.
      - Some possible differences in trends in vibrations could be from
        - » Differing speed in climbing up verses down
        - » Differing amount of "bounce" involved in climbing versus descending stairs
        - » Potential slight differences in regularity of gait in ascending versus descending
    - Why the thigh?
      - Perhaps the thigh vibrations are more regular than the foot vibrations, allowing trends like modes of vibrations to be more apparent in the course of walking.

# What does it mean? (Background on Emphasis of Specific Features)

Level 2 primary features used

- For walking vs climbing stairs
  - Maximum foot accelerometer in y direction
    - Why the acceleration in the y direction?
      - When stair climbing, either slow or fast, the amount one moves forward in each step (~2/3 of a foot) is smaller than the amount one moves forward in a step on flat ground (2-3 feet). As a result, the acceleration in the y direction, which corresponds to the forward direction, will be decreased for stair climbing in comparison to walking on a flat surface.
    - Why maximum acceleration?
      - The decreased acceleration should mean a decreased average, decreased standard deviation, and decreased maximum.
      - Stair climbing also adds changes in elevation, which potentially adds additional vibrations due to the increased energy of each footfall, particularly on the way down.
      - These vibrations will increase the standard deviation, offsetting the earlier mentioned decrease.
      - Vibrations vary the acceleration a lot in every direction. If the accelerometer perfectly captures the acceleration over all values, the average acceleration should be zero, since after all of the vibration, we do not change in speed. However, the accelerometer does not sample perfectly capture the acceleration over all times, making it plausible that the accelerator would sample more at forward accelerating moments than backward accelerating moments, which it would interpret as a net acceleration forwards. As a result, increased vibrations can add error to the mean acceleration (along with our default vibrations potentially adding error to the mean acceleration), which could explain why mean was a less consistent parameter to differentiate our behaviors
      - The vibrations could, plausibly, not change the maximum if the acceleration involved in beginning a step was larger than the accelerations involved in the vibration of a foot.
      - As a result of the above, we can make a plausible explanation of why maximum acceleration in the y direction was a reliable method of differentiating walking and climbing stairs
    - Why the foot?
      - While the foot definitely moves forward by different amounts depending on whether one is moving on a flat surface or a stair surface, the thigh may move approximately the same amount on a staircase as a flat surface. This is because the thigh also moves an additional amount forward depending on the amount up one is moving, which offsets the decreased amount forward one is moving in stair climbing.
  - Maximum energy of foot accelerometer
    - Why the accelerometer maximum energy?
      - When one takes a step upwards, there is a significant acceleration in both the upwards and forwards directions. In addition, when one finishes a step downwards, there is also a significant acceleration in both the upwards and forwards directions. Whereas when one takes or finishes a step forwards, there is only an acceleration forwards, and a smaller acceleration upwards. As a result, the maximum energy expended in climbing stairs is higher. (which intuitively makes sense. It takes more energy to climb a single step slowly than to take a step quickly on a flat surface, and most of that energy is in the beginning of the step.)
      - The mean accelerometer energy could potentially be also used, but as mentioned earlier, it is subject to error from vibrations, and overall, the difference mean energy may just be less pronounced than the difference in maximum energy.
    - Why the foot?
      - The maximum energy peaks are higher in the foot, which may offset the increased potential for error.
      - The motion of the thigh is more similar between stair climbing and walking than the motion of the foot.

# What does it mean? (Background on Emphasis of Specific Features)

Level 3 primary features used

- For walking flat / walking on a slope:
  - Average thigh acceleration in the z direction
    - Why the z direction?
      - The z direction is the direction that the thigh is rotated in when the thigh rotates.
      - In addition, when the thigh becomes high enough,  gravity's acceleration is applied to it.
      - As a result, both of these would be different when walking on a slope in comparison to walking on flat ground.
    - Why the thigh acceleration?
      - While thigh acceleration in the z direction may not be as good at distinguishing between upward and downward slope movement, as I shall explain later, it still remains sufficient in distinguishing between climbing a slope and walking on a flat surface, because there is a lot more upward thigh movement in climbing a slope than walking on a flat surface.
    - Why the average?
      - The standard deviation may be susceptible to error from footfall vibrations.
  - Standard deviation of foot gyro energy
    - Why standard deviation foot gyro energy?
      - The most plausible explanation of this working is that the hill we were walking on has a less hard surface, making the vibrations caused by footfall less  strong, and with it, making the energy of the gyro accelerations reduced.

# What does it mean? (Background on Emphasis of Specific Features)

Level 3 primary features used

•For Up/Down:

- Average foot acceleration in the z direction
  - Why the average acceleration in the z direction?
    - Logically, the average acceleration in the z direction should make the most sense as the variable to differentiate upwards slope climbing versus downwards slope climbing, since we're moving up on average on the slope up, and moving down on average on the slope down.
    - For stair climbing however, it was not used, potentially because it was susceptible to error from footfall vibrations, and because we had better variables available.
    - However, in slope climbing, our footfalls are less hard due to landing on an incline, and due to landing on grass, potentially causing less error from footfall vibrations.
    - In addition, since the movements associated with moving up and down a slope are much more similar than the movements associated with moving up and down the stairs, we may have fewer other variables to use to differentiate our movements.
    - The above two points can explain why, plausibly, average acceleration in the z direction was the best distinguishing parameter for slope climbing and not for stair climbing.
  - Why the foot?
    - While more susceptible to error from vibrations, the acceleration upwards on the foot is more constant than the acceleration of the thigh upwards, which alternates between accelerating upwards and downwards, which may make a mean change easier to observe, and less susceptible to error .
- DP ratio of foot pitch change
  - Why the pitch DP ratio?
    - In stair climbing, we were able to differentiate based on the mean pitch change, because the pitch was relatively constant for climbing stairs upwards, and varied significantly for climbing stairs downwards
    - In slope climbing, while there are differences in foot pitch in ascending or descending a slope, they are not as straightforward as stair climbing, because the foot changes pitch significantly both when ascending and descending the hill.
    - Other trends may potentially still emerge in the pitch of the foot, due to the difference in ascending and descending the hill, however, and the DP ratio could have plausibly reflected these, since the DP ratio appears to be a measure of how spread out the frequencies are.
    - Some possible differences in pitch trends in ascent or descent could be from
      - » Differing angles in the foot when starting or ending a step
      - » Differing speed in climbing up verses down
      - » Differing amount of "bounce" involved in climbing versus descending stairs
      - » Potential slight differences in regularity of gait in ascending versus descending

# Other Challenges And Solutions

# Available for Use Now!

- Two .STL files: casing_top.stl and casing_bottom.stl
- Shell is an imperfect prototype
  - Top and bottom do not lock together yet
  - Dimensions of top and bottom can be refined
    - Lighter, smaller, more precise fit, faster production time

# Five Levels, Five Trees?

- Every level has specific data unique to it
  - Walking
  - Stair climbing
  - Hill climbing
  - Multiple steps
- Yet, the WHSFT toolkit analyzes single files
- A solution was necessary

# Merge_datasets.m

- Based on format_data.m
- Takes as input the sensor name, and the data from two different trials
- Returns a single file with the data of the second trial appended to the first

# Data Pre-Processor

- Generalized version
  - Accept multiple input files at once, remove the need to call the function several times to combine several inputs together
  - Combine this functionality with that of format_data.m
    - This would allow direct use of the BlueRadios files
  - Addition into the UI of the WHSFT, as a “Pre-Processor”

# Team and Responsibilities

- Data Collection
  - Anthony Nguyen as primary test subject
  - Chase Zhou on laptop, procedure
- Feature Finding
  - Frank Wan
- Features and Reality
  - Corbett Cappon

# Project Management Tools

- Retroactively applied at the end of Level 3
- Microsoft Office Project
- Will be employed going forward
  - Help with scheduling events, viewing dependencies of the project on individuals

# Thank You!