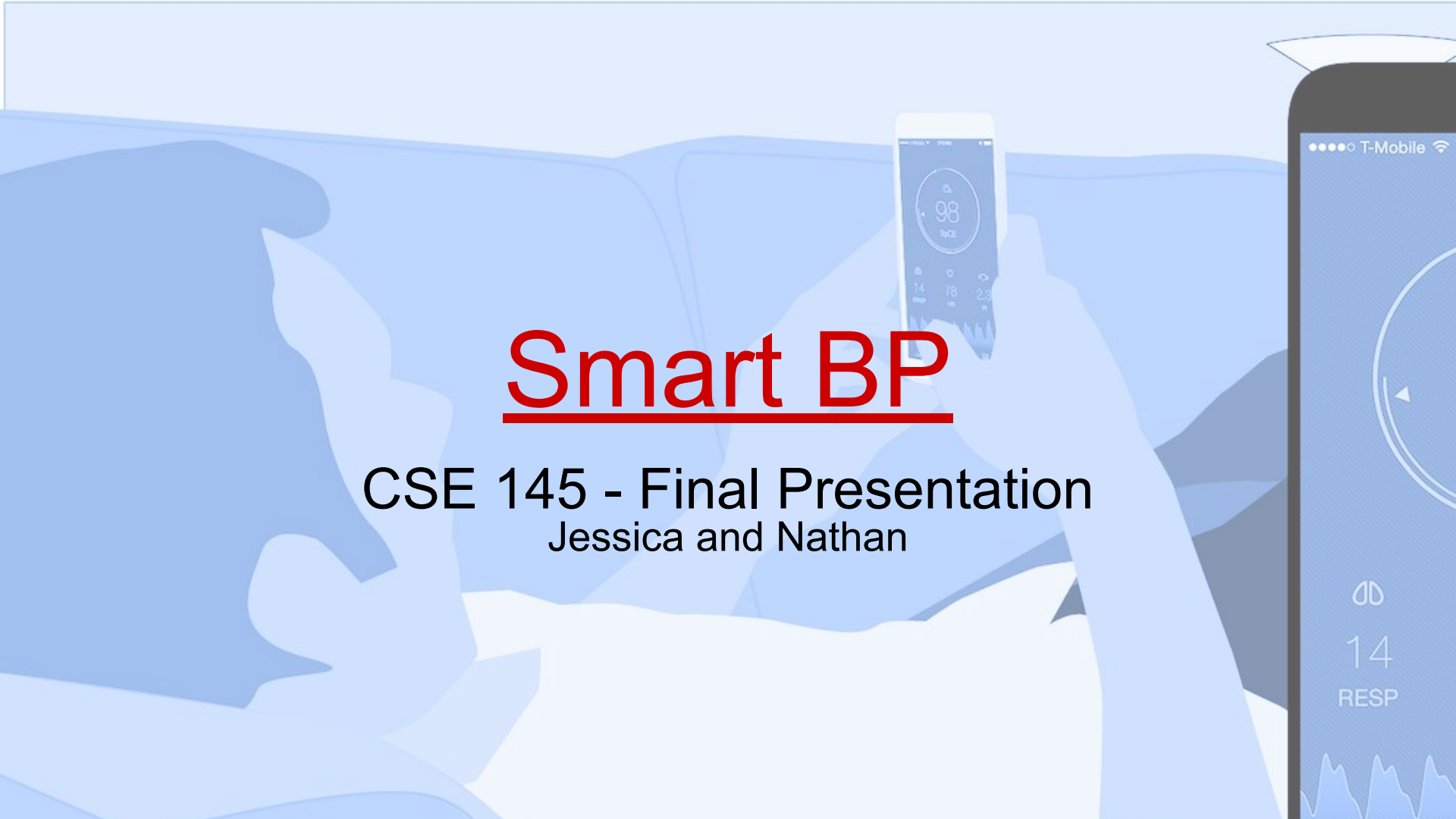
Smart BP

CSE 145 - Final Presentation

Jessica and Nathan



The Problem

- Challenges of measuring Blood Pressure for users with comorbidities.
- Multi-measurements require bring the device everywhere.
- Lack of access to BP devices due to its high cost and lack of access to health facilities.

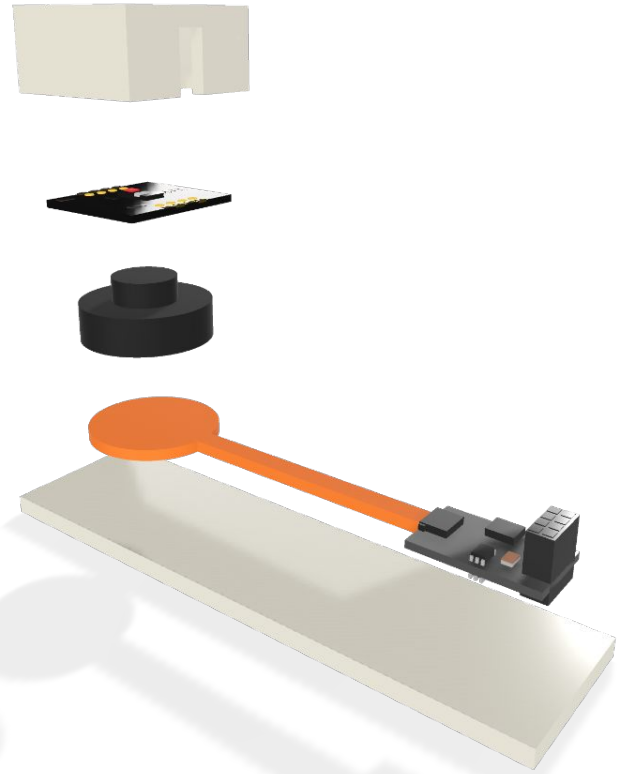
What did we do?

- Implemented the device with a PPG and force sensor
- Replicated the blood pressure algorithm from Chandrasekhar et al.
- Completed our MVP: We are able to take blood pressure measurements just from our index fingers on the device
- Collected a small data set
- Tested several different machine learning techniques and compared results with the replicated algorithm
- “Models” tried: Hidden Markov Model, Boosted Trees, Time Series Hashing, Dynamic Time Warping K-Nearest Neighbors (last two aren’t really “models” - just glorified pattern matching)

Hardware Implementation

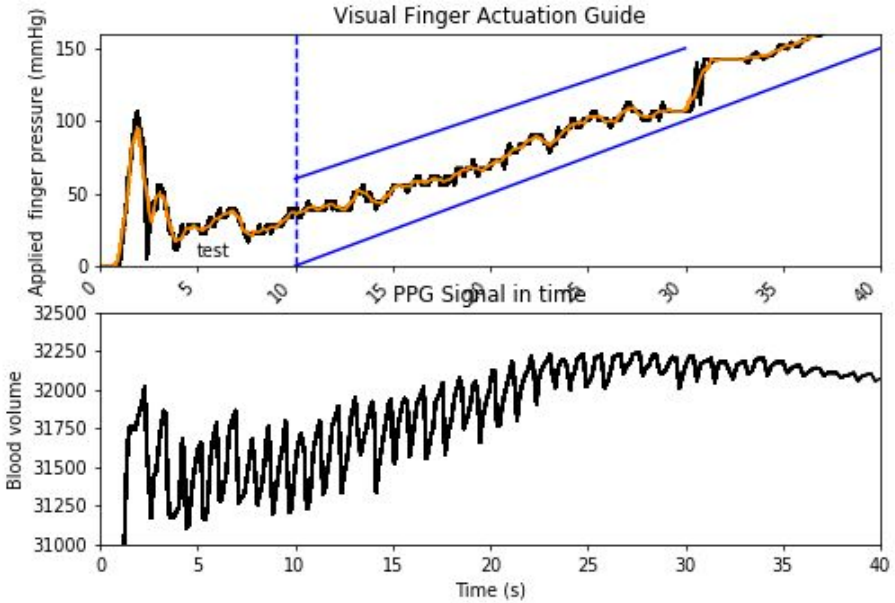
- Assembly of Force sensor (CAL 15MM DIAMETER, 4.5N/1.0LB) and PPG sensor module (High-Sensitivity Pulse Oximeter and Heart-Rate Sensor for Wearable Health).

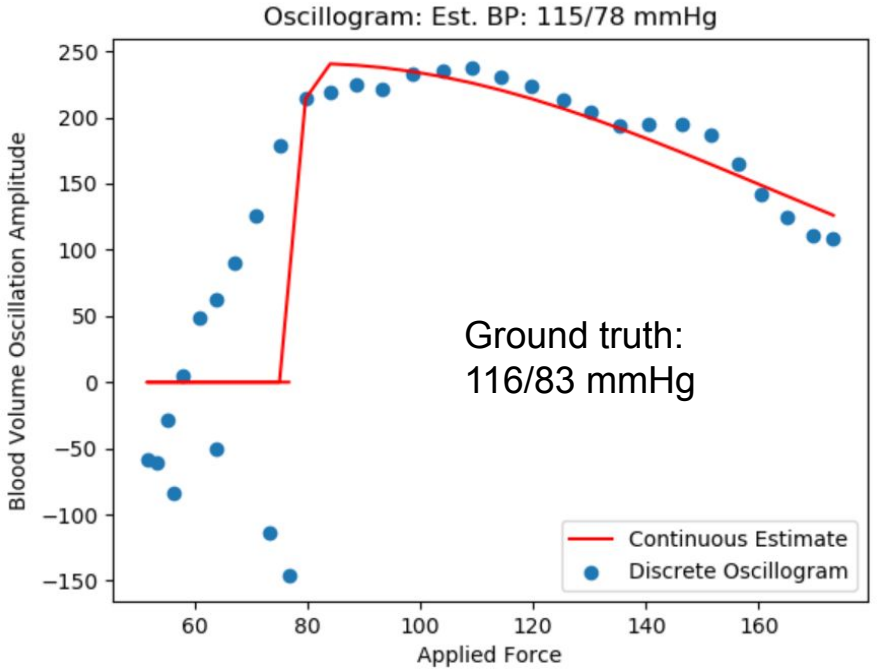
- Arduino Programming for access the I2C-based sensors and Python Serial Interface with modules for real-time data acquisition.



Realtime Acquisition and BP Estimation

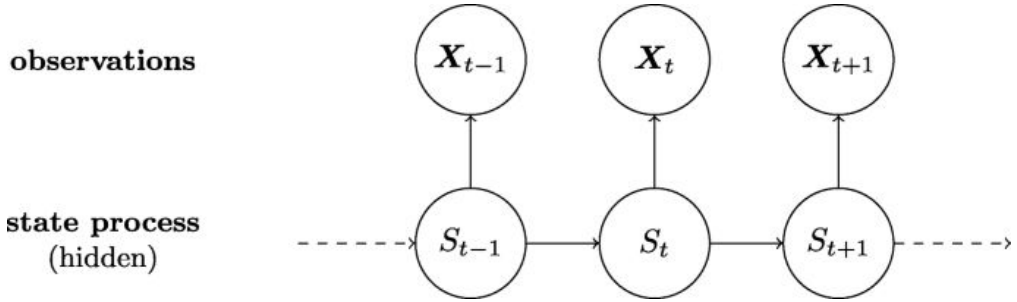
- Continuous PPG sensing and force sensing.
- Force sensing is acquired with users continuously increasing the applied force in the device.

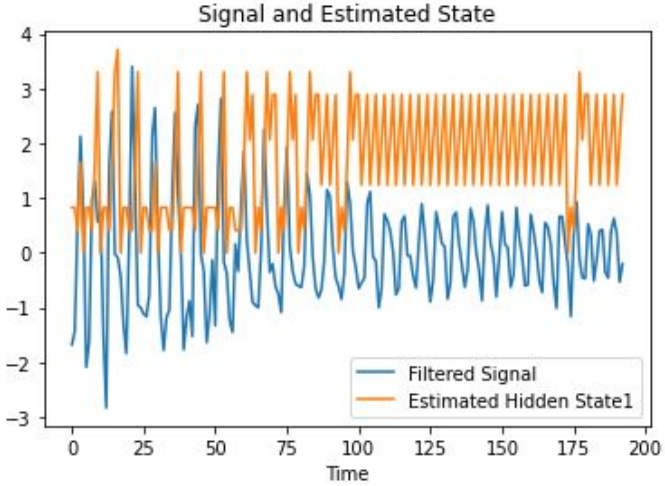




Most promising model tried so far: Hidden Markov Model

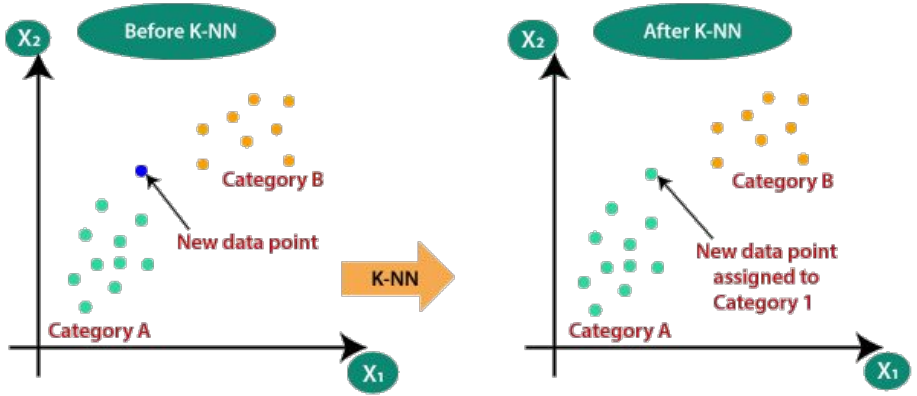
- Idea: Blood pressure is related to the oscillations in the PPG signal when pressure is applied
- Oscillations can be dictated by a “hidden state”. We try to actually learn the hidden state sequence
- Use the learned models to classify people into “normal BP” and “elevated BP”
- Ongoing: How can we get a real-valued blood pressure number?





Runner Up: Time Series Hashing/KNN

- Compress the signals into multiple binary codes using “bag of patterns” and weighted jaccard hashing
- New signals get hashed, then hashed database is searched using K-Nearest Neighbors, get K most “similar” signal and statistics retrieved
- Predict BP and BP class with weighted majority vote
- Problem: Doesn’t try to understand blood pressure or signals at all. Will make doctors unhappy, even if accuracy is high

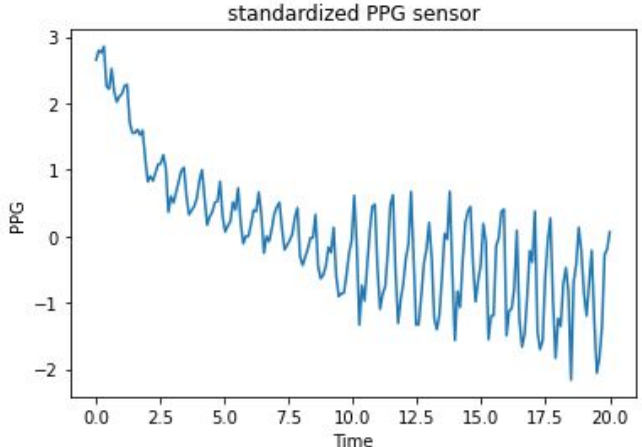


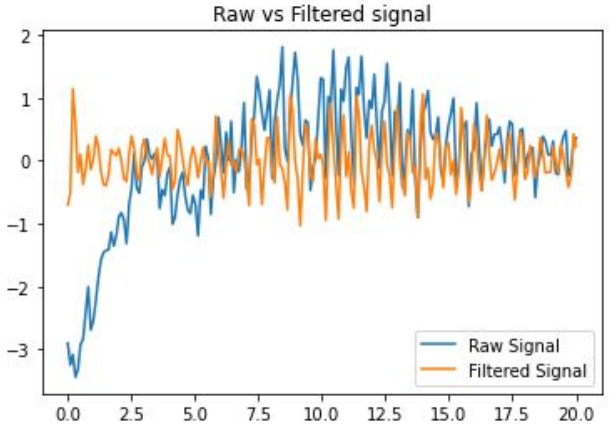
Preliminary Results (32 signals)

- Baseline Algorithm:
  - Systolic/Diastolic Avg Error: 5-10 Hgmm
  - Standard Deviation: B I G (anywhere between 10-30 Hgmm depending on initial params)
- Hidden Markov Model
  - Classification Accuracy: 3 mistakes
    - 2 False Positives (Said High BP when actually low BP)
    - 1 False Negative (Said low BP when actually high BP)
- KNN/Hashing
  - Systolic/Diastolic Avg Error: 0.5 Hgmm (whoa)
  - Standard Deviation: 8.6 (systolic) / 6.7 (diastolic)
  - Classification Accuracy: 4 mistakes
    - 2 FP, 1 FN
- Boosted Trees: Similar to KNN/Hashing

Problems Faced and Major Challenges

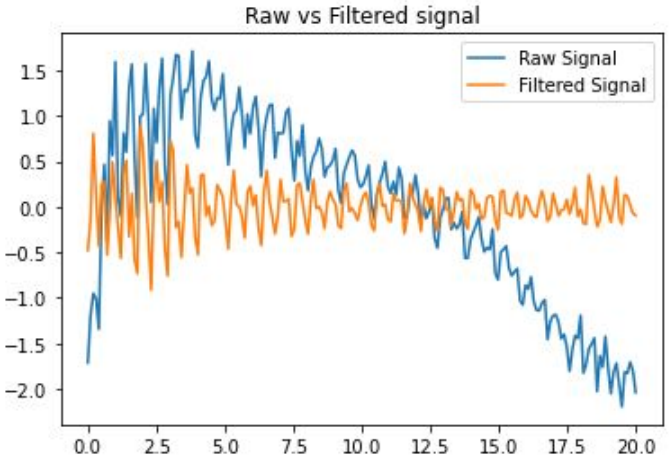
- The PPG sensor on the finger gave extremely noisy measurements
- Led to numerical stability issues in Chandrasekhar's BP algorithm
- Also affects the accuracy of the ML models
- Careful filtering required to address
- Also tried some signal compression to "squeeze out" the noise





Problems Faced and Major Challenges

- Limited time = Limited data
- Met our goal: got at least 30 signals, but not enough
- No way to apply powerful deep learning methods
- Approach: Simpler ML models, Leave-one-out-cross validation, statistical analysis, consider classification instead of “prediction”



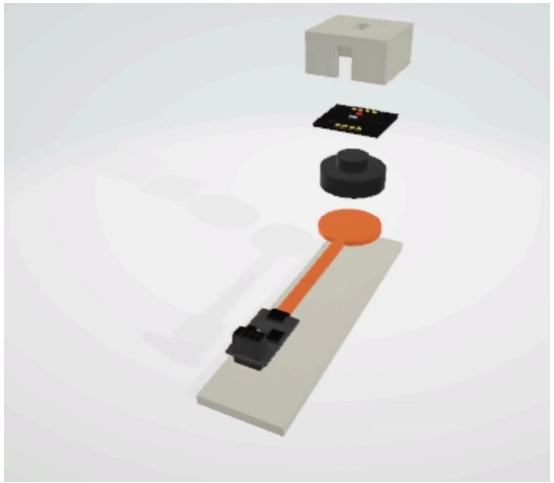
Blood Pressure Categories

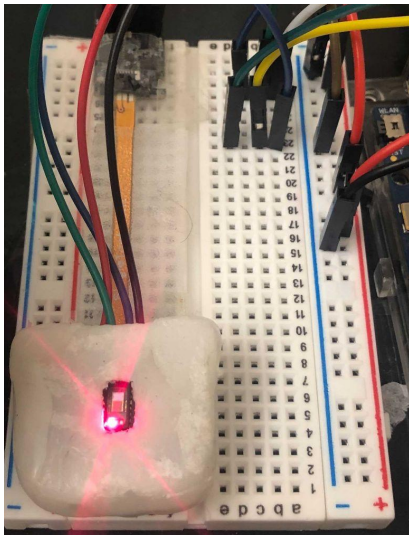
American Heart Association | American Stroke Association

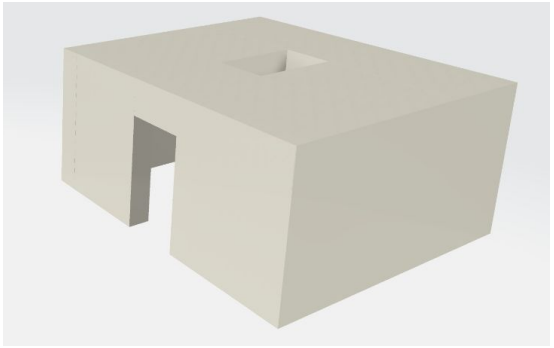
BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

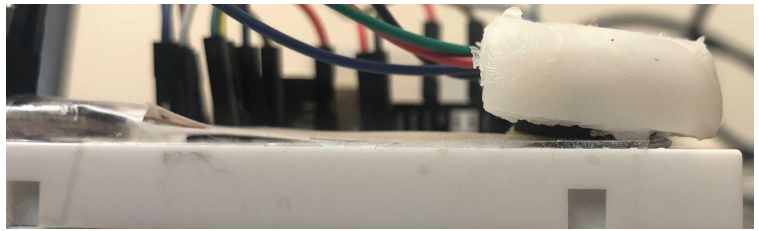
Problems Faced and Major Challenges

- The PPG sensor on the finger gave extremely noisy measurements
- Adaptation of a flat surface to help reduce that









What we did not do

- Smartphone implementation using the camera
- Settled on a “final” model for predicting BP given PPG and pressure measurements
- Integrated the different ML models into software for real-time testing (Happening this weekend)
- Obtained a large, varied dataset with more people, possible our data is an “easy” problem” (Still fixable?)

Conclusion

- This device may not be indicated for using with older adults or people with Parkinson’s disease, since the sensing was extremely noisy and this causes uncertainties with the BP estimation.

- We were able to have our MVP met with the BP estimation from the replication of Chandrasekhar et al. work, and some added ML estimation.

- The larger data collection will happen in the Summer quarter for the poster submission (possibly CHI or IMWUT, deadlines in August/September).