Human-Machine Interface for Myoelectric Applications using EMG and IMU

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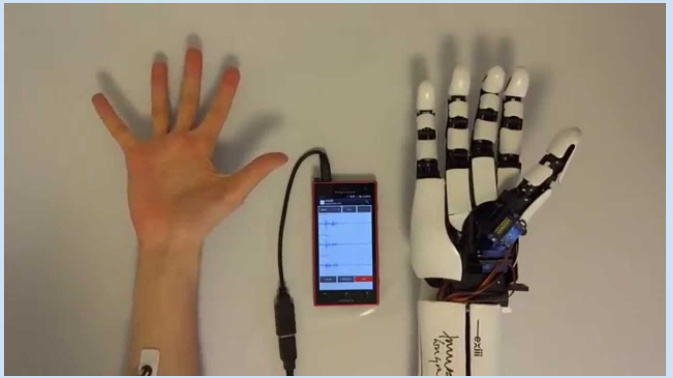
Outline

- Goals, Timelines, and Background
- Backend Machine Learning
- App Design
- Cloud Storage and Computing
- Experiments
- Future Tasks

HMI for Myoelectric Controlled Applications

- HMI (Human-Machine Interface) - controller operating panel for interaction
- Myoelectric - electric properties of muscles
- Designed to aid and improve human lifestyle
  - Rehabilitation:
    - Exoskeletons
    - Prostheses
  - Virtual Reality
    - Gaming
    - Phobia Therapy



https://i.ytimg.com/vi/_OKfu1ZPifE/maxresdefault.jpg

Requirements

- Fast → Needs to work in real time: Lag time < 200ms
- Portable → Can be taken anywhere
- Reliable → Predict gestures accurately
- Durable & Robust → Withstand everyday occurrences like sweat and shifts in the armband

https://rigor.com/blog/2016/03/5625

https://www.gamestop.it/Switch/Games/103312

http://myassignmenthelp.info/reviews/

https://www.phonearena.com/news/These-are-the-best-rugged-most-durable-smartphones-right-now-2015-edition_id69527

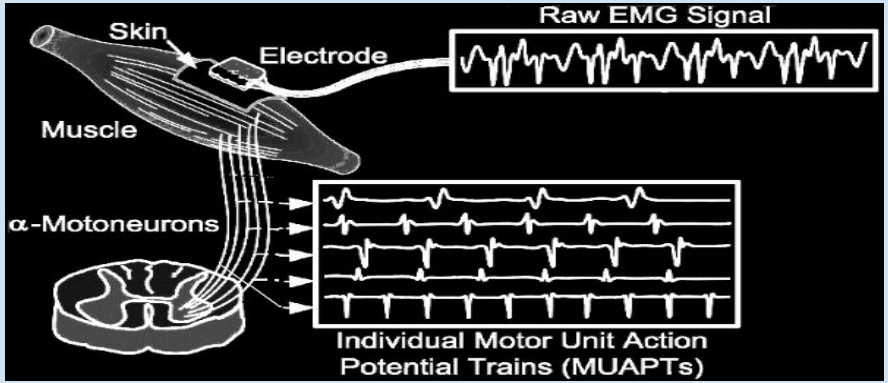
Goal

- **Before our project**
  - PC-Based Myoelectric HMI - Low cost, flexible, and open source
  - Predicted gestures accurately and efficiently
  - **Limitations:**
    - Not portable
    - Stand alone, limited computing power
- **Main Goal:** Translate the PC application onto a more portable android device and create the foundations for a cloud computing platform

http://www.hortonsoandp.com/the-science-behind-fabricating-prosthetic-hands-and-arms/

Background

- Data collected from the MYO Armband with 8 sensors surrounding the forearm
- Electromyography (EMG): electrical activity of muscle tissue



- Inertial Measurement Unit (IMU): measures acceleration, angular velocity, and magnetic forces

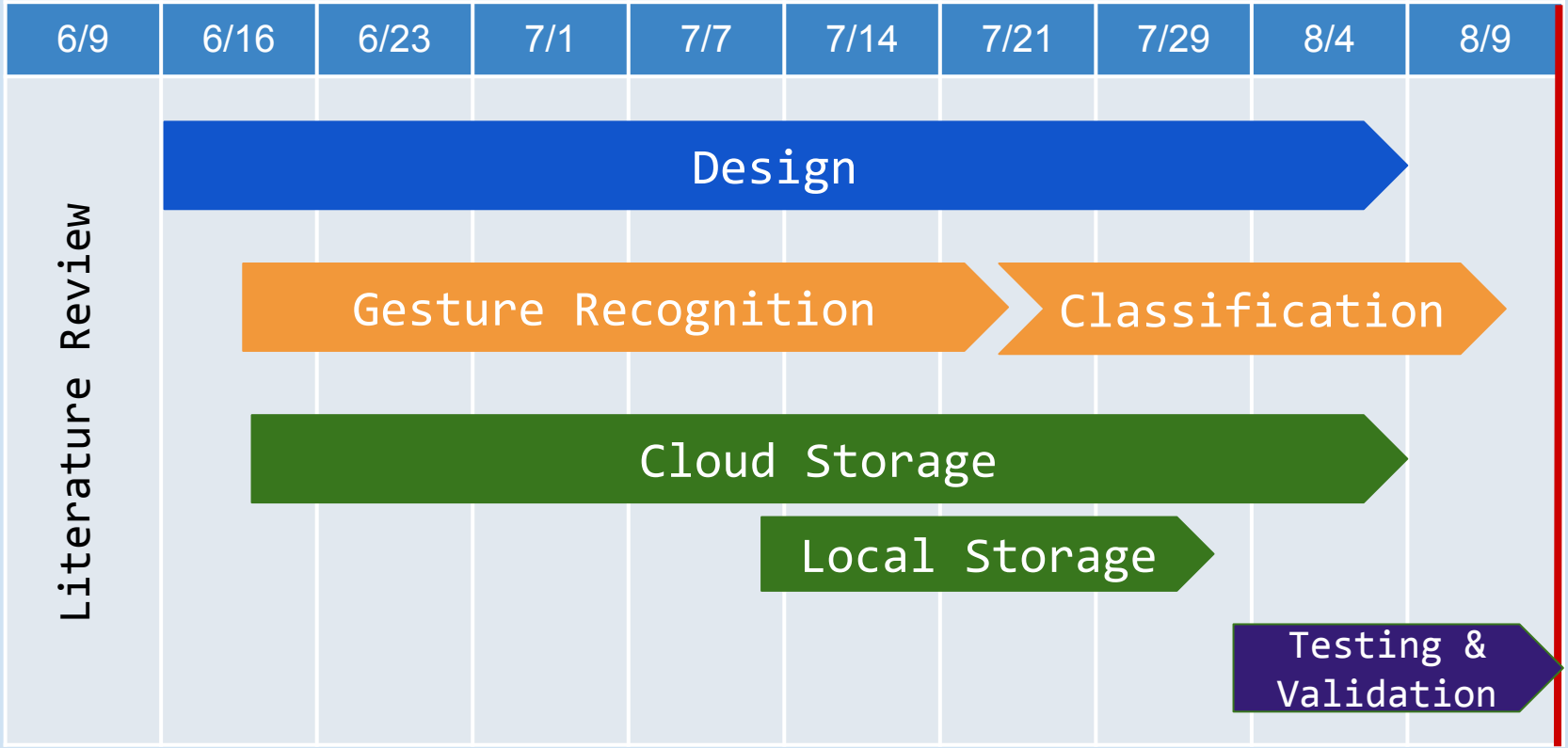
Purpose of Cloud Computing

- Able to analyze data from a large user base
- Able to create independent classification methods for specific users
- Migrate processes to cloud server to save local CPU

https://www.pcmag.com/roundup/306323/the-best-cloud-storage-providers-and-file-syncing-services

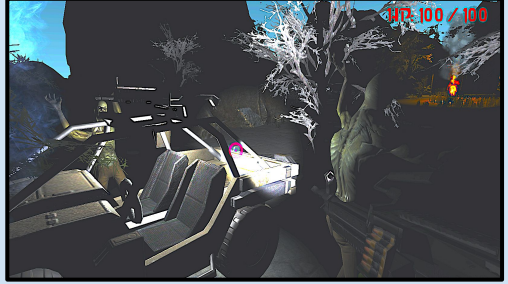
http://computer.howstuffworks.com/cloud-computing/cloud-computing.htm

Summer Timeline



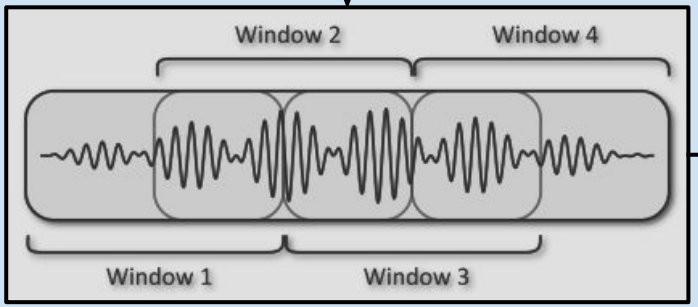
Methodology

https://www.myo.com/



http://www.businessinsider.com/muscle-gestures-control-prosthetics-with-2016-1

http://www.huffingtonpost.com/2014/07/14/armband-motion-controls-computer-mouse_n_5585574.html



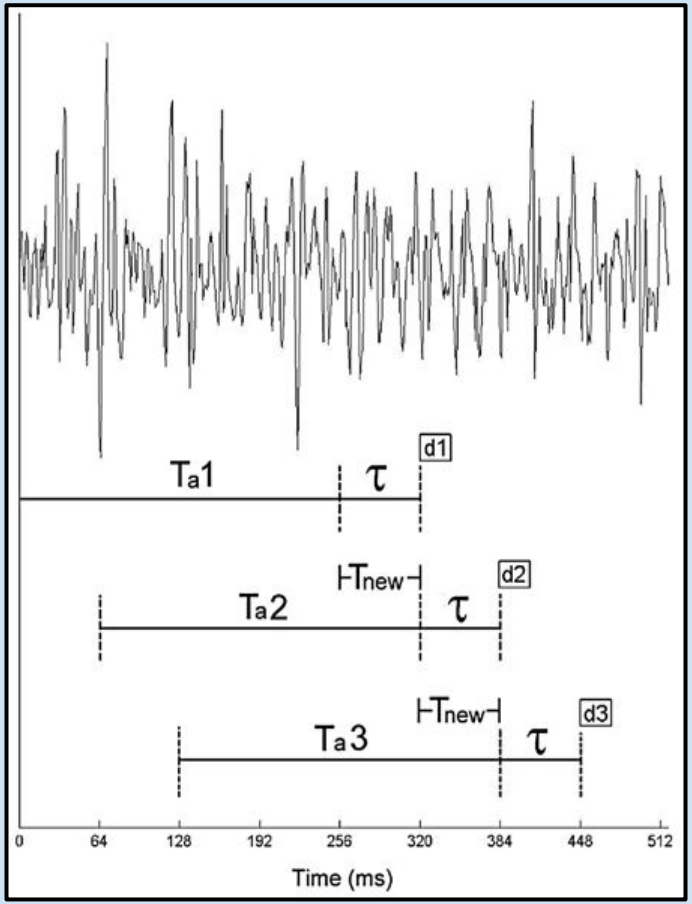
https://www.barryvan.com.au/page/13/

Feature Extraction

Classification

Classifier Training

Data Windowing



http://www.rehab.research.va.gov/jour/11/486/farrell486.html

Features

- Mean Absolute Value

$$MAV_i = \frac{1}{N}\sum_{k=1}^{N}|x_k| \quad for \quad i=1,\ldots,i$$

- Waveform Length

$$WAVE = \sum_{k-1}^{N}|x_k - x_{k-1}|$$

- Zero Crossings

$$(x_k > 0 \wedge x_{k+1} < 0) \vee (x_k < 0 \wedge x_{k+1} > 0)$$

and

$$|x_k - x_{k-1}| \geqslant \epsilon$$

- Slope Turns

$$(x_k > x_{k-1} \wedge x_k > x_{k+1}) \vee (x_k < x_{k-1} \wedge x_k < x_{k+1})$$

and

$$|x_k - x_{k-1}| \geqslant \epsilon \quad \text{or} \quad |x_k - x_{k+1}| \geqslant \epsilon$$

- Scaled Mean Absolute Value

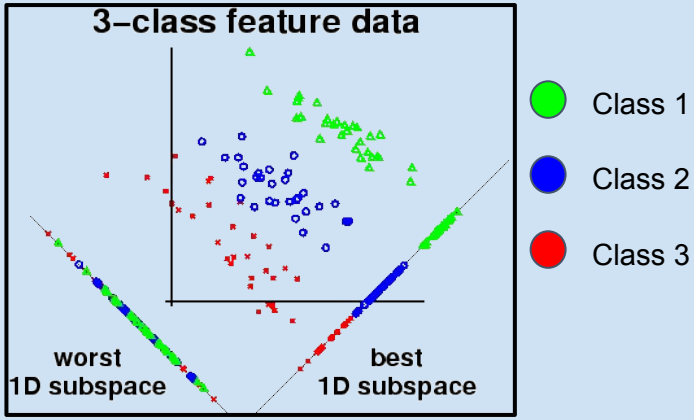
$$SMAV = MAV_i \; / \; \frac{1}{i}\sum_{i=1}^{8} MAV_i$$

- Adjacent Uniqueness

$$AU_c = \frac{1}{wl}\sum_{n=1}^{wl}\left|\frac{x_c[n]}{MAV_c} - \frac{x_{c+1}[n]}{MAV_{c+1}}\right|$$

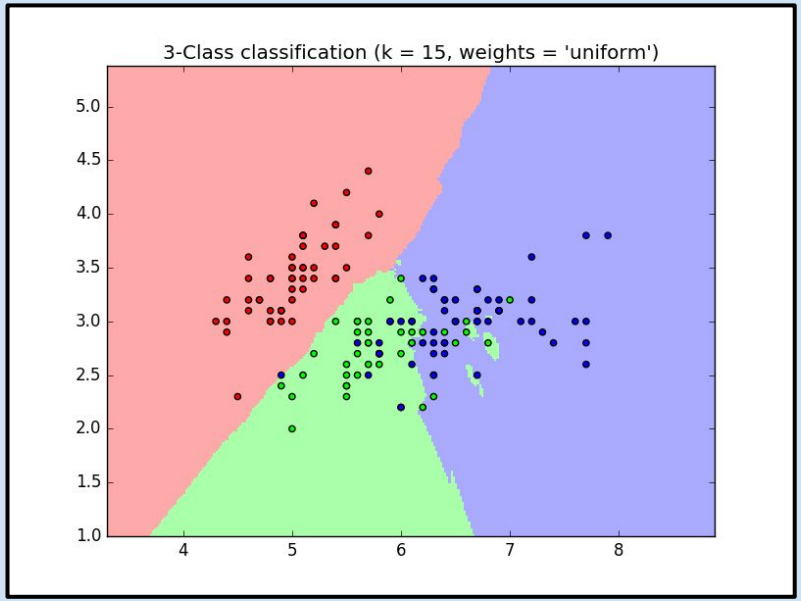
Classifiers

- Linear Discriminant Analysis



https://www.quora.com/How-does-Linear-Discriminant-Analysis-work-in-laymans-terms

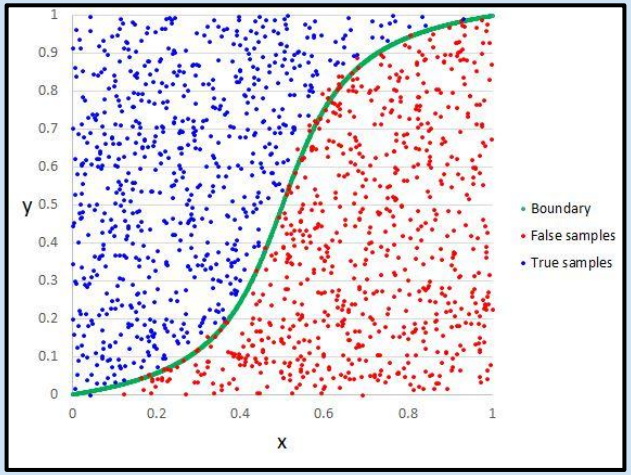
- K-Nearest Neighbor



http://scikit-learn.org/stable/modules/neighbors.html

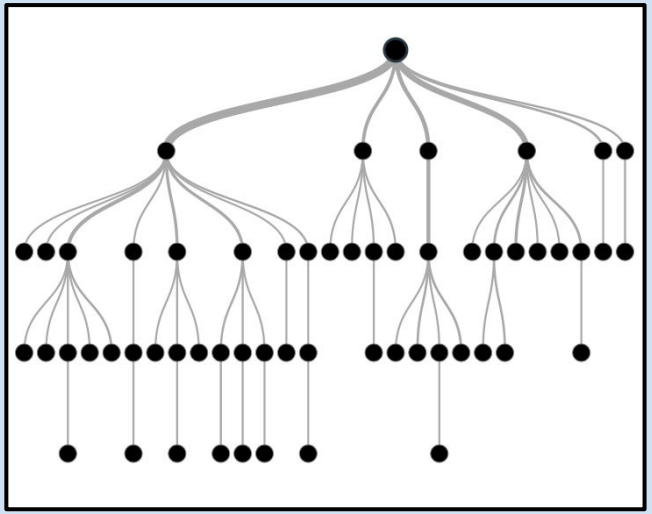
Classifiers

- Logistic Regression



https://www.mssqltips.com/sqlservertip/3471/introduction-to-the-sql-server-analysis-services-logistic-regression-data-mining-algorithm/

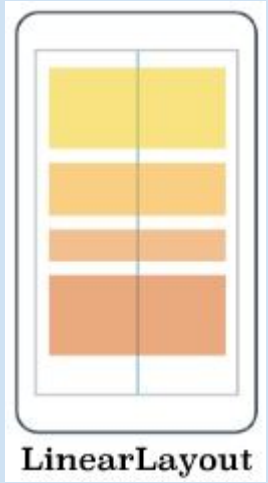
- Decision Tree

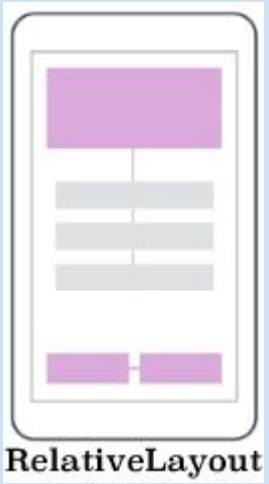


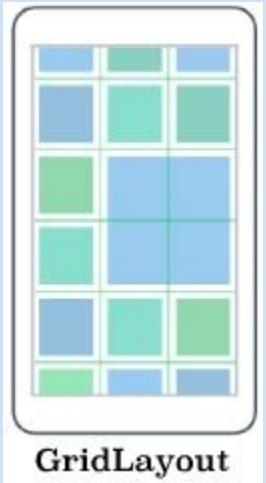
https://www.analyticsvidhya.com/blog/2016/04/complete-tutorial-tree-based-modeling-scratch-in-python/

Layout Purpose

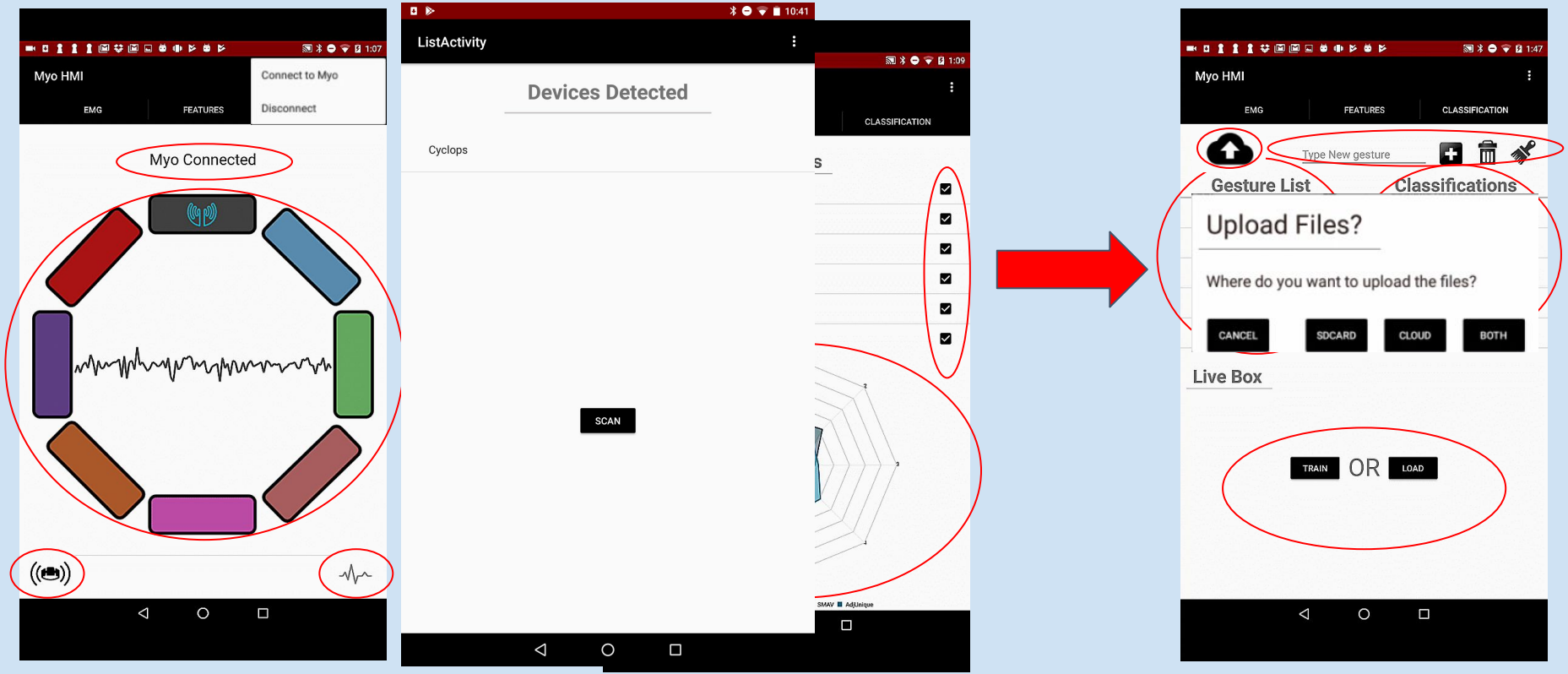
- What is a layout?
  - Defines application's visual structure
    - Skeleton
    - Can adapt to any device size
- Android Studios has 3 common layouts
  - LinearLayout - displays an item after the other
  - RelativeLayout - relation between positions
  - GridLayout - places items in a rectangular grid
  - Combination is possible
- eXtensible Markup Language (XML)





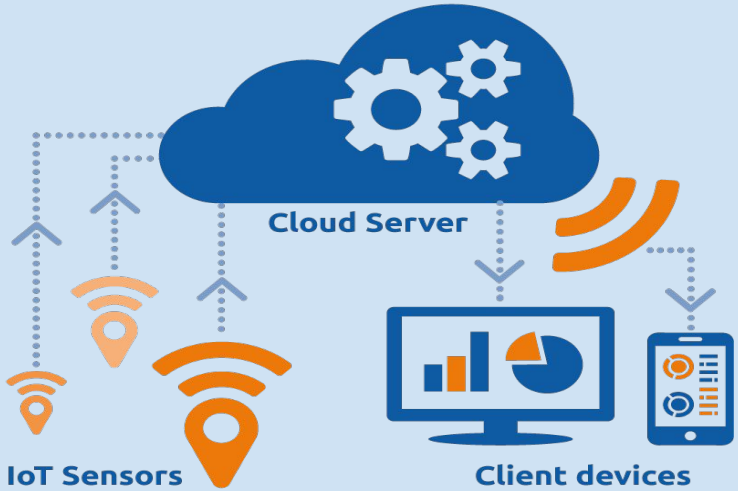


Our Design/Functionality



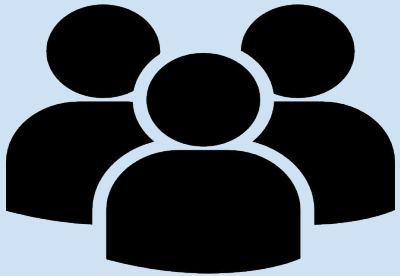
What is Cloud Computing?

- Storing and accessing data instead of your computer’s hard drive.
- Provides 1.2 million total servers, increased computing capabilities.



Internet of Things & Cloud Storage

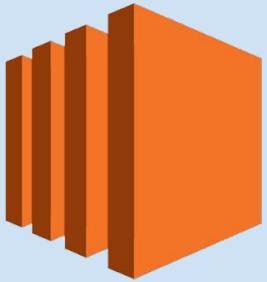
- Can be stored for further research and analysis
- Compiling data from multiple users allows large scale data analysis
- Future further improvement of application
- Increases efficiency and mobility



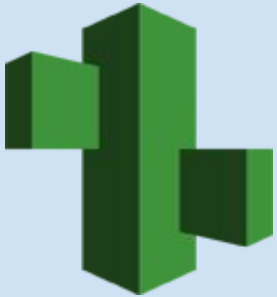
Amazon Web Services

- Offers cloud services, database storage, content delivery and offers compute power with flexibility, reliability and scalability

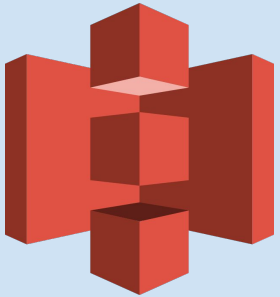
Elastic Compute Cloud (EC2)
Virtual Cloud Computer



Elastic Beanstalk
Cloud Server

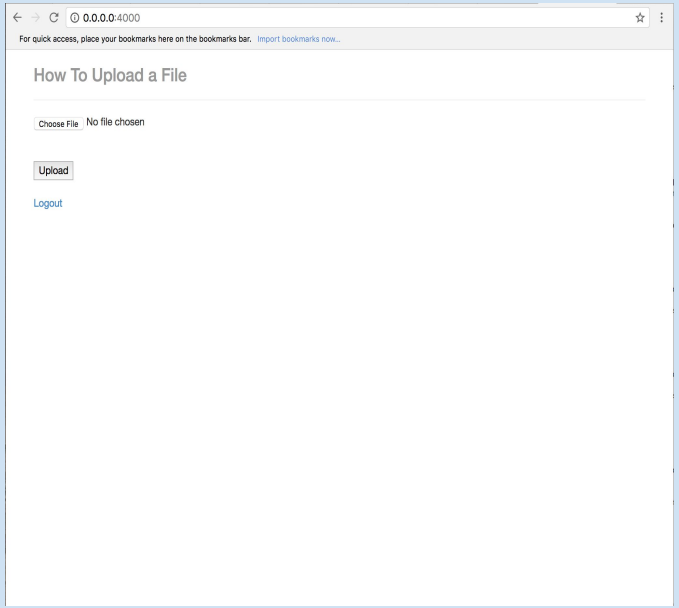


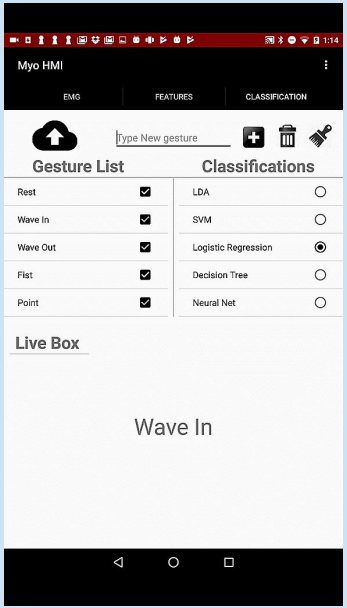
Simple Storage Service
Cloud Storage



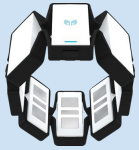
Cloud Upload

- Python based micro framework--adaptable & convenient
- Connected to the application and stores data from the app





Experimental Protocol



Offline(In-lab)

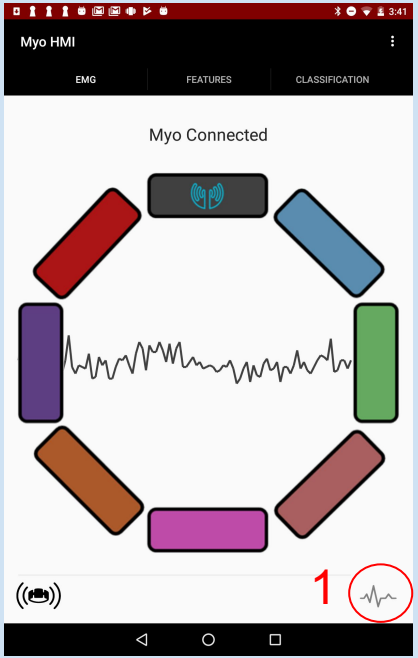
- Classifier-feature accuracy testing
- Chose most optimal combination

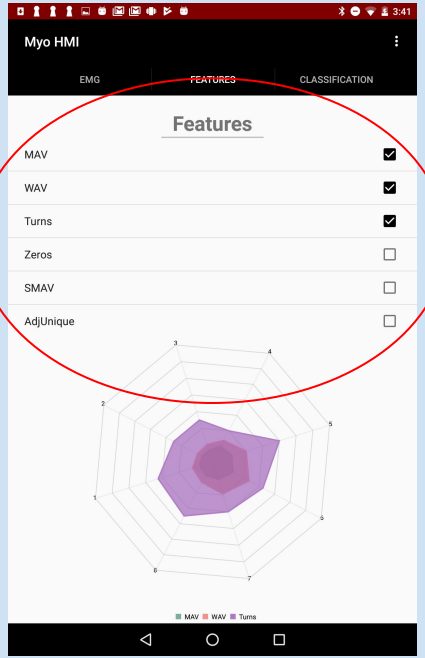
Online(Real-time)

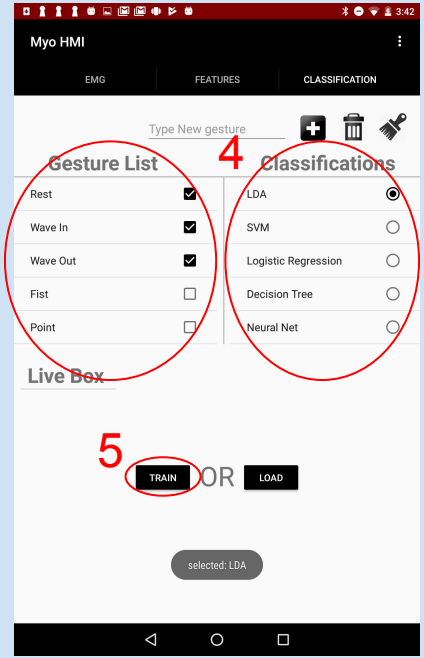
- 10 test subjects
- Classifier: K-nearest neighbor
- Feature: SMAV
- Survey

- Trials: 3
- Gestures: rest, wave in , wave out, point, fist, open hand, supination, and pronation

How to Train Gestures

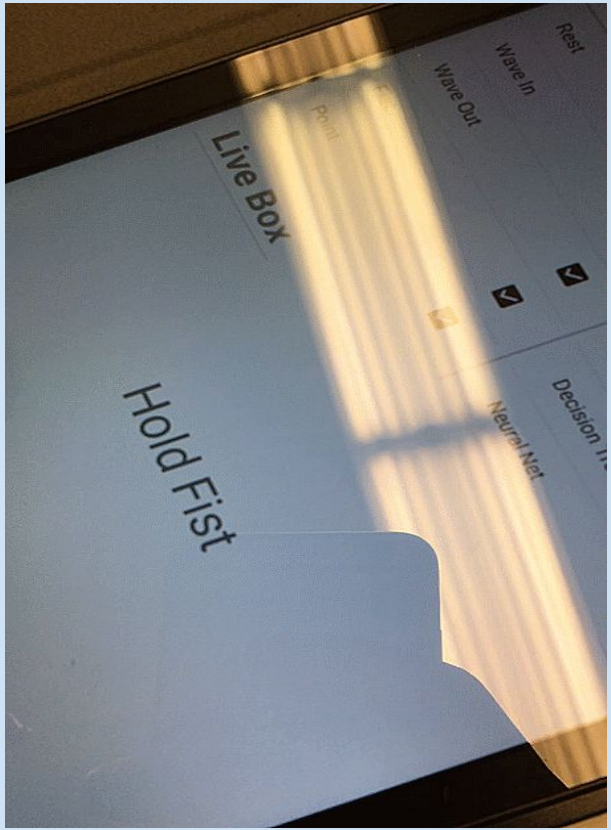






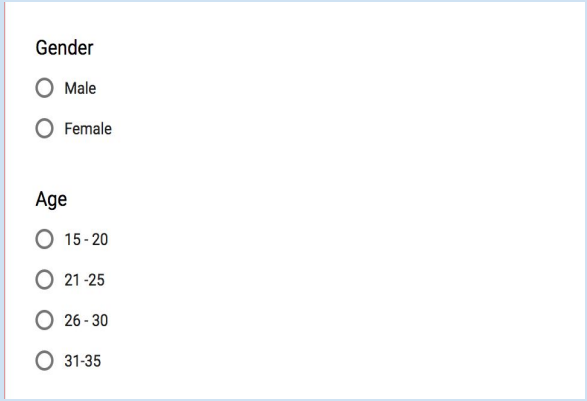
Training & Prediction Demo

Training Gestures

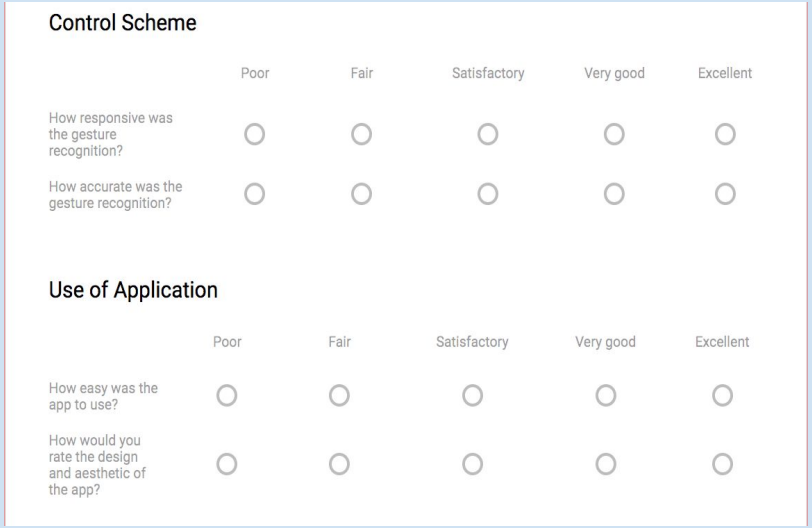


Survey

1


Gender
Male
Female
Age
15 - 20
21 -25
26 - 30
31-35

2


Control Scheme
Poor
Fair
Satisfactory
Very good
Excellent
How responsive was the gesture recognition?
How accurate was the gesture recognition?
Use of Application
Poor
Fair
Satisfactory
Very good
Excellent
How easy was the app to use?
How would you rate the design and aesthetic of the app?

3


Is there anything you would change in the design of the application?
Long answer text
Additional comments and suggestions to improve the app
Long answer text

Results

Offline(In-lab)

Classifier	Average	Standard Deviation	MAV	WAV	Turns	Zeros	SMAV
LDA (%)	98.54762	±2.33	99.50	98.50	91.75	92.75	98.375
Logistic Regression (%)	99.48214	±1.03	99.75	100.00	96.75	96.625	99.75
Decision Tree (%)	98.86905	±1.37	98.00	99.375	96.50	94.125	99.625
K-Nearest Neighbor (%)	99.69643	±.81	100.00	100.00	97.625	97.00	100.00
Average (%)	-	-	**99.313**	**99.469**	**95.656**	**95.125**	**99.438**

Online(Real-time)

Question Topic	Responsiveness	Accuracy	Ease of Use	Aesthetic
Average Rating	4.4	3.6	4.5	4.5

Conclusion

- Functional, appealing, and user friendly design
- Portable - can be taken anywhere
- Reliable - very accurate
- Durable - withstands daily use / environment
- Fast - real time working app

Future Tasks

- Implement more classifiers and features may allow for more accurate predictions
- Further improve the cloud computing framework
- Connect the app to a client application

Questions?