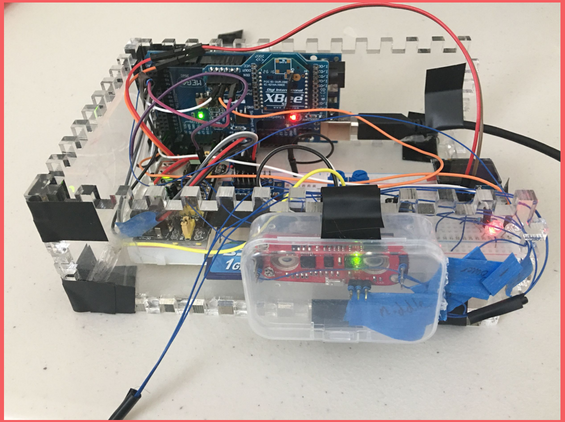
SpeakUp: A Machine Learning Based Speech Aid to Enable Real-Time Silent Communication for the Paralyzed by Translating Neuromuscular EMG signals to Speech

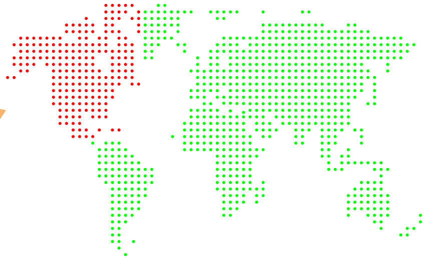
SpeakUp
- A ML Based Speech Aid to Enable Silent Communication



Varun Chandrashekhar

Introduction to Speech Interfaces

Stroke / ALS / Cerebral Palsy



7.5 Million

Conventional Speech Interfaces (CSI) - Eye/Cheek Tracking

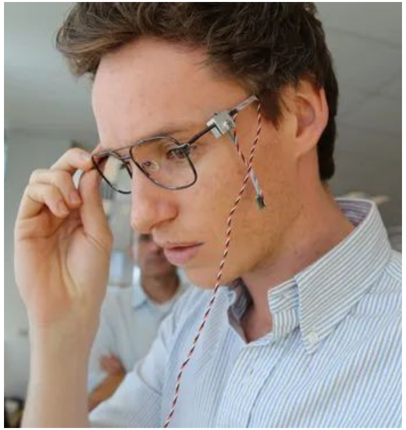


Image shows cheek tracker used by Stephen Hawking to communicate

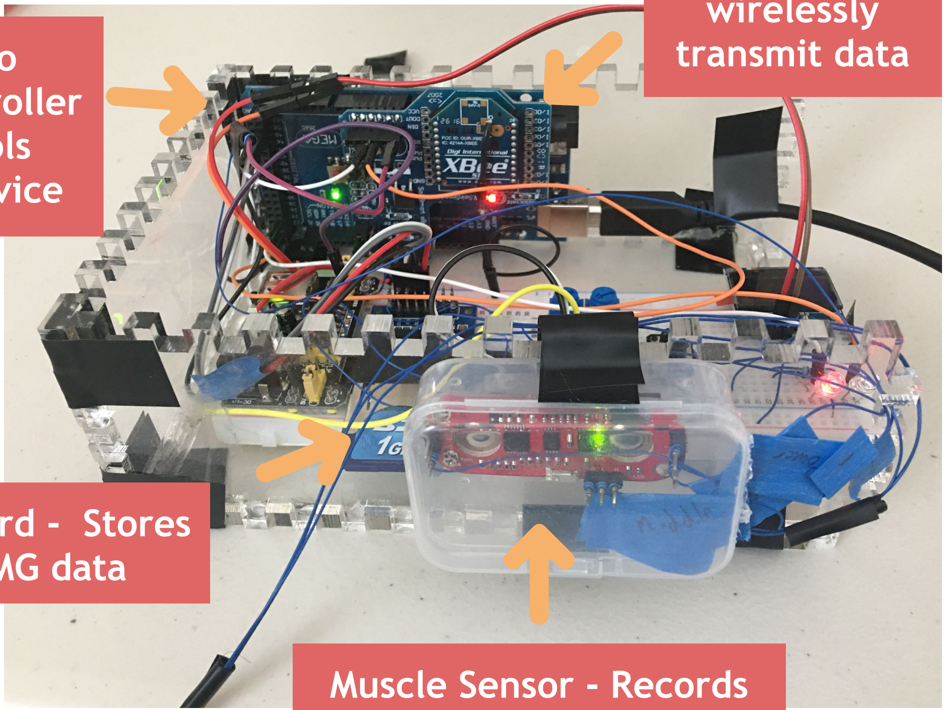
Fatiguing

Slow / Inaccurate

SpeakUp Hardware

Arduino Microcontroller - controls whole device

Radio to wirelessly transmit data

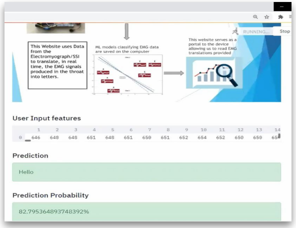


SD Card - Stores EMG data

Muscle Sensor - Records EMG Signals

EMG Signals Picked Up by Device and wirelessly sent to Computer

Computer Automatically Translates EMG Signal



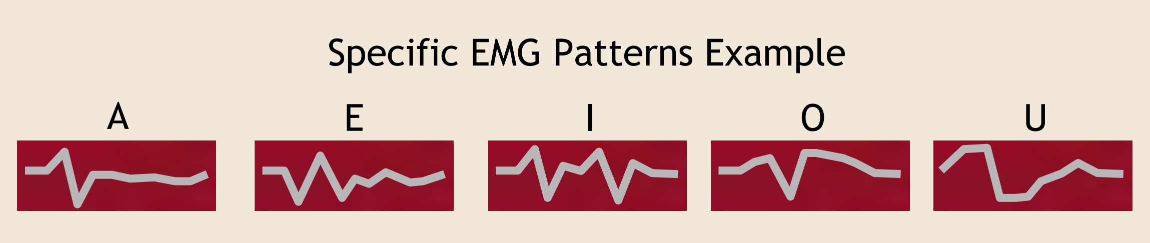
Translation is displayed on Python Based Web Application

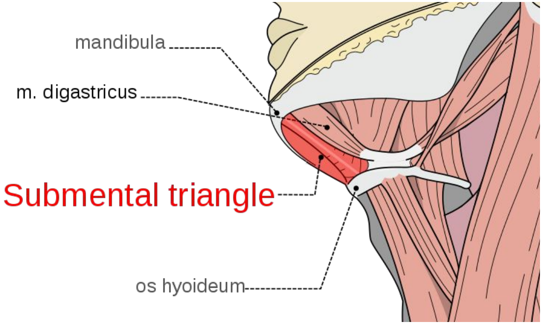
Silent Speech

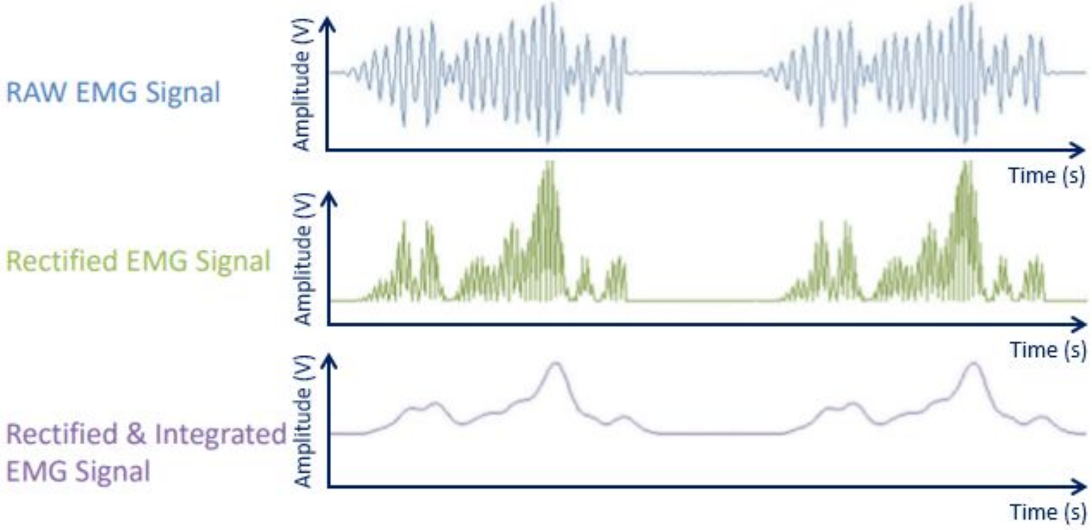
Silent Speech: minimally or internally articulating words without producing sounds or moving the mouth

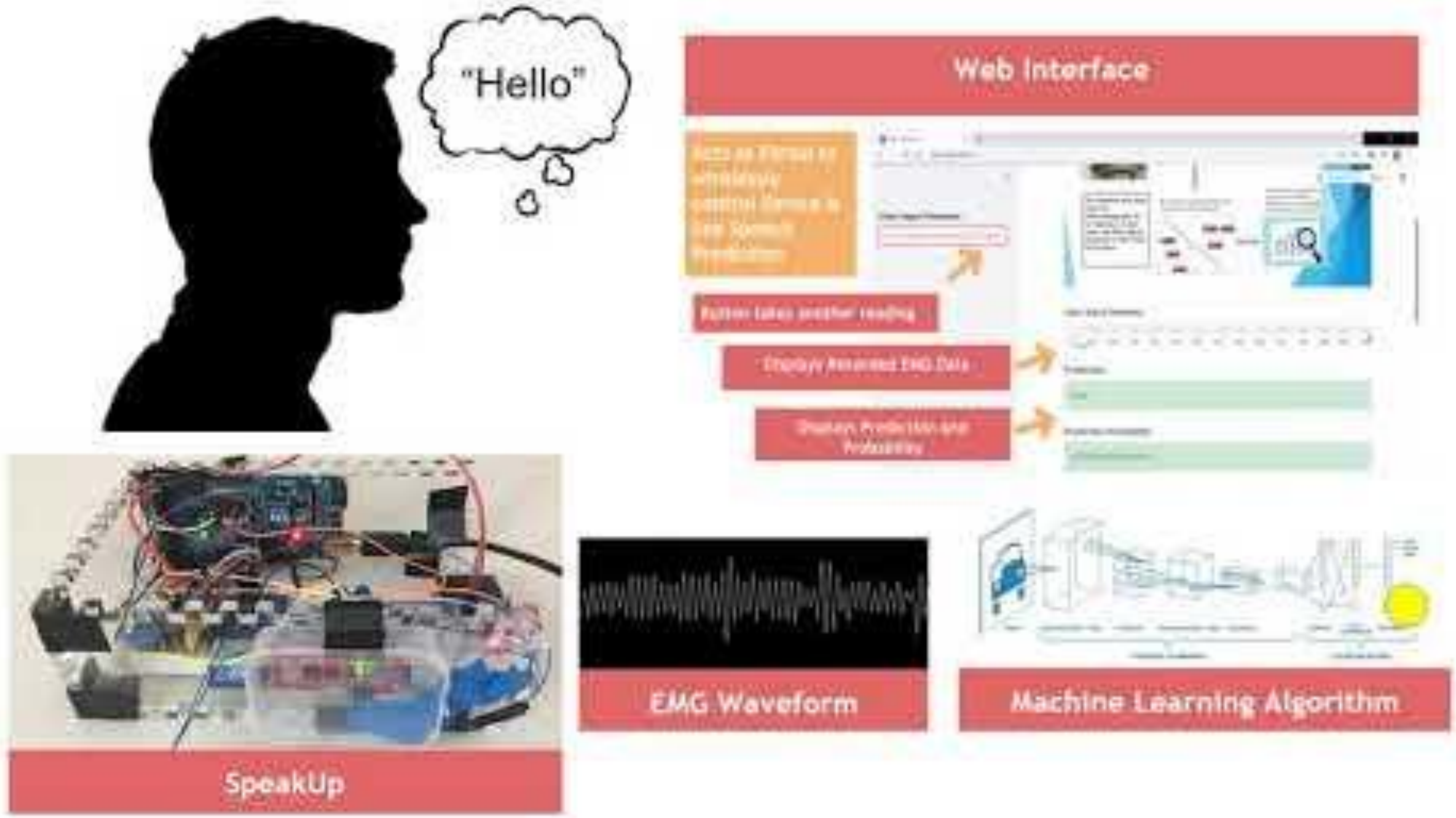
ElectroMyoGraph (EMG) signals: electrical signals generated by muscle contractions

sEMG signals: EMG signals collected from surface electrodes into real time speech



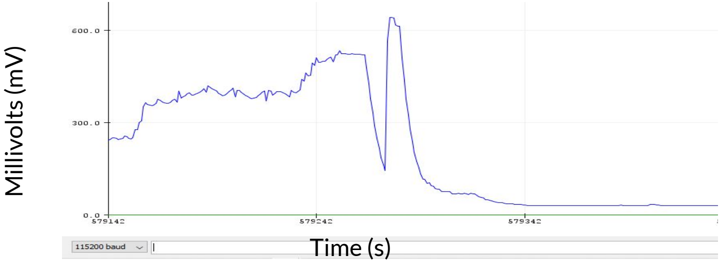




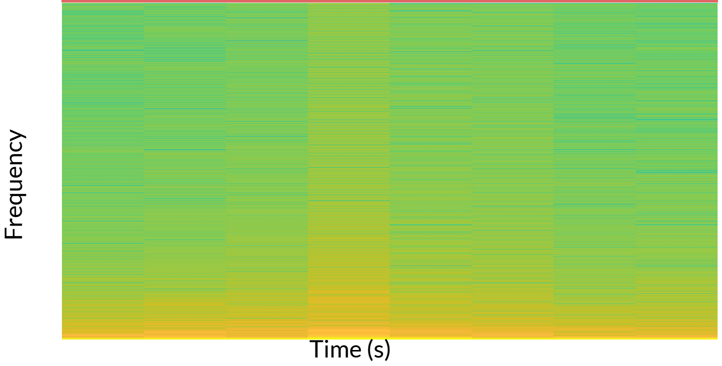

"Hello"
Web Interface
Button takes another reading
EMG Waveform
Machine Learning Algorithm
SpeakUp

Raw EMG Signals

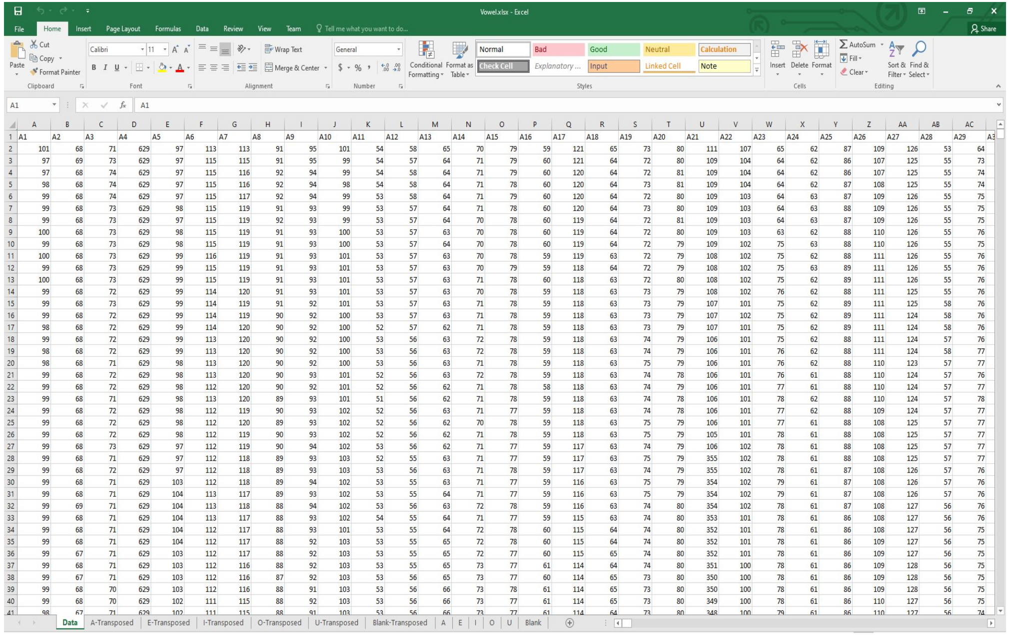
Graphed



Spectrogram



Excel - Dataset



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29
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6	99	68	74	629	97	115	117	92	94	99	53	58	64	71	79	60	120	64	72	80	109	103	64	63	87	109	126	55	75
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11	100	68	73	629	99	116	119	91	93	101	53	57	63	70	78	59	119	63	72	79	108	102	75	62	88	111	126	55	76
12	99	68	73	629	99	115	119	91	93	101	53	57	63	70	79	59	118	64	72	79	108	102	75	63	89	111	126	55	76
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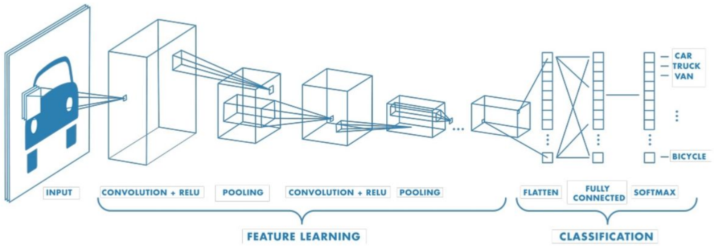
Machine Learning Algorithms used in SSIs

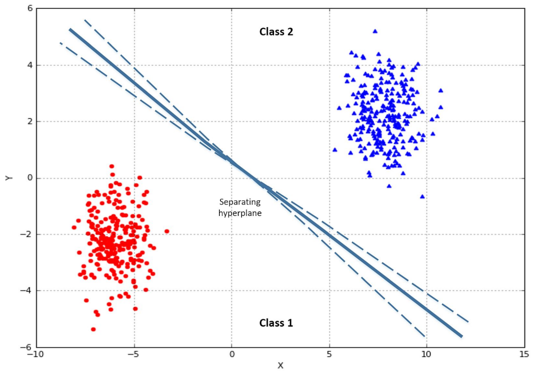
Convolutional Neural Networks (CNN)



CNN passes images through a series of layers that attempt to **learn features and classify the images** into different categories

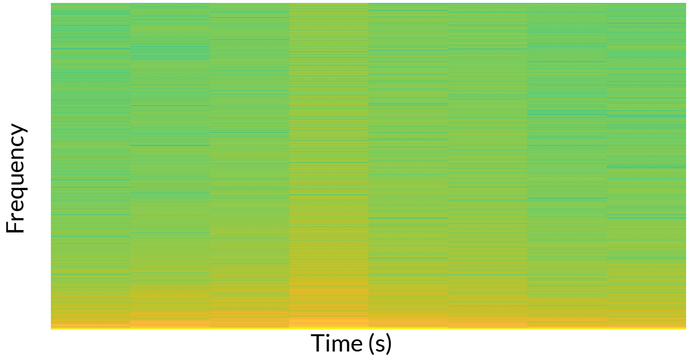
Pattern Recognition

Pattern Recognition algorithms attempt to **develop a division between multiple classes** which are represented in red and blue in this image.

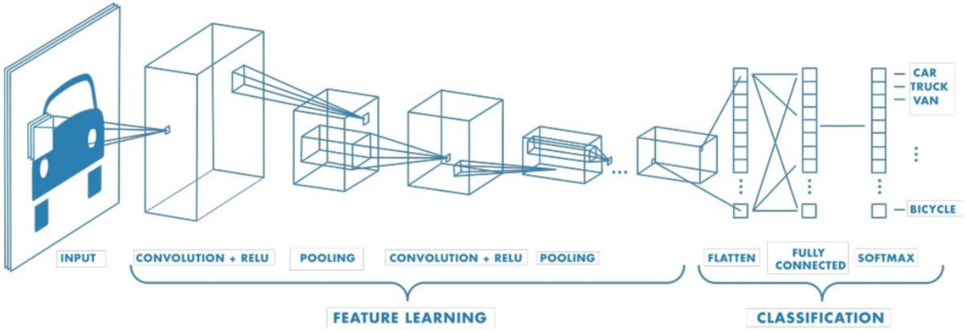


CNN - GoogleNet

- GoogleNet - Most Accurate CNN developed
- Transfer Learning - Making use of an existing CNN for a different application
- Transfer Learning was used to develop a CNN

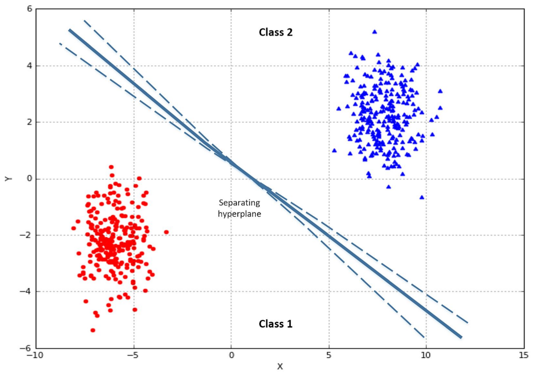


Spectrogram for Letter A



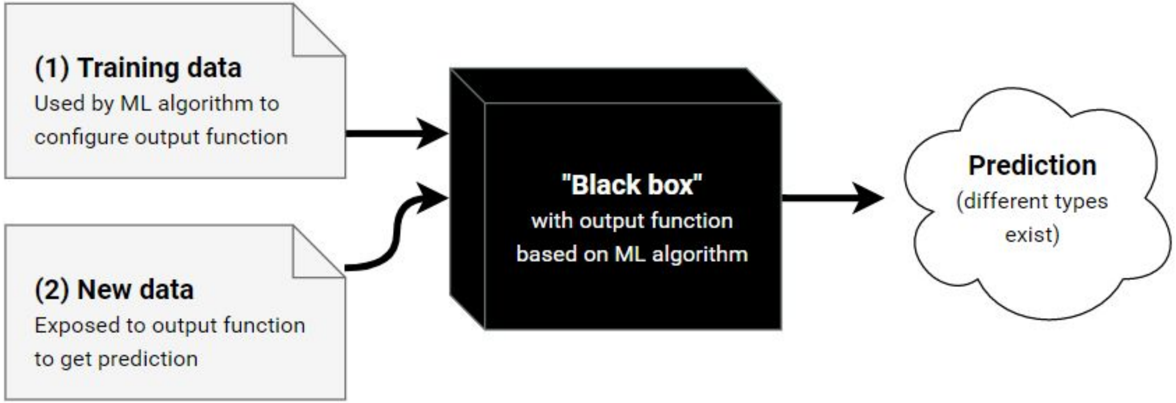
Pattern Recognition

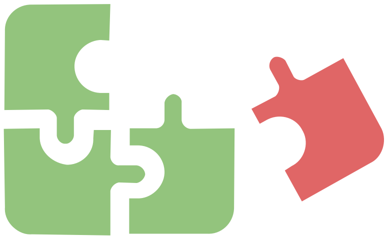
- Various ways to create a division between two classes
- These 7 Pattern Recognition Algorithms were tested in this study



Algorithm		Division/Assumption
Linear Discriminant	→	Linear Line
Quadratic Discriminant	→	Quadratic Line
Naive Bayes	→	Independent Predictors
Tree	→	Split into large sets
K Neighbors	→	Closest Data Point
Ensemble	→	Combine 2+ models
Support Vector Machine (SVM)	→	Line with boundary

Research Gap





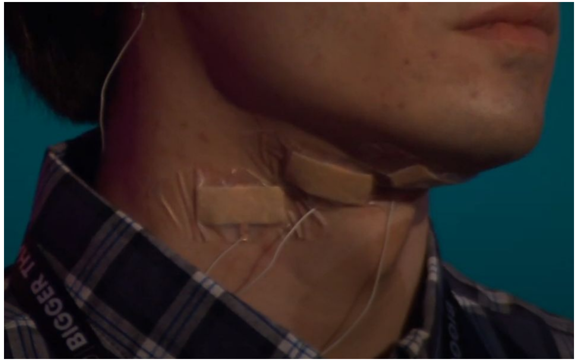
- Machine Learning is a black box
- Cannot identify optimal ML model for a given problem without testing out various models

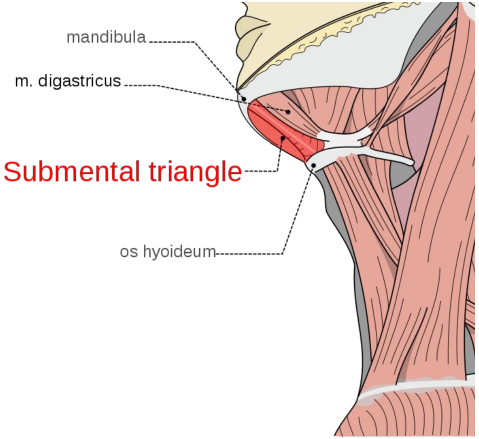
Research Question & Engineering Goal

Research Question:

Which type of Machine Learning Algorithm (CNN or Pattern Recognition) is most accurate at classifying surface ElectroMyoGraph (sEMG) signals from the submental triangle (area under the chin) to develop a Non-Invasive Silent Speech Interface?

Engineering Goal: To Develop a Non-Invasive Silent Speech Interface that can both collect and classify sEMG signals from the submental triangle (area under the chin) with greater than 80% accuracy.





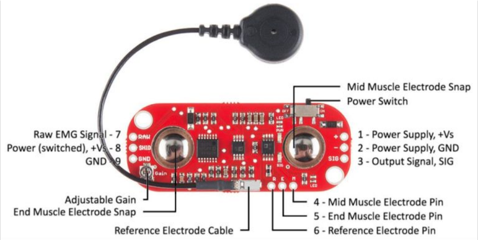
Assumptions and Value

Assumptions

1. It is possible to obtain accurate EMG data from low-cost muscle sensors such as the myoware
2. The Arduino would have a high enough sample rate to generate detailed data for the machine Learning models

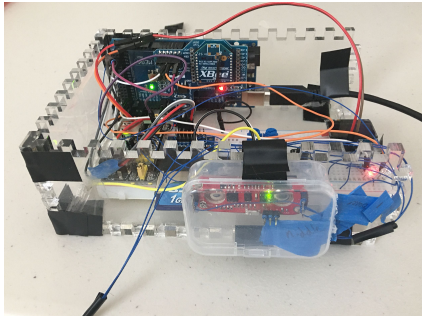
Value

1. Real time speech
2. High Accuracy
3. Helps even those with complete paralysis



EMG Accuracy

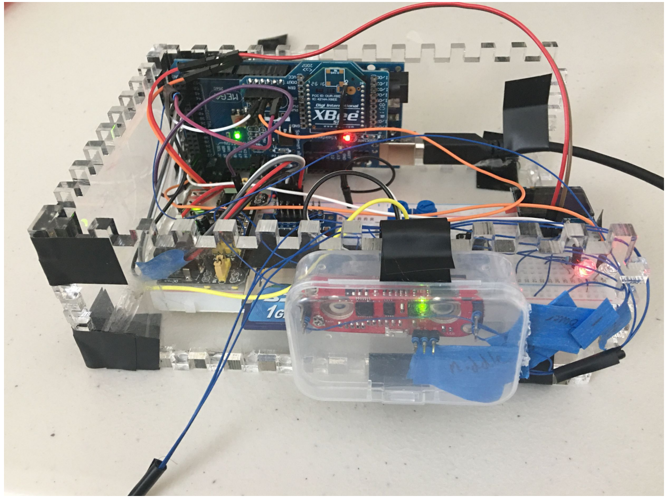
High Sample Rate

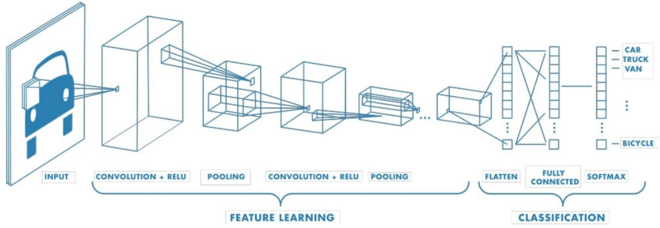


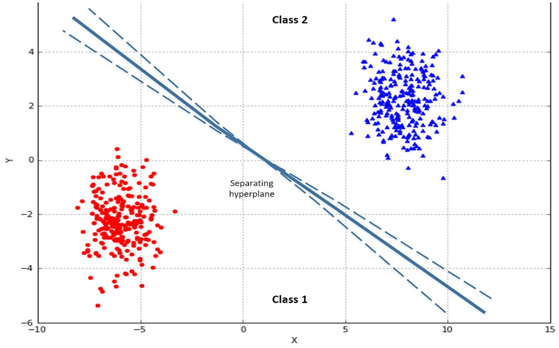
Device Speed & Accuracy

Methods

Engineering	Quantitative True Experimental
Create SSI Device	Evaluate Best ML Model

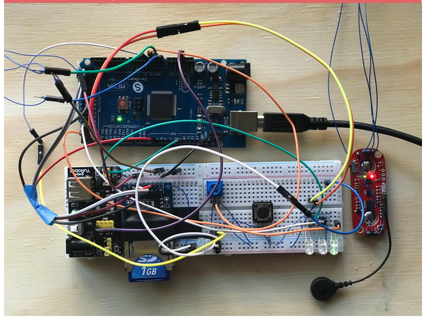




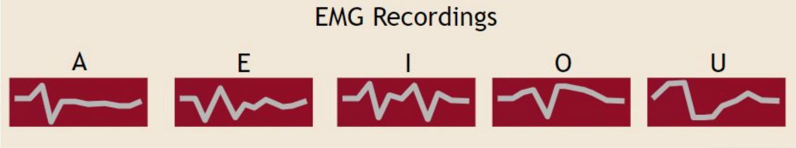


Methodology

Create Electromyograph using the Myoware muscle sensor

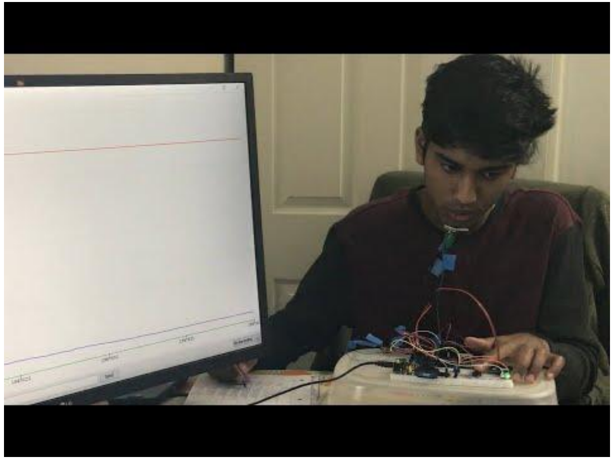


Generate EMG recordings and save it on the laptop/cloud

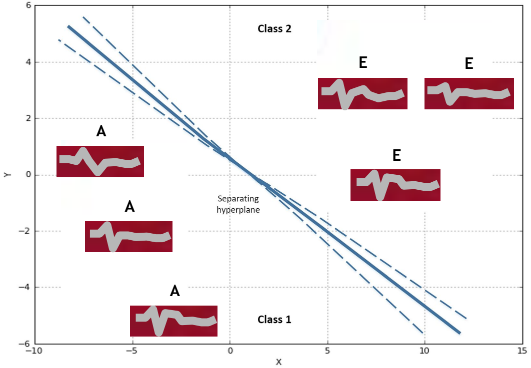


Data generated:
Signals- values ranging from 0-1023 (EMG signal)
Evaluation- Accuracy Percentage & F-scores

Methods:
Engineering - to create device
Quantitative True Experimental - determine effectiveness of SSI

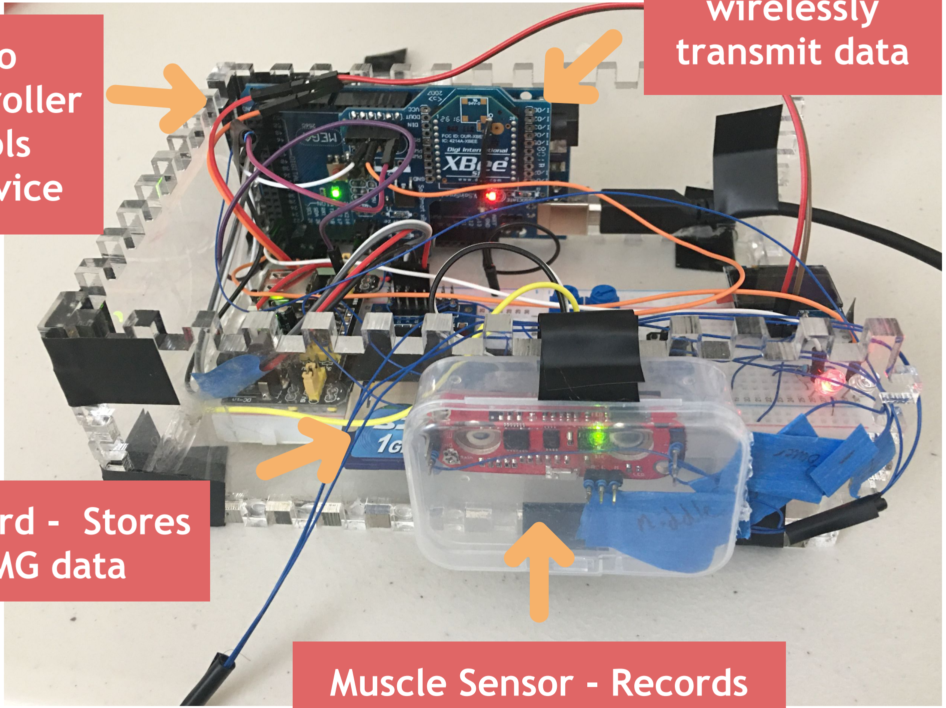


Develop and Deploy Multiple ML models on EMG data



Compare each ML Model accuracy values to identify best EMG Classifies

SpeakUp Hardware



Arduino Microcontroller - controls whole device

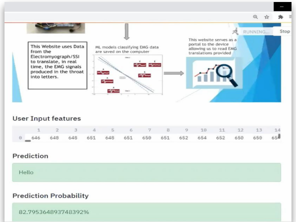
Radio to wirelessly transmit data

SD Card - Stores EMG data

Muscle Sensor - Records EMG Signals

EMG Signals Picked Up by Device and wirelessly sent to Computer

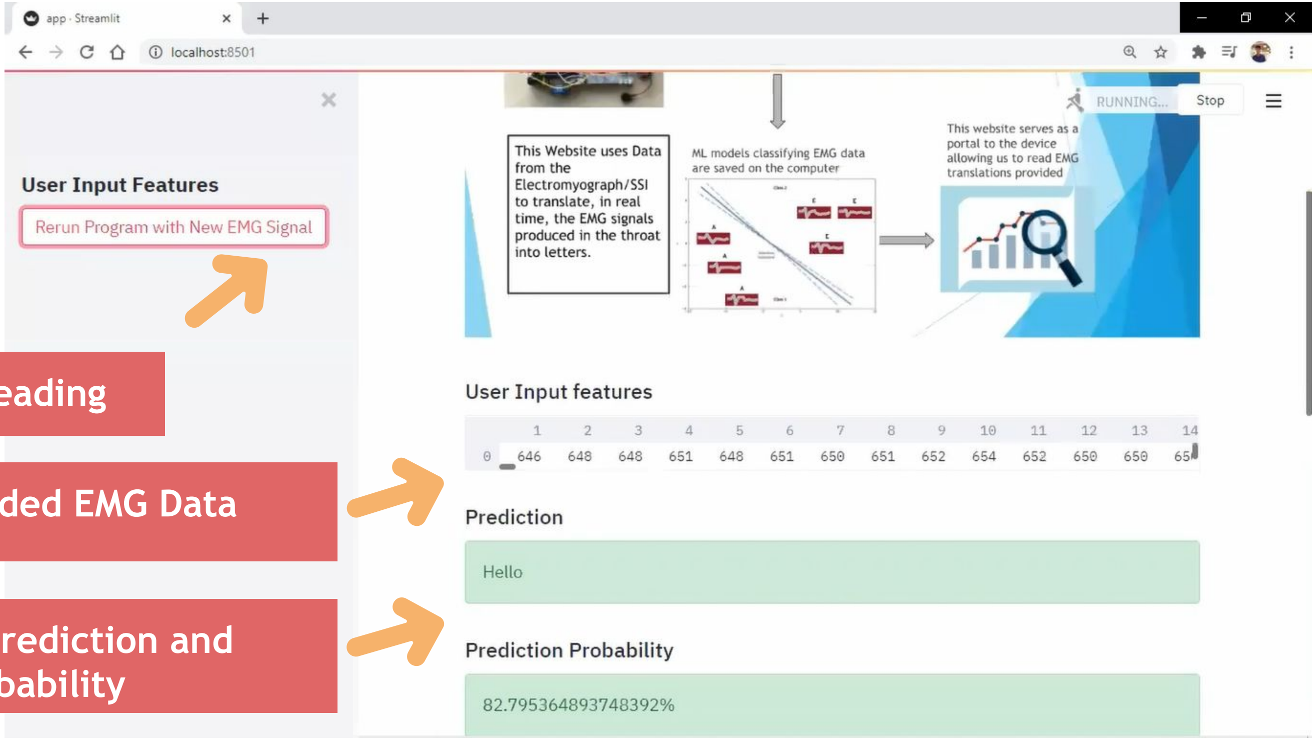
Computer Automatically Translates EMG Signal



Translation is displayed on Python Based Web Application

Web Interface

Acts as Portal to wirelessly control Device & See Speech Prediction



Button takes another reading

Displays Recorded EMG Data

Displays Prediction and Probability

SSI Device Demonstration

Device Capabilities

- Trained to identify letters
- With more data device could translate words/sentences

Video Shows Demonstration of Web Interface and SSI Device Classifying Words and Letters

Results

- Best Performing Model: SVM - 80.10% accuracy
- Device Accuracy: 80.10%

Engineering Goal Met > 80%

SVM model best classifies sEMG signals in an SSI

CLASSIFICATION ACCURACY AND F-SCORES

MODEL	CLASSIFICATION ACCURACY	F1 SCORES
CONVOLUTIONAL NEURAL NETWORK (CNN) - GOOGLENET	54.90%	0.60
SUPPORT VECTOR MACHINE (SVM) - GAUSSIAN	80.10%	0.81
ENSEMBLE - BAGGED TREES	74.60%	0.73
K-NEAREST NEIGHBORS (KNN) - WEIGHTED	66.70%	0.70
TREE - MEDIUM	59.80%	0.65
NAIVE BAYES - KERNEL	59.30%	0.65
QUADRATIC DISCRIMINANT	55.50%	0.54
LINEAR DISCRIMINANT	49.50%	0.48

Results

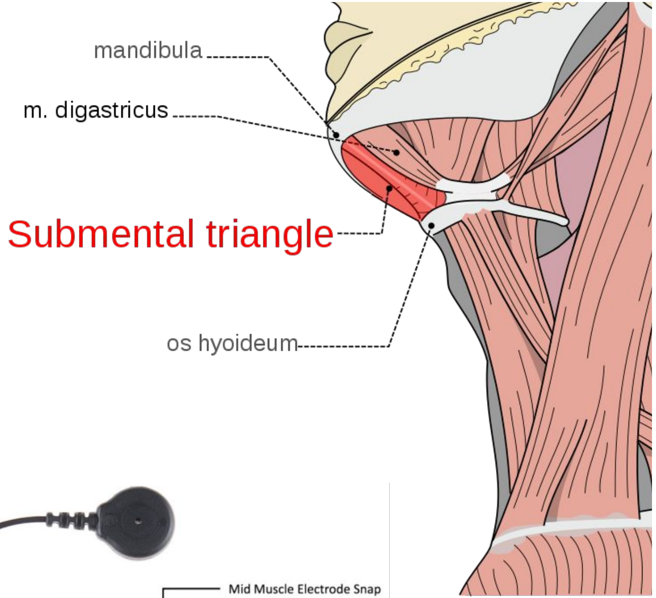
CNN Confusion Matrix

True Class \ Predicted Class	A	B	E	I	O	U
A	20.6%		14.7%	35.3%	14.7%	14.7%
B		100.0%				
E	17.6%		32.4%	23.5%	11.8%	14.7%
I	11.8%		11.8%	38.2%	23.5%	14.7%
O	2.9%		5.9%	14.7%	58.8%	17.6%
U					17.6%	82.4%

SVM Pattern Recognition

True Class \ Predicted Class	A	B	E	I	O	U
A	64.7%		8.8%	14.7%	8.8%	2.9%
B		100.0%				
E	20.6%		58.8%	11.8%	8.8%	
I	8.8%		17.6%	64.7%	8.8%	
O	8.8%		2.9%	14.7%	67.6%	5.9%
U	2.9%				8.8%	88.2%

Limitations / Enhancements

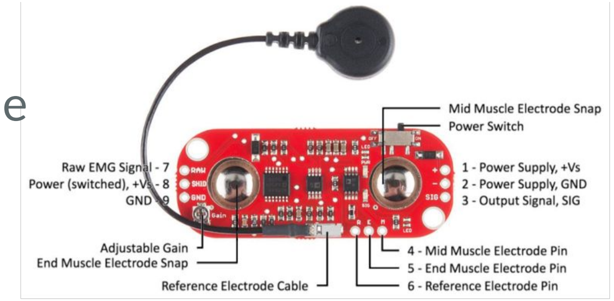


Current Limitations:

- Tested only on healthy individuals
- Records signals from one muscle group
- Accuracy is roughly 80%

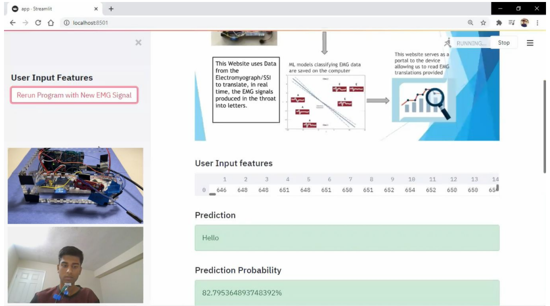
Future Enhancements:

- Test on ALS/paralyzed patients
- Record signals from all speech muscle groups
- Use multiple muscle sensors



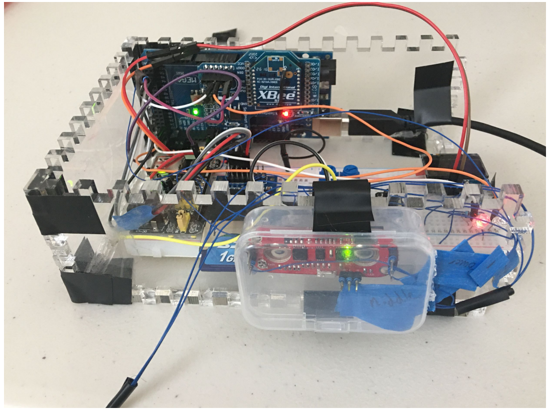
Conclusion

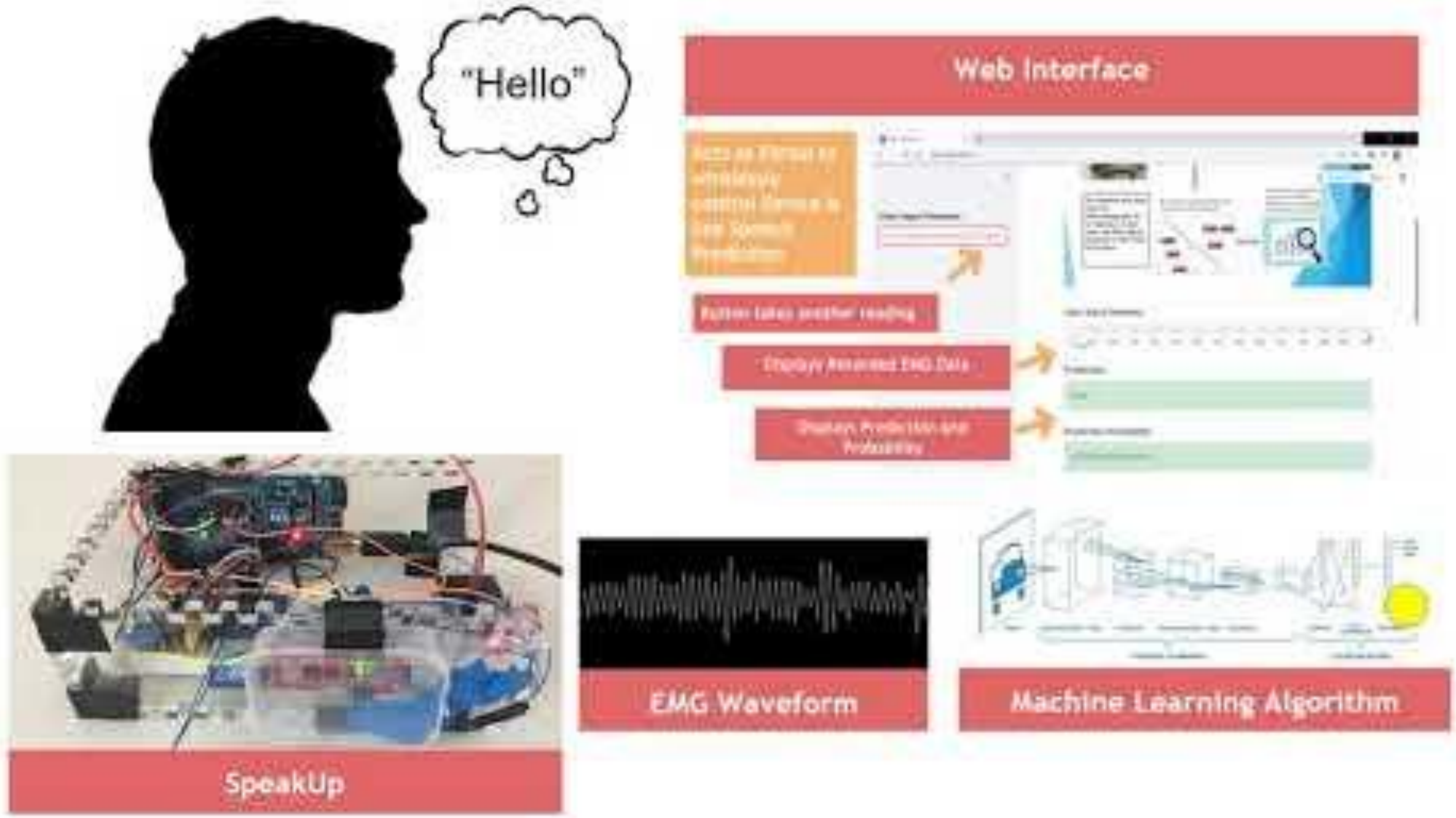
- An SSI was created to help the paralyzed communicate silently
- This study analyzed various Machine Learning Models to determine which ML model best classified EMG data.
- This device has an 80.10% accuracy and has the potential to revolutionize speech and communication aids



SVM model best classifies sEMG signals in an SSI

Engineering Goal Met > 80%




"Hello"
Web Interface
SpeakUp
EMG Waveform
Machine Learning Algorithm

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