Problem

- People with hearing impairments are unable to sense their environment outside of their field of vision, which leaves them in danger of missing crucial sounds that could pose a danger in their everyday lives.

Goal

- The overall aim of this project is to engineer a wearable device that allows the hearing-impaired to gain more awareness by identifying the direction of incoming sound with availability for all, low cost, short latency and minimal invasiveness.

Purpose

A majority of hearing impaired people cannot afford to buy modern assistive devices. They cost a fortune and are very delicate. They require multiple meetings, and even surgery to implant. A device that is able to help all people with varying level of hearing impairments universally, and one that is much cheaper is necessary. It needs to be robust to help those in 3rd world countries or other less controlled environments.

Background

- Hearing Impairments cause a loss of awareness of the environment
  - Heavy communication barrier
  - Present danger when alone
  - 466 Million People suffer from disabling hearing loss, over 5% of the world
  - Current Solutions are too expensive
- Cochlear Implants
  - Newest Technology that deals with hearing loss
  - Surgically Implanted Devices that translate sound into electrical signals for the brain
  - Cost upwards of $200,000 up to about $400,000
  - Have logistical problems
  - Difficult to get used to, and struggle with certain types of noise
  - Not accessible to all people with disabilities
- Hearing Aids
  - Only help those with incomplete hearing loss
  - Invasive
  - Hard to maintain, and easy to lose
  - Require fittings and many adjustments
  - Cost between $1000-$4000

Criteria

- Accessibility
  - The device needs to reach as many people as possible
  - Help all those who need relief from problem helped by their hearing loss
  - Problem with Cochlear Implants and Hearing Aids
- Effectiveness
  - Whatever the product desires to do must be done well
  - Counts reliability
- Cost Effective
  - A crucial problem to be solved is the price of the current technology
  - Must be addressed
- Light Weight
  - Any type of wearable assistive device needs to be light
  - Otherwise may interfere with normal processes of everyday life
  - Takes into account materials and hardware put into it
- Compact
  - Even if the device is light, it cannot be large
  - The larger the device the more it would interfere by getting in the way of normal life
- Latency
  - The device must notify the user quickly
  - Could be the difference between functionality and failure
  - Creates more safety if its faster
  - Allows more effective sensing of the environment

Decision Matrix

	Prototype Design Concepts	Hearing Aids	Cochlear Implants	SSL Neural Network	SSL Algorithmic	360 degree video & whos talking	AR transcription of sound	Dangerous Sound classifier & identifier	NN based Lip Reader	Sign Language interpreter
Criteria	Weight	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**
Light Weight	7	10	10	9	5	7	10	10	10	10
Compact	7	10	10	7	4	3	8	8	8	8
Cost Effective	9	3	1	8	6	4	8	8	8	8
Latency	7	7	7	7	5	3	6	5	5	5
Accessibility	8	4	4	10	7	9	10	10	10	10
Effectiveness	8	7	7	7	7	5	5	3	2	2
Total	460	304	286	369	264	239	360	337	329	329
Percentage	100	66	62	80	57	52	78	73	72	72

Pursued Solution

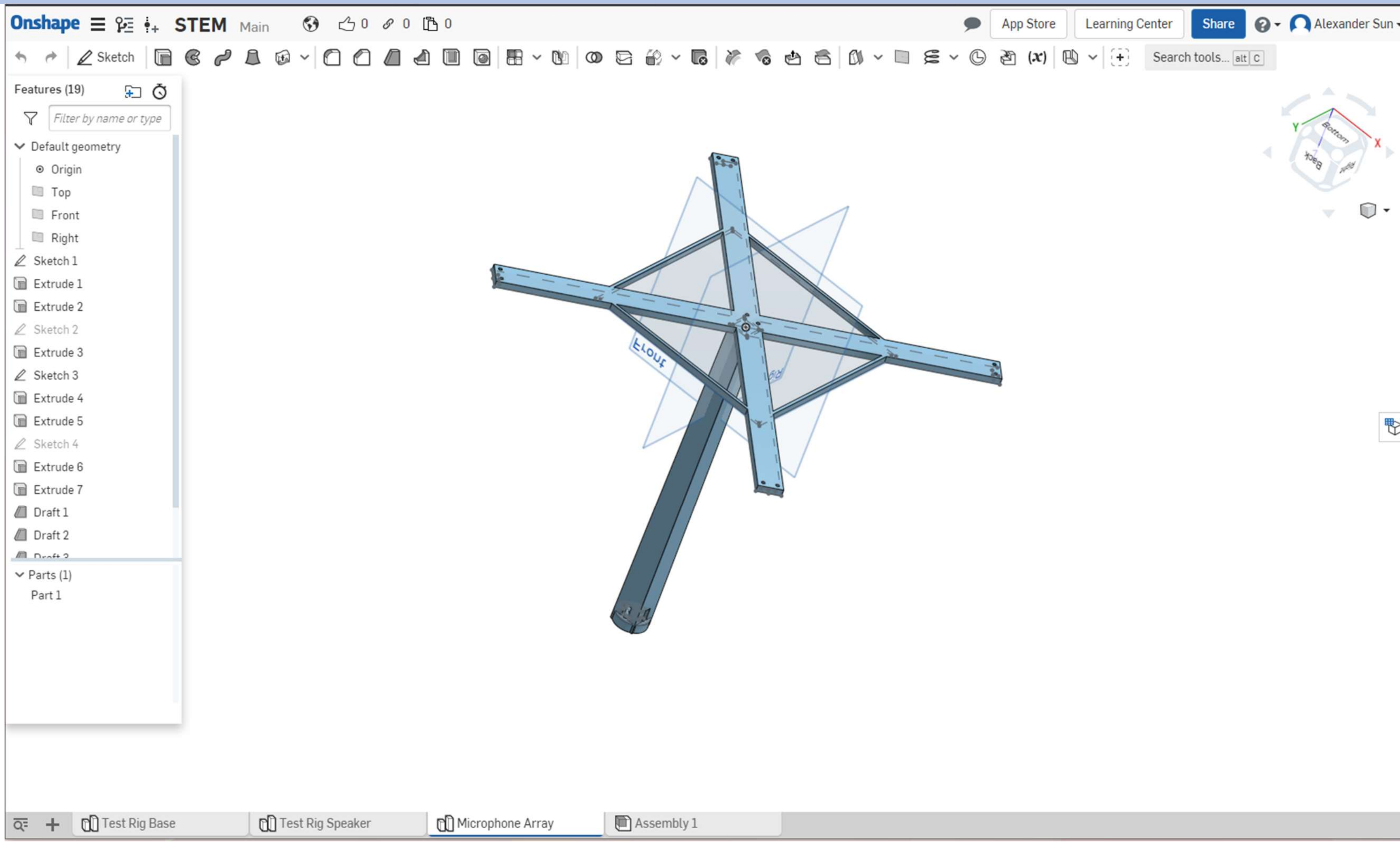
The device will sense loud incoming sounds and notify the user of the direction that the sound comes from. This will allow a deaf person to gain more independence and confidence going out in public without fear of missing sounds or being completed isolated in their environment. The device needs to be able to identify the correct direction the sound comes from in order to notify the user accurately of where their attention needs to be brought.

The device will be doing a process called Sound Source Localization (SSL). This is technique commonly utilized on robotic systems that allows a system to sense the presence, direction, and possibly distance that sound arrives from. The most common solution involves the creation of a microphone array and running some determining algorithm from the differences in the time of arrival from the device.

This project will make use of neural networks to accomplish sound source localization. Supervised machine learning will be used to train a model by playing sounds from different azimuth angles. If this method is successful it will create a significantly less computationally heavy method of determining the correct sound location, allowing it to be viable for use on an embedded or wearable system. This method would cover all the criteria as no heavy and expensive computation devices would be necessary for lowering cost and making the device less invasive. The delay would be kept minimal as well. The processing could be done on a raspberry pi and easily fit in the pocket of a backpack.

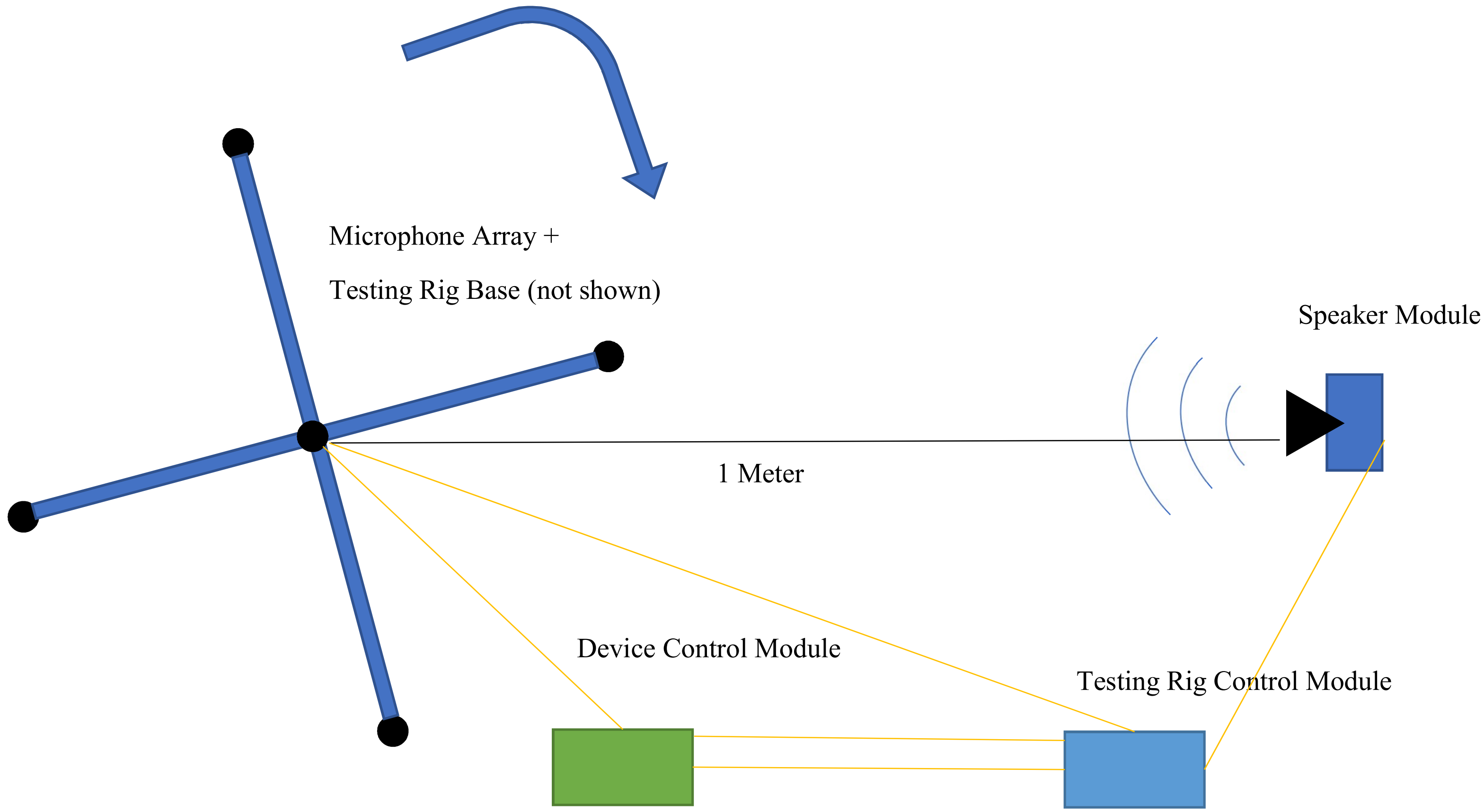
The device also has to notify the user when it finds the sound source. This will be done through a wearable belt-like strap with vibration motors at a different location. Haptic feedback will indicate the direction the sound comes from allowing the user to react accordingly.

CAD Designs

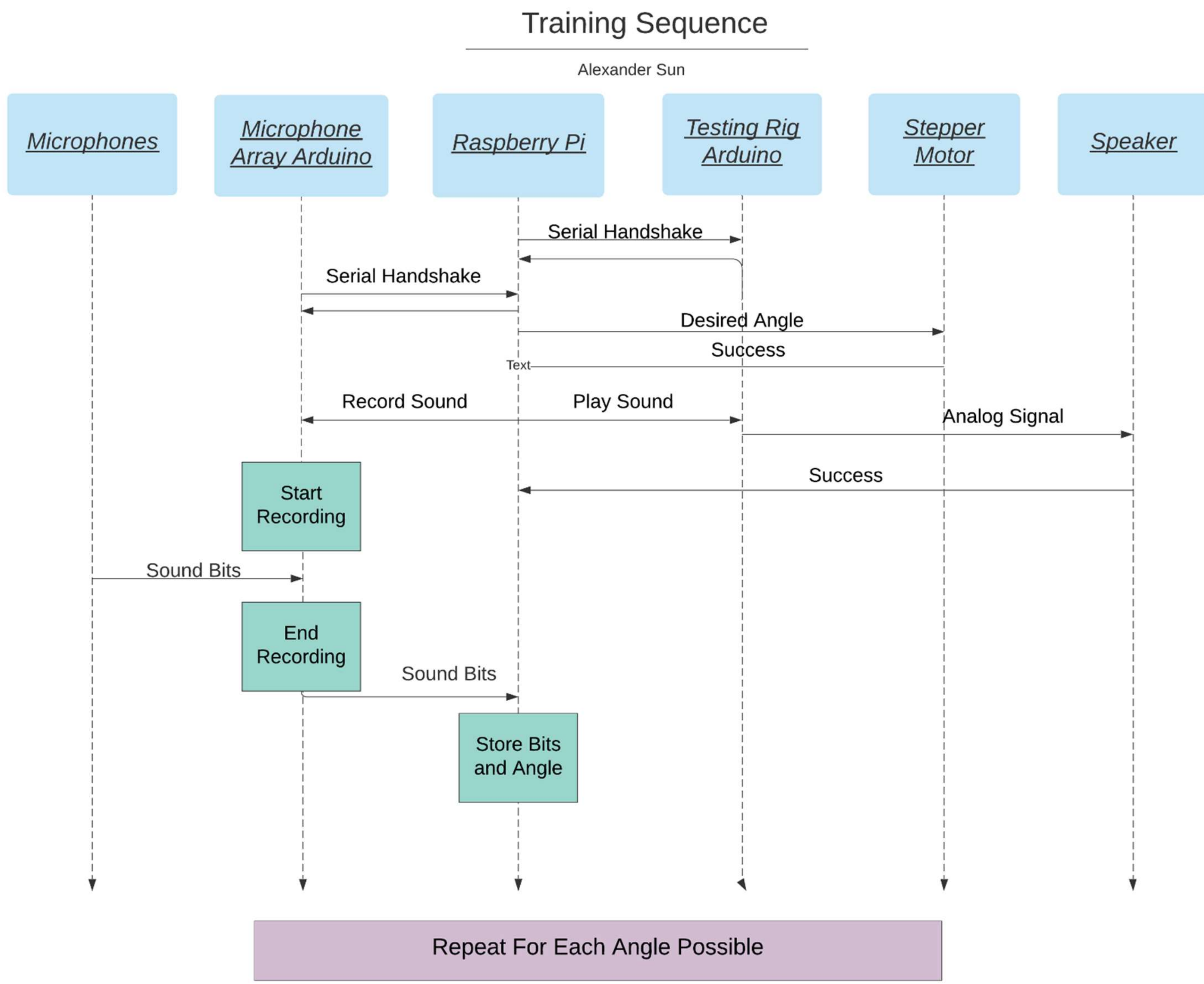


The design shows the preliminary thought process behind the first prototype. The four bars will each hold a microphone to space them apart and the center pole will be used for mounting eventually.

Process Diagram



Training Sequence



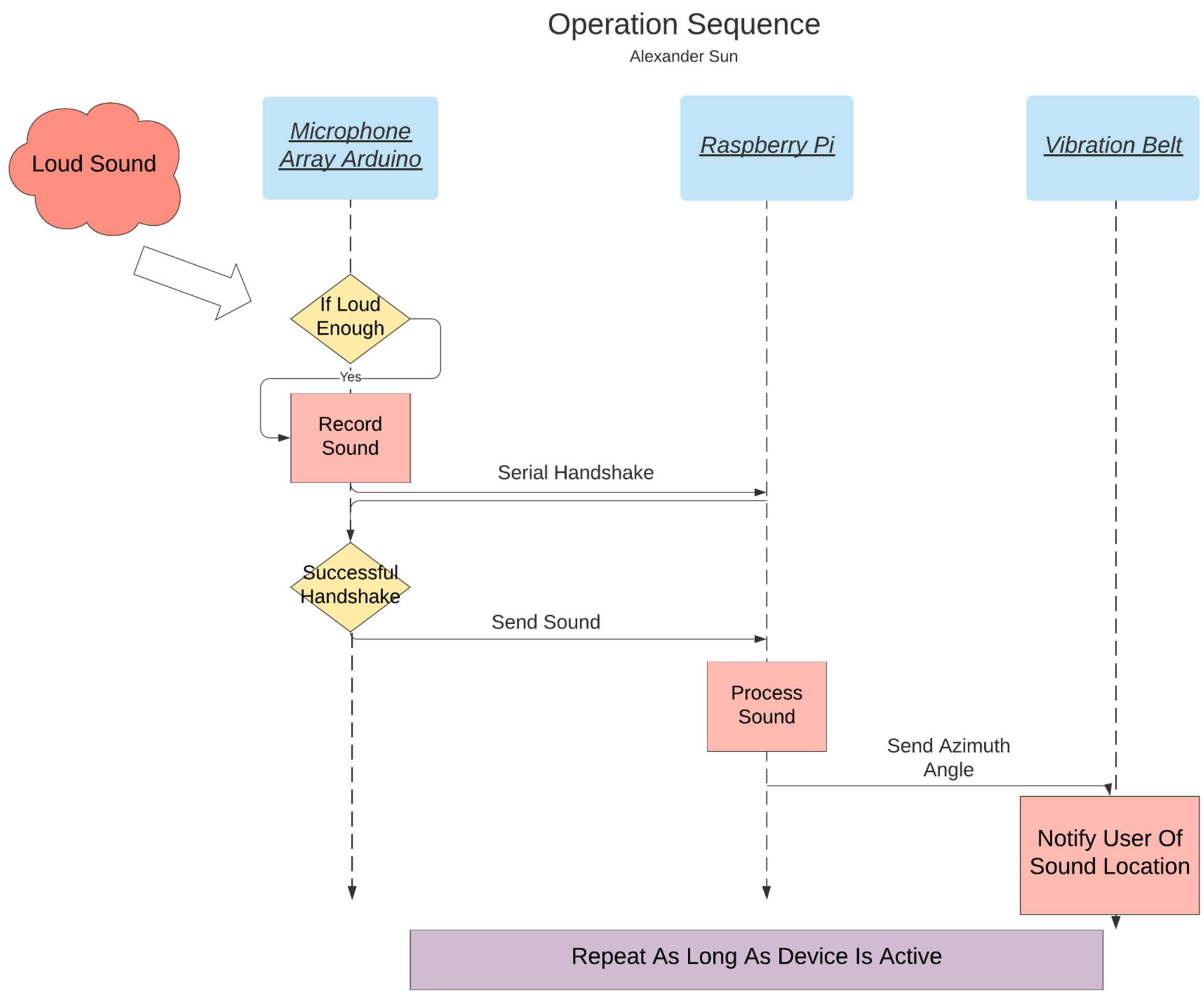
Data Acquisition Procedure

The microphone array needs to be built, and an automatic testing rig needs to be created in order to gather enough training data to accurately determine the sound source location. In order to create the microphone array, microphone and amplifiers will be needed, as well as arduino and Raspberry Pi controllers to process and store the testing data. The holder can be created through CAD and the use of 3D printing. Next a separate wire connected component will be connected that uses vibrating motors that correspond to the predicted sound location. This device will be able to take in ambient sound information, process the information and notify the user using these components and materials. No hazardous materials will be necessary.

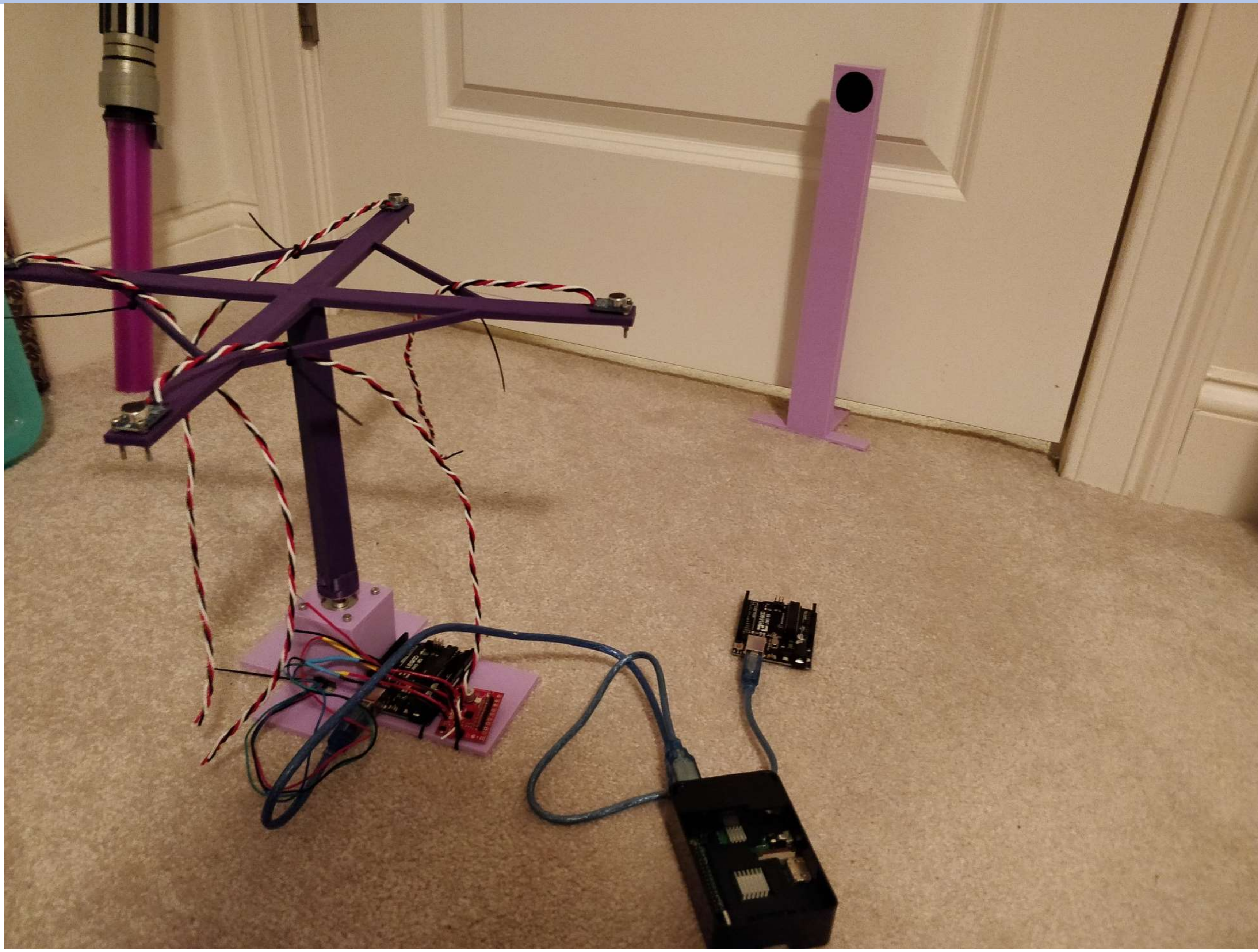
The testing rig will be able to rotate the microphone array in reference to the speaker, so that multiple azimuth angles can be tested. The rig will be controlled by an arduino which will drive a stepper motor. This allows the arduino to pinpoint rotate to angles that can then be used to create the data set. The testing rig will then be setup in my house in order to collect data. Furthermore, this process will be automated so that thousands of data points may be recorded without needing my presence to be available.

Next, the training set created by the testing rig, will then be used for training of the convolutional neural network model. The model will be trained using Tensorflow Keras, and the finished model's accuracy will be tested through the creation of a validation set. The testing set will be a division of the original training set. Each tested model will improve and once the training is sufficient the model will be flashed onto the Raspberry Pi. Then the device will be tested using the testing rig and the accuracy will be measured over the test set with real life reverberation and conditions.

Operation Sequence



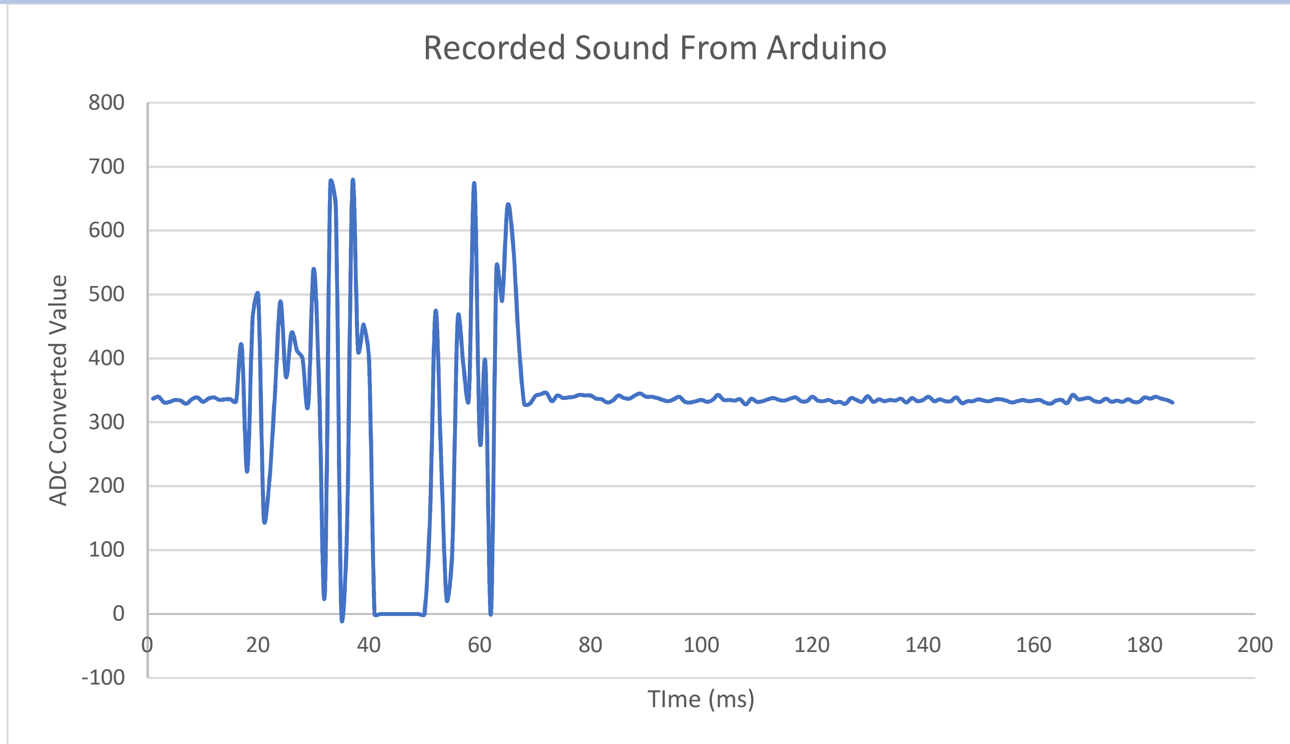
Current Progress



Future

- Locate a better power supply
  - Current Battery solution is not cutting it
  - Too heavy and not enough capacity
  - Voltage is high and LiPo batteries have safety concerns
- Obtain Training Data
  - Needed for completion of the project
  - Current obstacles are the completion of the testing rig
- Train Machine Learning Model
  - Most difficult part of the project
  - Once training data is obtained, making the inputs for the model is difficult
  - Watch for overfitting and input inaccuracies
- Setup Notification Belt
  - Simpler steps of the project
  - Requires material purchasing
- Iterative Testing and Improving
  - Every part will have the potential to be improved to create an altogether better process

Sound Graph



Recorded Sound From Arduino
ADC Converted Value
800
700
600
500
400
300
200
100
0
-100
0
20
40
60
80
100
120
140
160
180
200
TIme (ms)

Cost

Wearable Device		
Item	Quantity	Price
Raspberry Pi	1	$35.00
Arduino Uno R3	1	$10.00
Microphone Breakout	4	$4.00
Power Supply	1	$15.00
Material	1	$5.00
Haptic Output	8	$0.50
Total		$85.00

Sound Source Localization

- Sound Source Localization (SSL) is use of acoustic technology to determine the location of sound
- Crucial Capability in humans
  - allows for increased comprehension of speech, by allowing for separation between different sound sources
  - Commonly used subconsciously every day to sense the environment
- Currently, researchers aim to recreate these systems for a variety of uses
  - including sound source tracking, speech enhancement, virtual reality, and human-robot interaction
  - Some researchers are studying how cameras can use this technology to track different speakers during a meeting and recreate the meeting virtually for a more immersive experience (Mandlik, Nemec & Dolecek, 2012)
- Older approaches utilized TDOA algorithms
  - Method based on differences in time between spatially separated identical microphones
  - Computationally difficult
- Newer methods utilizing Machine Learning
  - More efficient, and shorter inference time (Risoud et al, 2018)