

What's That Sound? A 2-D Locator

Project Closeout

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Design Impact Assessment

Public Health, Safety, and Welfare Impacts

Hearing is a key part of sound localization, and loss of hearing can cause issues with locating who is speaking and can impact learning as many school activities are based on active listening [5]. The project will have a positive impact in these areas as it serves as a means of locating sounds in an environment independently of one's ability to hear. One's overall welfare could be improved because the device allows users to better interact with their environment and feel more "integrated" with the world than if they were just using their sight and touch to interact with the environment.

Cultural and Social Impacts

Hearing impairment can significantly impact one's education and quality of life, and commonly leads to discrimination as one is unable to communicate or listen in the same way [4]. This device will have a positive impact in that area as it will aid hearing impaired users in accomplishing tasks normally reserved for the hearing abled, such as speaker location. However, this device potentially has negative impacts in the way its materials are sourced. Mines for the raw materials for the electronics used in the device have the potential to be in native lands or in areas that have poor health and safety standards, leading to the destruction of the culture and society in that area[4].

Environmental Impacts

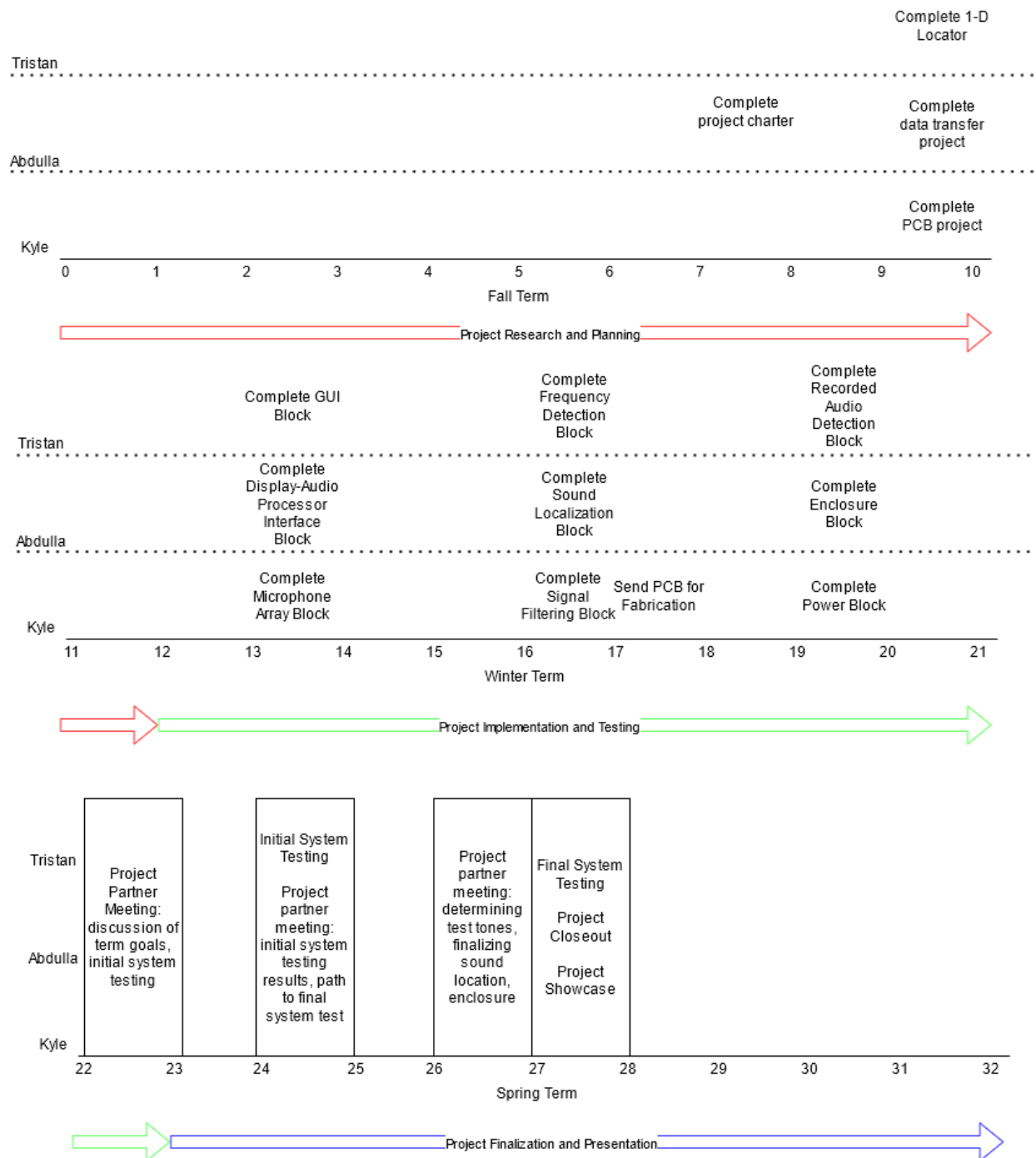
The positive environmental impacts of the device include improved methods of locating wildlife[1]. Locating and recording wildlife autonomously with our device could provide a low-disturbance means of keeping track of wildlife in an area. However, there are many negative effects related to the mining of resources for the electronics being used in the device. Mining leads to air pollution, water pollution, damage to land, and loss of biodiversity[7]. There are also concerns about E-waste. About 9.4 million tons of e-waste are produced each year [2], and this device may contribute to that number as it is made of a number of electronic components. However, there are also means of recycling many electronic components, which may reduce the e-waste impact of the device.

Economic Factors

The three most important factors that affect the demand for consumer goods is employment and wages, prices and interest rates, and consumer confidence [8]. All these factors have gone down in recent time due to the 2008 financial crisis and the COVID19 pandemic. The device, requiring at least \$60 (microphones + microcontroller) plus the cost of an android phone, will likely be reserved for those who are in the middle class or above due to the need for spare income. However, this device may also improve the economic chances of those who require

assistance in sound localization as it will enhance their ability to work. The sound locator may even open up new jobs in wildlife and speaker tracking as it provides an innovative way to locate sound in an environment.

Project Timeline



Scope and engineering requirements summary

Name	Project Partner Requirement	Engineering Requirement
Adjustable Frequency	The frequency to be identified must be variable.	The user can specify through the user interface the lower and upper bounds of frequency detection.
Cell Phone Battery Powered	Device must be battery powered	System must not consume more than 100mA
Cell Phone Compatible	The device must be able to communicate with a phone reliably	The system is able to maintain wired communication with a smartphone without losing connection
Easy to Use	User interface must be easy to use	9/10 people must be able interpret instructions on how to use the user interface.
Handheld Size	Device must be handheld	System must not be larger than 5 x 8 x 5 inches, corresponding to height, length, and width, respectively.
Sound Recording and Location	The device must be able to locate pre-recorded sounds	The system must identify and locate a sound snippet of up to 1024 samples in length that contains frequencies between 300Hz-2000Hz and is louder than 50dB and is within 12ft
Real Time Sound Processing	Must process sound data in real time.	System must sample data and update sound location on-screen once every 700 milliseconds
Sound Detection	Must identify a sound in the environment the user points the device towards.	System will be able to accurately locate sounds within the same horizontal and vertical range as the

		FOV of the camera (80 degrees maximum), and from within 12 feet in an open environment.
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Risk register

Risk ID	Description	Category	Probability	Impact	Performance Indicator	Responsible Party	Action Plan
1	Hardware order delay	Timeline	15%	H	Shipping complications, Absence of arrival	Abdulla	Retain: Adjust shipping service & timeline as needed
2	Electrical Shock	Health	30%	M	Sustained personal injury	Kyle	Reduce: Follow proper circuit handling safety
3	Team member gets sick	Health	10%	H	Group member is unable to participate in project	Tristan	Reduce: Limit in-person meetings, regularly assess health
4	Expensive component required	Cost	60%	M	Needed component has high purchase cost	Kyle	Reduce and Avoid: Search for cheapest options, rework design with cheaper components
5	Loss of digital work/documentation	Timeline	10%	H	Online database (Google Docs, Github) experiences data loss or outage	Tristan	Keep backups of important files on safe hard drives

Future Recommendations

1. Use a microcontroller that is capable of fast (150,000 HZ) sampling

Problem

When using a cross-correlation based TDOA (Time Difference of Arrival) method to locate signals, a trade off arises where the angular resolution increases with a faster sampling rate, but the frequency resolution decreases. The angular resolution is dictated by the number of samples possible between two signals arriving from the microphones, $\frac{d}{c} * fs$, with d being the spacing between microphones, c being the speed of sound, and fs being the sampling rate. However, if the spacing between the microphones becomes too high, the approaching soundwaves can become in-phase by the time they hit the microphones, causing false TDOA measurements (max distance is $d \leq \frac{\lambda}{2}$)[3]. At a frequency of about 150,000Hz, the angular resolution is about 3 degrees, which is appropriate for a 1ft. accuracy. However, as the sampling rate increases, the frequency accuracy decreases due to the microcontroller ADC not having enough time to adequately sample the voltage.

Solution

One can either decrease the sampling rate during the frequency sampling phase and increase it during the angle finding phase or obtain a microcontroller that is capable of accurately sampling at 150,000HZ.

2. Use of a more advanced, non-linear sound filter

Problem

Our system suffers from susceptibility to noise, especially those close to our desired frequency range. While our simple low-pass filter was sufficient enough in removing highly disruptive noise for accurate sound location, precision of location could be further improved by using a more complex filtering architecture.

Solution

Further improvements could be made by using a non-linear sound filter between the microphone array and the computational hardware. Teams would need to properly devise a

transfer function that more accurately reduces the gain of undesired frequencies while keeping desired frequency gain intact. This would also result in more expensive, more complex, and larger hardware, posing additional threats to system constraints.

3. Utilizing more than 4 microphones

Problem

Due to size and complexity constraints, our device used 4 microphones in a square formation as our microphones array. While this is a popular method of sound location, there exists more accurate models for localization. As a result of this simplification, our device works best at short range (within 5 feet) and has a small degree of inaccuracy for localization.

Solution

An improvement could be made to the system by using a localization geometry that makes use of more than 4 microphones. One of such models is a 5 microphone cross array, which boasts considerable improvements over 4 microphone models. Further increases in microphone quantity continue to improve accuracy of localization. Teams would need to consider the sizable increase to complexity that these models would pose to their system. In addition to the increased hardware for the array and it's filtering, the localization algorithms would also become much more complex as more advanced geometry is utilized.

4. Use an “irregular” sound source for testing the angle finding system

Problem

When using a cross correlation algorithm, irregularities in detected angle can occur when using a pure sinusoid sound source to test sound localization. These irregularities can occur because there may be many plausible points where the two signals meet, causing large delay values.

Solution

It is better to use a signal that is in an “envelope”, such as a swept frequency signal or a square wave signal that will have a definitive start and end in the sample window.

5. Start early when working with an STM32 microcontroller

Problem

STM32 microcontrollers differ from Arduino microcontrollers in that they are both much more advanced than Arduinos and use a less documented software ecosystem. It can be difficult to find documentation and tutorials for STM32 features, and it may take more extensive research to find proper solutions. Delays can arise when attempting to learn the STM32 ecosystem while also implementing the sound localization and communication system as there may be unexpected idiosyncrasies that arise when attempting to develop for the first time.

Solution

Start developing early in order to avoid excessive delays in completing the software portion of the sound locator. Websites like deepbluembedded.com are good sources for tutorials on common STM32 functionality and the STM32 forums are good for determining the causes of some common issues.

6. Check endianness between phone and microcontroller

Problem

One issue we faced when developing the communication system was that the microcontroller was a different endian than the phone, meaning that the microcontroller would send 16 and 32 bit numbers in reverse order compared to what the phone was reading them as.

Solution

Decode the bytes into integers in reverse when receiving them on the STM32 or phone side.

7. Install a serial terminal like RealTerm for serial debugging

Problem

Debugging the serial connection between the phone and locator device is difficult because there is no direct way to inspect the serial data going between the phone and microcontroller. The microcontroller side is particularly difficult because it is required to be connected to a PC to read debugging output, unless a system is established on the phone to display all serial input sent to it.

Solution

One way to get around this is to get a serial terminal that allows for the sending and reading of individual bytes. The one that we used is called RealTerm[6], which allows for sending and

receiving bytes as numbers and aligning the output based on specific starting bytes. Using a serial terminal allows for one to simulate the locator device or GUI by sending information manually through the serial terminal.

8. Have frequent meetings

Problem

While heavily exacerbated by COVID, this project is particularly challenging to integrate because the communication between the phone and microcontroller is opaque when connected together. Additionally, the sound localization results are sensitive to minute differences in microphone spacing and arrangement, making collaboration on the enclosure and microphone mounting design essential.

Solution

Come to agreement early on the design of the microphone array, enclosure, and phone-microcontroller communication protocol so that the system can be more easily integrated. Spend at least 2 hours a week collaborating on the design of the device and if possible perform “test fits” of blocks together to ensure that they will work before the entire device is integrated.

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