Initial Project Document

Distributed Sound Event Location - DiSEL

University of Central Florida
Department of Electrical & Computer Engineering

EEL4914 - Senior Design 1
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Group D

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1. Project Narrative Description

Sound plays a major role in our world, from being used for communication by humans and animals, to echolocation used by dolphins and other animals to hunt in low visibility conditions, to the distant sound of thunder warning of an incoming storm. From a technical standpoint, sound is a very powerful tool which can be utilized in many unique and valuable ways. Advancements in modern technology, and a large amount of research in audio signal processing, have paved the way for many technologies that incorporate audio broadcasting, audio synthesis, 3D sound localization, noise cancellation, audio fingerprinting, sound recognition, and much more.

This project will focus on implementing two specific applications of audio signal processing: 3D sound localization, audio fingerprinting, and sound recognition.

DiSELs purpose is to detect shared sounds at different locations, calculate the time of arrival at each location, determine a possible origin of the sound (category and location), and then serve this data through a web application. This technology would be designed to be modular to have use in a variety of applications ranging from safety and security, hunting, research and conservation of animal species of interest, or even general hobbyist activities such as birdwatching.

This technology would be extremely useful for law enforcement in active shooter situations, by connecting their smart devices to our DiSEL sound network installed at that location, personnel will be able to receive valuable tactical information on the shooter’s firearm and current whereabouts so that they can make an informed plan-of-action. In addition, civilians at the location would also be able to connect to the network and be given information that will aid them in making decisions that would increase their safety.

The DiSEL network will be expandable in order to provide optimal coverage in a variety of different scenarios (ie. using a low number of devices in a small enclosed area or a higher number of devices in a larger outdoor area).

In outdoor applications where it would be difficult to maintain the battery levels of each device in the DiSEL network, the devices will use solar power in order to maintain operable power for extended periods of time.

2. Project Summary

2.1 Goals and Objectives

The project will satisfy the following goals and/or objectives shown in Table 2-1.

An array of multi-directional audio sensors to detect multiple categories of sound events. Connected to both solar and battery power for indoor and outdoor use.
An application to allow users to interact with data that is retrieved and analyzed from the devices.
A microcontroller connected to the sensors to analyze sound events.

Table 2-1: Goals and Objectives

2.2 Specifications

The project will satisfy the following specifications shown in Table 2-2.

The array of sensors are connected to a central server.
The central server analyzes the sound events from multiple sensors. It will determine if all sounds being analyzed are of the same origin by filtering out other noise.
The sensors will timestamp all audio that is transmitted to the central server.
The central server triangulates the location of the sound event using time of arrival.
The central server is supported by machine learning and a database of sound samples consisting of multiple categories including discharging of different firearms, weather such as thunder, and bird calls.
The program will adjust for environmental factors such as temperature that may affect the distance a sound might travel when determining the originating location of a sound event.
Sensors will be mountable to pre-existing light or utility poles for outdoor applications, and wall or ceiling mountable for indoor applications.
Sensors will be able to withstand various environmental conditions for outdoor use.

Table 2-2: Specifications

2.3 Requirements

The project will satisfy the following requirements shown in Table 2-3.

Identify the originating location of the sound event within:	5	Meters
Verify the same sound is being analyzed from all sensors with greater than:	90%	Accuracy
Identify what originated the sound event with greater than:	90%	Accuracy
Analyze the location and label the sound event within	5	Seconds
Have a minimum required distance between sensors of less than:	5	Meters
Have a maximum operating distance between sensors of greater than:	100	Meters
Determine the temperature of environment within:	1	℃
Maintain a sensor weight of less than:	5	lbs
Have a sound event capture range of greater than:	100	Meters
Achieve an IP rating for sensor equal or better to:	I45	IP
Maintain a cost of less than:	500	USD

Table 2-3: Requirements

2.4 Quality of House Analysis

2.4.1 Understanding House of Quality

Section will explain how the house of quality diagram is built and what all of the sections mean and are used for in the process of design for a project.

2.4.2 House of Quality Diagram

Diagram 2-1 shows our groups determined customer requirements along with the technical requirement that will be used to satisfy those of the customer. Their relationship between each other is then shown in matrix form that is labeled by red, yellow, and green squares symbolizing a strong, moderate, and weak relationship respectively. A correlation matrix shown above the functional requirements is a representation of the correlation between each of the functional requirements and how one being improved/accomplished may have an effect on another.

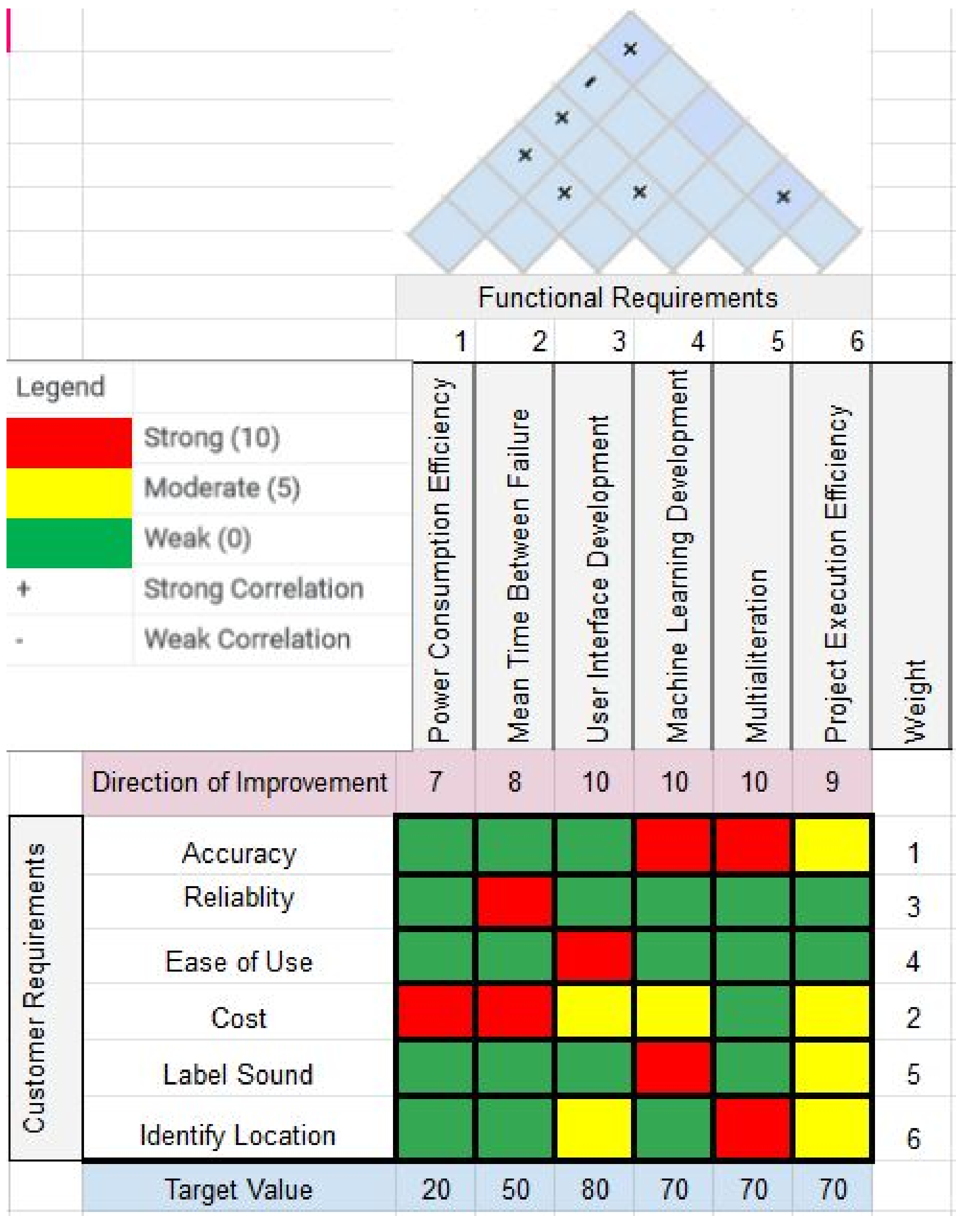


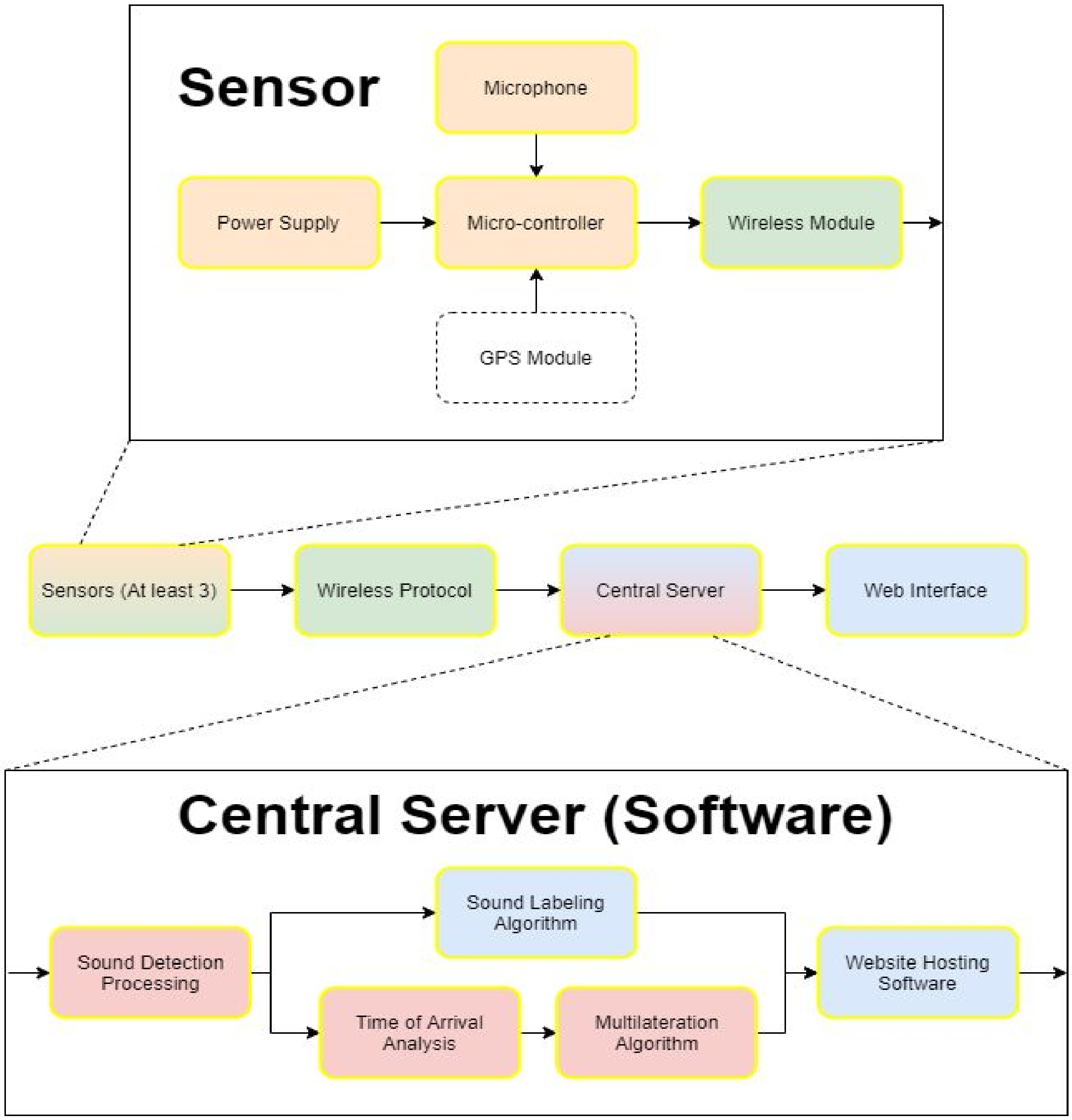
Diagram 2-1: House of Quality Diagram

2.5 Block Diagram

Table 2-4 gives the description of each block associated with the projects block diagram.

Block Name	Description
Power Supply	Provides power to the units of the system.
Sensors	Listens to the sounds being emitted from the surrounding environment.
Communication	Relays information and data between both the multiple units in the systems and the central server.
Central Server	A central hub that will connect the multiple system units and provide the ability to analyze all sounds acquired by the units.
Sound Location	Software that will determine the location of the object that is emitting the sound by analyzing data received from the system's sensors.
Sound Labeling	Software that will determine what object is emitting the sound by analyzing data received from the system's sensors.
Sound Detection	Software to determine if at least three sensors heard the same sound, and when each one did relative to the others.
User Interface (Web Application)	A web application formatted user interface that will allow a user to view data acquired by the system.

Table 2-4: Block Descriptions



Block Diagram Key	
Assigned Blocks	**Status**
Christopher Santana	Research
Brandon LaGuerre	Acquired
Mark Judy	Design
Drew King	Prototype
	Completed

Diagram 2-2: Block Diagram

3. Research and Theory

3.1 Existing Projects

Products and projects that deal with sound identification, and using sound waves to locate specific targets, have been utilized in the defense industry for decades to increase the safety of military personnel and give them a tactical advantage on the battlefield. More recently, similar technologies have begun being implemented into the civilian world to alert police and civilians to active situations. Additionally, two previous senior design projects have attempted to design simpler, more affordable devices using these concepts.

3.1.1 Project GLASS

3.1.2 Project Minutemen

3.1.3 Guardian Indoor Active Shooter Detection System

3.1.3 Boomerang

Initially developed by DARPA, this

3.1.4 Louroe Gunshot Detection

3.1.5 ShotSpotter

Currently the most popular commercial gunshot locator on the market,

3.2 Technologies and Theory

3.2.1 Batteries

3.2.1.1 Lithium-Ion

Lithium-ion batteries work by passing lithium ions from the the anode through the electrolyte and to the cathode. Lithium-ion batteries have several advantages such as a high charge storage per unit mass and a high voltage of 3.7 volts. This means that they can deliver large amounts of current for high power applications. Lithium-ion batteries have no memory effect, meaning that repeated partial discharge of the battery will not reduce the overall capacity of the battery. In addition to this, lithium-ion batteries have a low self discharge rate of about 1.5% per month ("Lithium-Ion Battery"). So when the batteries are not in use, they will hold their charge. Lithium-ion batteries are also very reliable. They require little maintenance and can withstand anywhere from 300 to 500 charge cycles ("BU-808: How to Prolong").The main disadvantage of lithium-ion batteries is its safety. The batteries are subject to overheating and sometimes combustion.

Another disadvantage is that, like most batteries, they start to fail with age ("Lithium-Ion Battery").

3.2.1.2 Nickel-Metal-Hydride

Nickel-metal-hydride batteries were invented to be a more environmentally friendly alternative to the nickel-cadmium battery. Nickel-metal-hydride uses nickel hydroxide for the positive electrode, hydrogen for the negative electrode, and potassium hydroxide for the electrolyte ("NiMH Battery Charging Basics"). The nickel-metal-hydride battery has an output voltage of 1.2 volts and an energy density of 50 to 70 Wh/kg. The advantage of nickel-metal-hydride is that they offer a very similar voltage to disposable alkaline batteries. This means that any device that uses alkaline batteries can also use nickel-metal-hydride batteries. Nickel-metal-hydride batteries can also be deep cycled. The disadvantage of the nickel-metal-hydride battery is that it has a very high self discharge of 20% to 50% within a month ("Nickel Metal Hydride").

4. Constraints and Standards

4.1 Standards

802.11 Wireless Standard					
IEEE Standard	802.11a	802.11b	802.11g	802.11n	802.11ac
Frequency	5Ghz	2.4Ghz	2.4Ghz	2.4/5Ghz	5Ghz
Max Data Rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps	1 Gbps
Typical Range Indoors	100 ft.	100 ft.	125 ft.	225 ft.	90 ft.
Typical Range Outdoors	400 ft.	450 ft.	450 ft.	825 ft.	1000 ft.

Table 4-1: Wireless Standards

IEEE 60529 IP Code

4.2 Design Constraints

The project will subject to the following constraints shown in Table 4-_:

Requires a minimum of three sensors.
The sensors should not have a weight of more than 8 pounds.
The project must stay at a cost below 750 USD.
All components of the projects must share the same clock rate when communicating.

Table 4-_: Design Constraints

4.2.1 Ethical Constraints

Explaining constraints that will be used regarding privacy since the device is looking for sound events to ensure no user can use the device to spy on others.

8. Administrative

8.1 Project Budget and Financing

Table 8-1 shows the projected budget and financing for the project.

Part	Quantity	Price	Total
Microphone	3	$30	$90
PCB	5	$0.40	$2
Casing	3	$7	$21
MCU	3	$60	$180
Solar Cell	3	$7	$21
Lithium-ion 18650 battery	6	$6	$36
Thermocouple temperature probe	3	$3	$9
Camera	3	$35	$105
Overall Cost			$464

Table 8-1: Project Budget and Financing

8.2 Milestones

Table 8-2 shows the list of our project milestones that are known at this time.

Task	Start	End
Research		
Group Formed	1/10/2020	1/20/2020
Divide and Conquer V1	1/10/2020	1/31/2020
Initial D&C Group Meeting	2/5/2020	
Divide and Conquer V2	1/31/2020	2/14/2020
Power	1/31/2020	2/14/2020
Communication	1/31/2020	2/14/2020
Sensors	1/31/2020	2/14/2020
Sound Labeling	1/31/2020	2/14/2020
Sound Location	1/31/2020	2/14/2020
Sound Detection	1/31/2020	2/14/2020
Web Application	1/31/2020	2/14/2020
Software-Hardware Integration	1/31/2020	2/14/2020
Assignment on Standards	3/9/2020	3/13/2020
60 Page Draft	2/15/2020	3/20/2020
Design		
Power	2/15/2020	4/3/2020
Communication	2/15/2020	4/3/2020
Sensors	2/15/2020	4/3/2020
Sound Labeling	2/15/2020	4/3/2020
Sound Location	2/15/2020	4/3/2020
Sound Detection	2/15/2020	4/3/2020
Web Application	2/15/2020	4/3/2020
100 Page Draft	3/20/2020	4/3/2020
Final Document	4/3/2020	4/21/2020
Implementation/Testing	4/21/2020	TBD
Power	4/21/2020	TBD
Communication	4/21/2020	TBD
Sensors	4/21/2020	TBD
Sound Labeling	4/21/2020	TBD
Sound Location	4/21/2020	TBD
Sound Detection	4/21/2020	TBD
Web Application	4/21/2020	TBD
Final Project Presentation	TBD	

Table 8-2: Milestones

9. References

1. *Lithium-Ion Battery.* Clean Energy Institute, University of Washington, https://www.cei.washington.edu/education/science-of-solar/battery-technology/. Accessed 13 February 2020
2. *BU-808: How to Prolong Lithium-based Batteries.* Battery University, https://batteryuniversity.com/learn/article/how_to_prolong_lithium_based_batteries. Accessed 13 February 2020
3. *Nickel Metal Hydride (NiMH).* Johnson Matthey Battery Systems, 2016, http://www.jmbatterysystems.com/technology/cells/nickel-metal-hydride-(nimh). Accessed 13 February 2020
4. *NiMH Battery Charging Basics.* PowerStream Technology, 31 July 2019, https://www.powerstream.com/NiMH.htm. Accessed 13 February 2020