



DVC Avoidance

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Introduction

Deer-vehicle collisions (DVCs) are extremely dangerous as these accidents can cause fatal injuries to both humans and deer. These types of automotive accidents are very common in the United States, especially with the current expansion into undeveloped areas, where many wildlife currently reside. Some estimates suggest that there are nearly 1.5 million DVCs that occur every year [1], resulting in 200 deaths in 2010[2]. On top of this, according to the National Highway Traffic Safety (NHTS) [3], fatal crashes involving animals increased by 39% over a 6-year period.

Despite these numbers, there are no currently known systems implemented by either the federal or state governments to prevent these accidents. There are, however, many animal deterrent products in the market that are designed to ward off small animals, including deer. Most of these products operate by constantly emitting an ultrasonic frequency audio signal, but eventually these small animals acclimate to the deterrent and learn to ignore the sound. To avoid this issue, we hope to condition deer to associate the noise with danger by only emitting when cars are nearby. If one can create a system that can cause a sufficient stimulus, it would possible to warn deer automatically of incoming cars.

Stakeholders

Our primary stakeholders are the residents residing in both urban and suburban areas as well as automobile owners who will commute through country roads for work, especially early in the morning or late at night when visibility is not ideal. There is no elegant method of stopping the deer from crossing or suddenly stopping the car without causing any damage. It is also very dangerous for driver to make a sudden stop when there are cars behind. This can easily lead into multi-car accidents in undeveloped areas. This project provides a means for both drivers and deer to avoid DVC accidents. Secondary stakeholders include highway patrol, the police, the fire department, hospitals and their corresponding staff, and the ecological community. When an accident happens, multiple agencies are required to

respond to the accident. If this system is implemented, the accident rate shall decrease, thus decreasing the load on first responders.

Project Goals and Objectives

Project Goals

1. The deliverable shall be scalable for future program expansion.
2. The deliverable shall aid researchers to experiment with different deer warning systems.
3. The deliverable shall reduce or prevent as many deer-vehicle-collisions as possible.
4. The deliverable shall not be constantly emitting noise; it shall be a flexible system that alerts deer only when vehicles are approaching.

Project Objectives

1. Develop a system that requires low power consumption or uses sustainable energy, such as, solar power.
2. Preserve and emphasize project maintainability throughout the design process.
3. Test all functionalities of the device thoroughly.
4. Maintain and emphasize documentation during the development process.

Project Outcomes and Deliverables

The targeted outcome for this project is to create and build a system that shall be placed alongside the roads where deer are often spotted in the area. The system shall detect an incoming car through a vibration sensor that is firmly mounted against the pavement or dirt road. Once movement is detected, the system will emit an ultrasonic frequency to alert the deer of potential harm. Deer shall either turn around and stop where they are at until the cars have passed. This system will interface with a vibration sensor

that will detect a moving car and emit the signal through a piezo buzzer. The system must also be powered either by battery or by more sustainable means.

Design Development

The backbone of this project was designed and built by a previous group [5], thus development began with understanding the previous group's work and then setting up the development environment. Since their work was split between hardware and software development, their work had yet to be integrated, but once this was done their system was used to collect road vibrations. These signals were analyzed to determine unique characteristics that cars have when driving on a road. Finally, the system was configured to output an audio waveform through a DAC and piezo buzzer.

System Design

For a detailed description of the system see “Electronic Deer Warning System” [5]. The previous group's final system can be seen in Figure 1, with the power electronics circuitry providing power to the sensor, the microcontroller, the DAC, and the piezo buzzer. The microcontroller currently used is the STM32F401RE Nucleo development board, which was chosen for its digital signal processing capabilities as well as its serial communication peripherals. The system has since been updated so that it can either use the sensor circuitry as shown in Figure 1, or interface with an accelerometer breakout board through I2C communication as shown in Figure 2. The firmware that runs on the system is implemented as a finite state machine, depicted in Figure 3, and has not changed since the previous iteration.

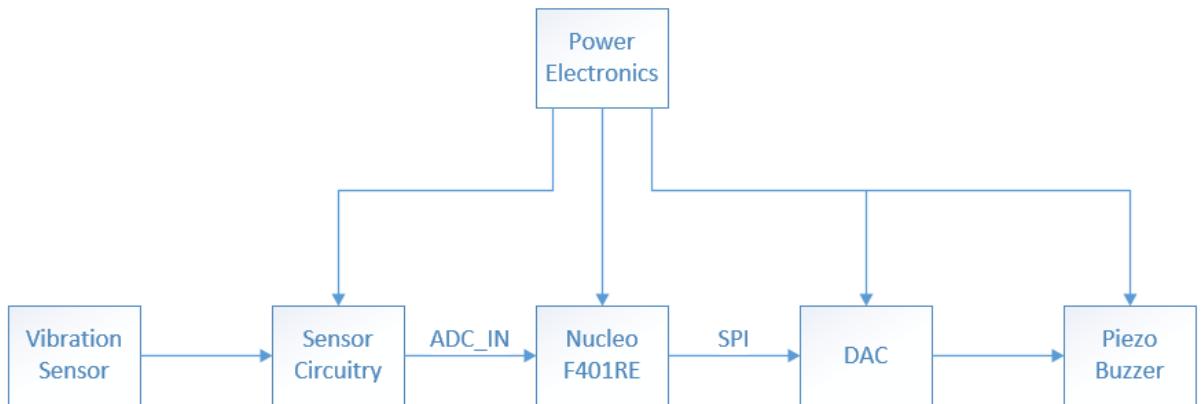


Figure1. Initial block diagram of system design

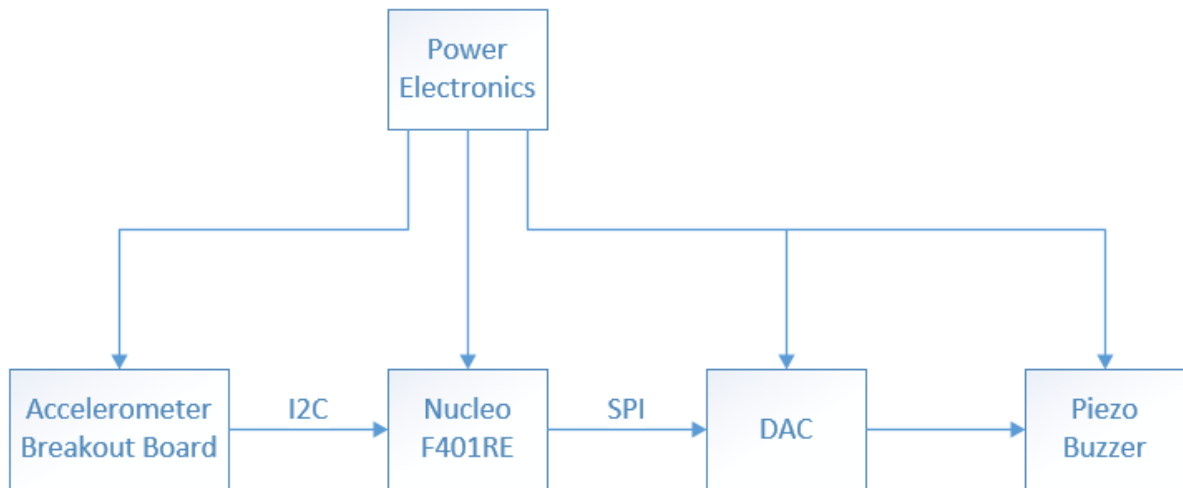


Figure 2. Updated block diagram of system design

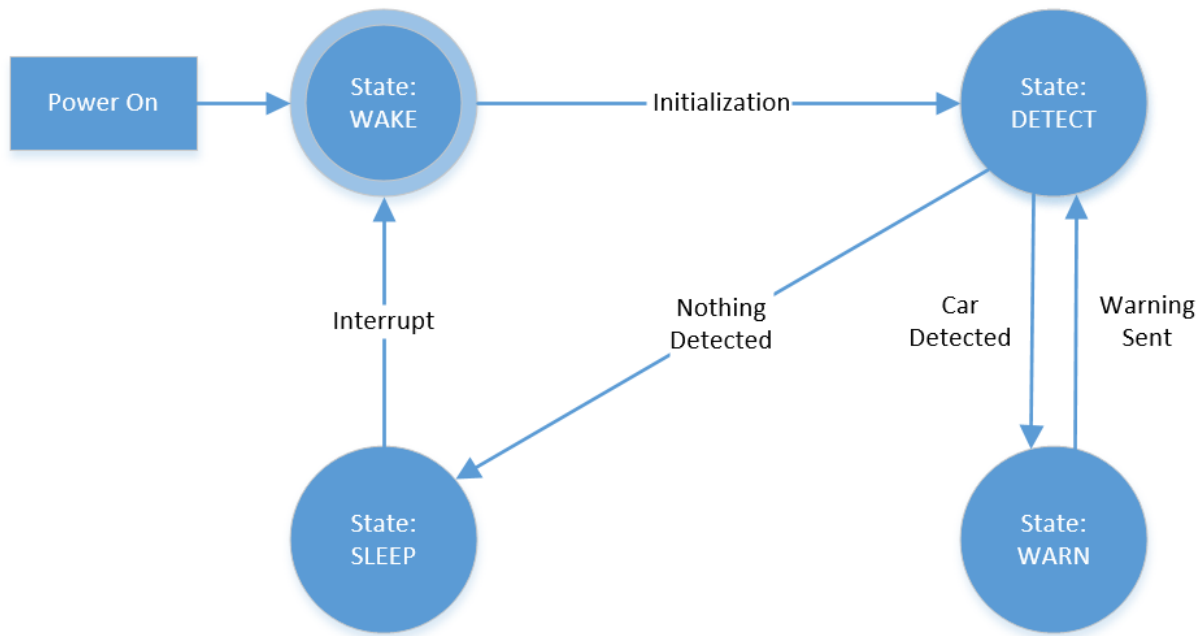


Figure 3. Firmware finite state machine

Development Environment

Two tools are required to compile the code and flash it onto the microcontroller. Compiling code for the STM32 requires the GNU ARM Embedded Toolchain [6]. Once the toolchain is downloaded, add the toolchain's "bin" directory to the system's PATH. Flashing the microcontroller requires Texane's ST-LINK tool [7]. Follow the instructions on their webpage to setup and configure the tool. **NOTE:** Although the tool is currently on version 1.3.1, it is important to download and install version 1.2.0. For unknown reasons, other versions of the tool have issues, where the host machine is unable to use UART communications to debug the board.

Once the development environment is set up, the project can be quickly compiled and deployed using a Makefile located in the "deer-deterrent/src/deer_deterrent_firmware/" directory. The command 'make debug' will compile the project for development and debugging. This will enable the board's LED

and will transmit UART messages through the USB connection to the host machine. The command ‘make release’ will compile the project without the debugging code and is intended for a final release.

Road Vibration Data Collection

Once the STM board is programmed, the system is ready to collect vibration data. Previously, a piezo vibration sensor along with a filter and amplitude circuit was designed to capture the road vibrations. This subsystem was capable of capturing vibrations when placed on a table, and exhibited low noise. When this subsystem was used in the field, however, it was unable to detect any vibrations from the road. This led to transitioning to using an Adafruit MMA8451 Accelerometer Breakout Board [8] to collect vibration data. The accelerometer was much more sensitive than the piezo vibration sensor circuitry and could pick up events such as heavy footsteps or stomping. However, the data was much more susceptible to noise. As a result, it is uncertain if the accelerometer was capable of detecting the vibrations caused by the car, or if those vibrations were masked by the noise.

To collect data, the system was mounted onto the side of a road while a single car drove by at speeds of 20/30/40 mph. While this was happening, the microcontroller would constantly read sensor data and then use UART to transmit the readings to the host machine. At the same time, the host machine would be running a Python script (shown in Figure 4) that would receive these UART messages, write them to a file, and plot the data in real time.


```

import serial
import numpy as np
from matplotlib import pyplot as plt

ser = serial.Serial('/dev/tty.usbmodem1413', 115200, timeout = None)
out = open('debug.out', 'w')

plt.ion() # set plot to animated

ydata = [0] * 1000
ax1=plt.axes()

# make plot
line, = plt.plot(ydata)
plt.ylim([3000,4500])

# start data collection
while True:
    data = ser.readlines(1000) # read data from serial
    out.write(''.join(data))
    data = map(str.strip, data)
    for point in data:
        ydata.append(point)
        del ydata[0]

    line.set_xdata(np.arange(len(ydata)))
    line.set_ydata(ydata) # update the data
    plt.draw() # update the plot
    plt.pause(0.1)

```

Figure 4. Python script used for data collection

Signal Analysis and Car Characterization

Matlab was first used to perform an FFT of the collected data and then plot the single-sided amplitude spectrum. A snippet of the code used can be seen in Figure 5. This was done for each data set collected. Figures 6 and 7 depict one of these time series and its corresponding single-sided amplitude spectrum.

```

raw = csvread('30mph_2.csv');
% Plot raw data
figure(1);
plot(raw)
title('Raw Data')

xfft = fft(raw);
Fs = 400; % Sampling Frequency
L = length(raw);

% Compute two-sided spectrum P2 and single sided spectrum P1
P2 = abs(xfft / L);
P1 = P2(1:L/2+1);
P1(2:end-1) = 2 * P1(2:end-1);

f = Fs*(0:(L/2))/L;
figure(2);
plot(f(2:end),P1(2:end))
title('Single-sided spectrum of Raw Data')

```

Figure 5. Snippet of Matlab code used to analyze signals

There are no clear peaks in the frequency domain of the data which suggests that there aren't any frequencies that are particularly dominant in this signal. This is suspected to be due to the fact that either the noise is masking out the subtle vibrations generated by the vehicles or the vibrations are simply too subtle for the accelerometer to pick up. In order to check if there were signals present in the noise, Matlab was used to try two different approaches for eliminating the noise: applying a moving average filter and applying a low pass FIR filter. The results of these filters can be seen in Figures 8, 9, 10, and 11.

These filters generated a less noisy time signal, but still no significant changes in the frequency domain. For the moving average filter, the window in which the filter averaged over was adjusted, but each span resulted in similar looking results. For the low pass FIR filter, the order of the filter and the cutoff frequency were adjusted, but this generated similar results.

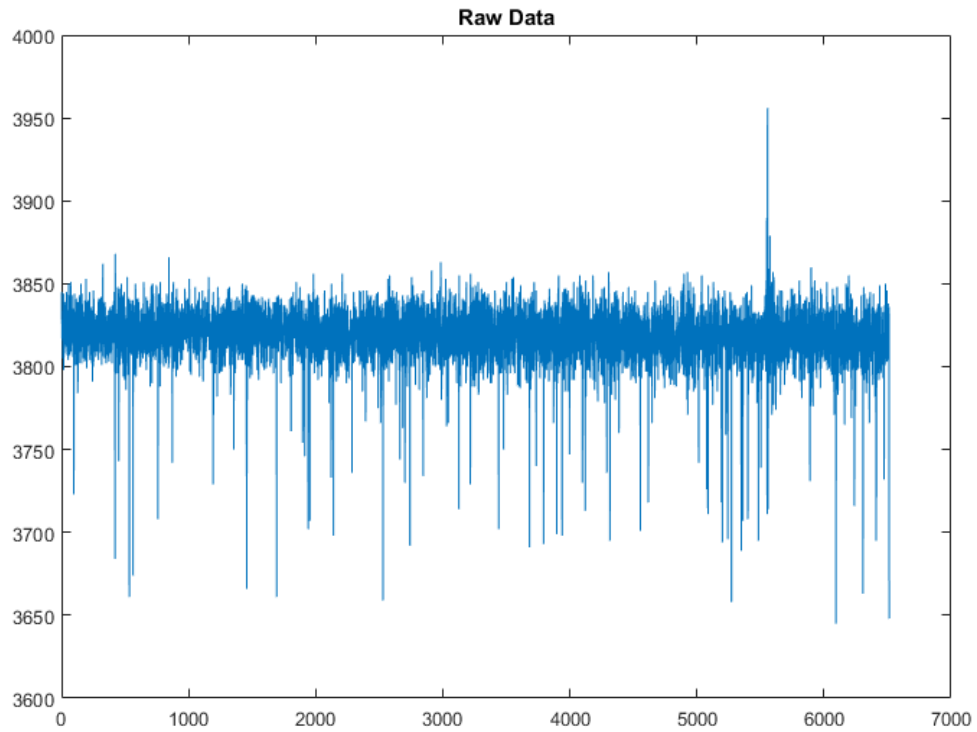


Figure 6. Accelerometer data time series

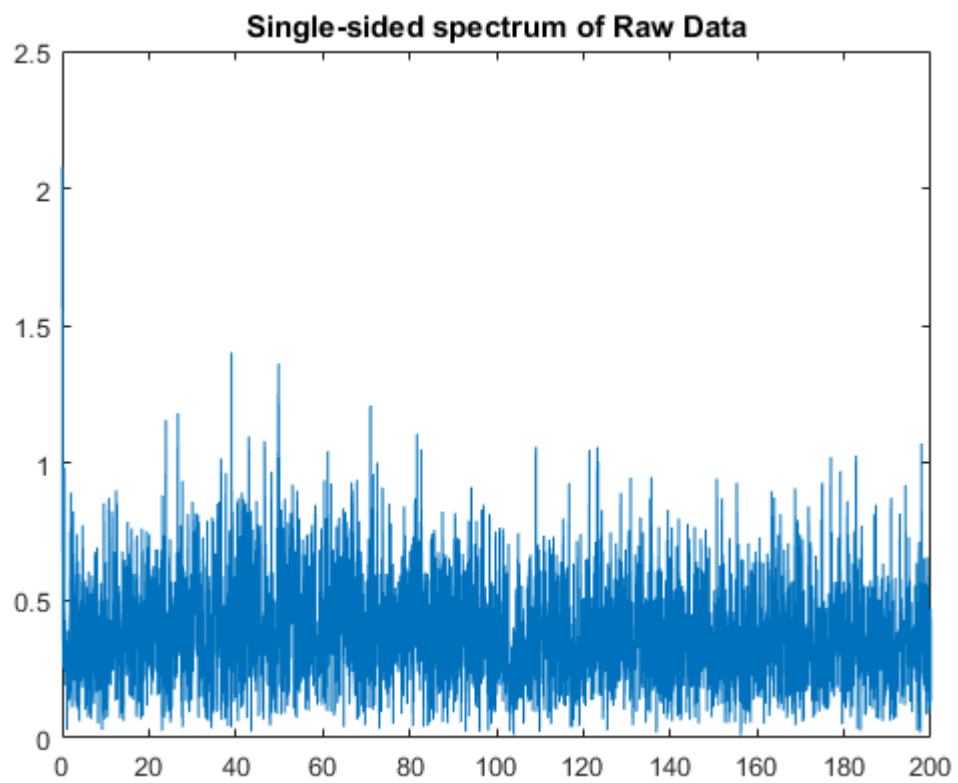


Figure 7. Single-sided spectrum of time series in Figure 6

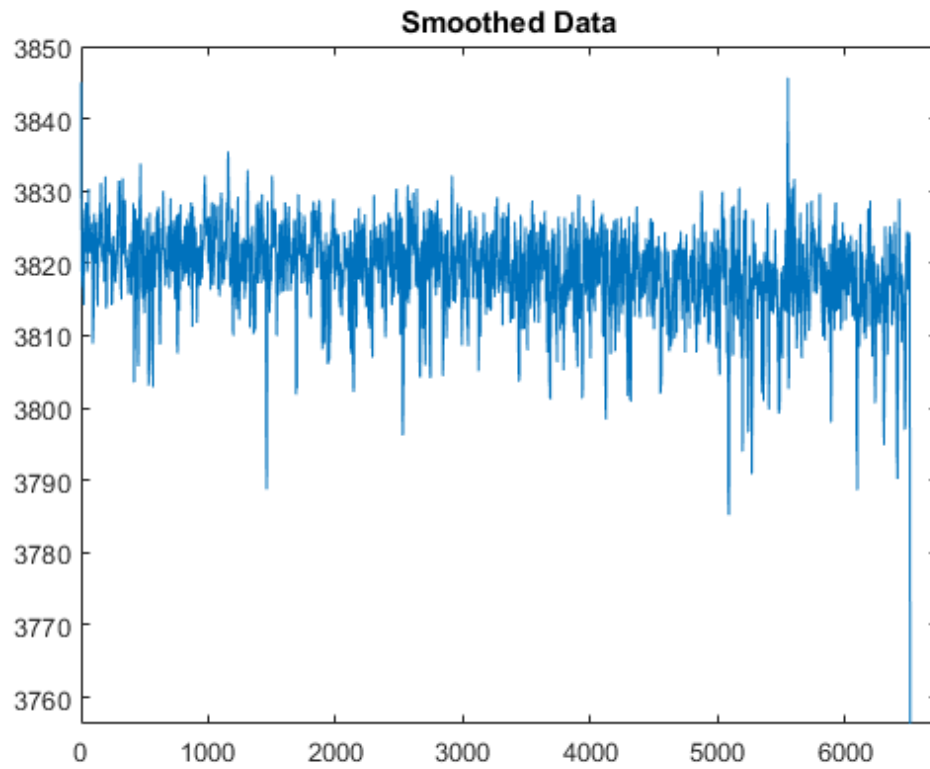


Figure 8. Moving average filter with a span of 21 applied to time series data in Figure 6

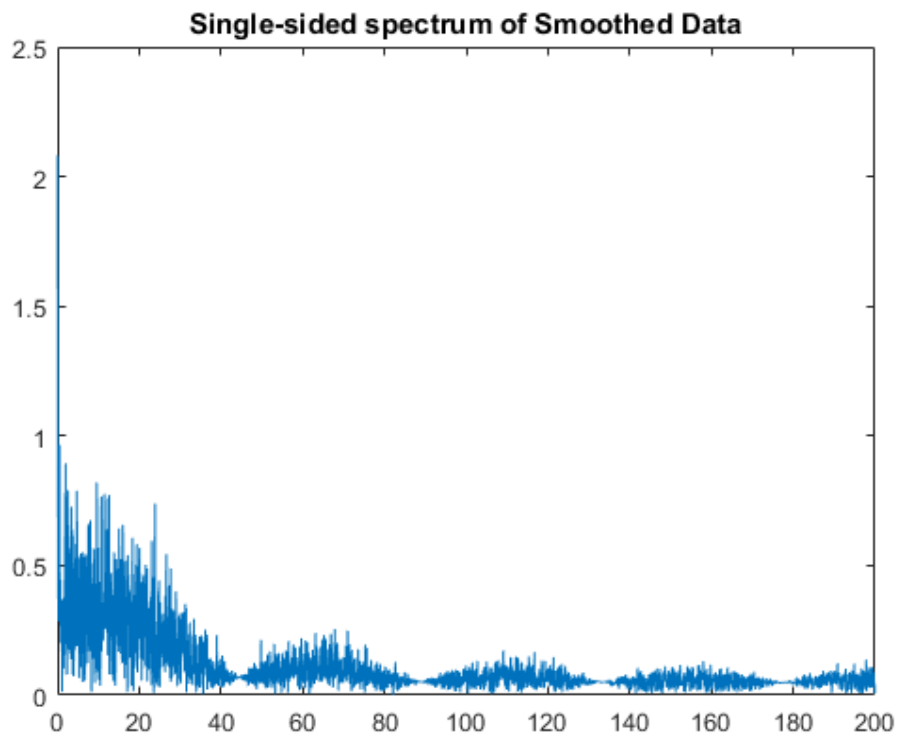


Figure 9. Single-sided spectrum of the smoothed time series

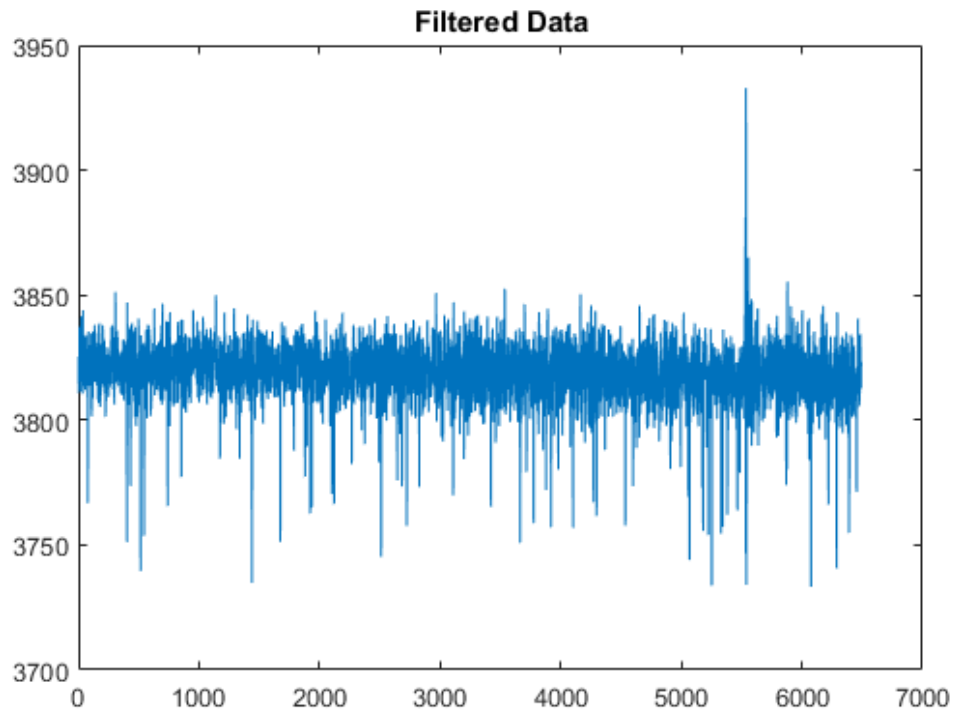


Figure 10. 3rd order low pass filter with cutoff frequency of 100 Hz

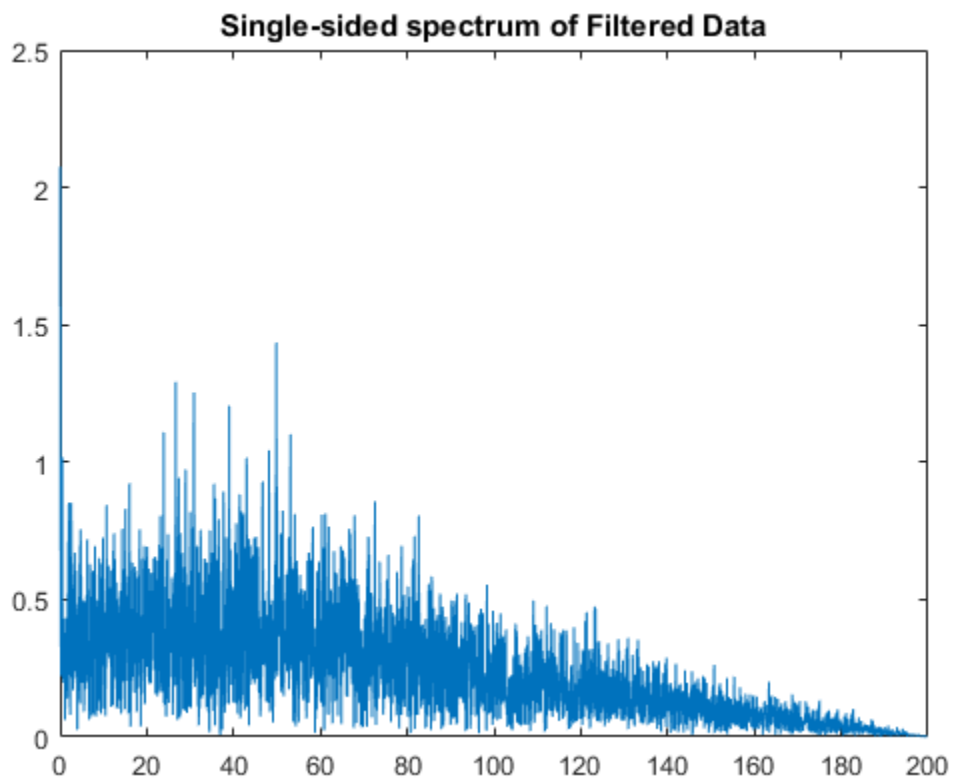


Figure 11. Single-sided spectrum of filtered time series.

Future Work

Different Sensors for Vehicle Characterization

The most crucial part of this project is vehicle characterization. The current system does not have a reliable way of detecting of incoming vehicles. The piezo vibration sensor circuit is low noise but not sensitive enough to pick up road vibrations. While the accelerometer is more sensitive to the activity on the road, it doesn't seem to be able to detect vibrations caused by vehicles. Future iteration shall consider testing different sensors for characterizing incoming vehicles. Future groups should consider looking into detection methods other than road vibrations.

Switch to a Networked System

With the current one-unit implementation, the system cannot detect any movement unless it is happening right next to the sensor. If future iterations would like to keep the current configurations and sensors use, they may want to consider separating the detector and emitter to two separate boards, and communicate wirelessly. Using this method, power consumption may increase, however, it will also maximize the distance between the detector and emitter and give better detection rates and response times.

Sustainable Energy

The current system relies on three AAA batteries to power or computer USB power, which is not flexible and sustainable. The estimated battery life is approximately three to six months depending on the how busy the road is. In the future iteration, research and development of a sustainable power supply is crucial to this project. It will reduce the maintenance intervals and the amount of eco waste as a result of the system.

Upgrade Parts

Currently not all parts are automotive grade. This is not an issue that requires immediate attention, because the current system shall be used as a research and development tools for experts. Eventually, the ultimate goal of this project is to design a system that is deployable on public roads. It is important that parts used in this project are at least automotive grade due to heavy usage and extreme weather environment the system will face.

Conclusion

Overall, we were very optimistic in trying to keep the detector and emitter using only one board. Other solutions for detecting cars would require the detector and the emitter to be placed several meters apart to give the system enough time to warn deer. That means that multiple boards would need to communicate wirelessly which would increase the cost and power consumption of the system. While it would not be as efficient, it would be a much simpler system to implement and test. Keeping everything in one location required our system to be able to detect vibrations from a long distance away and this proved to be difficult as we discovered that road vibrations caused by cars were too subtle. The vibrations aren't strong enough to be detectable by a simple sensor, so one would need a sensor that is much more sensitive. Because of the high sensitivity, however, the sensor would be much more prone to noise and would need to separate the activity caused by a car from all the other seismic activities that are occurring.

Appendices

Appendix A - Bill of Materials

| Part: | Quantity: | Cost per item (\$): | Total Cost (\$): |
|---|-----------|---------------------|------------------|
| STM32 Nucleo F401RE Board | 1 | 17.99 | 17.99 |
| Adafruit MMA8451 Accelerometer Breakout Board | 1 | 8.96 | 8.96 |
| 3 x AAA Battery Holder | 4 | 1.49 | 5.99 |
| Anti-static ground wrist strap | 2 | 3.99 | 7.99 |
| MCP4921 DAC | 1 | 2.03 | 2.03 |
| | | Total Cost: | 57.96 |

Table 1: Final Bill of Materials for DVCs Avoidance

Appendix B - Proposed Timeline

| Tasks: | Projected Completion Date |
|--|---------------------------|
| Familiarize both hardware and software system developed by previous group: <ol style="list-style-type: none">1. Assemble the hardware systems (to do)2. Compile the given libraries and drives (check)3. Understand the hardware system4. Compare and test the device with simulation data | NLT 17 FEB 2017 |
| Basic automobile classification complete | NLT 17 MAR 2017 |
| Research a new DAC to respond to a ultrasonic wave to generate not only square wave but the best waveform. | NLT 24 FEB 2017 |
| Improve Detection Time | Spring 2017 |
| Implement Direct Memory Access to make SPI and UART asynchronous | |
| Optimize energy usage | |
| Explore solar power option | |

Table 2. Original Proposed Timeline

Appendix C - Project Repository

This Git repository contains all the code for the project and all of the schematic files

<https://gitlab.com/davidzhuo/deer-deterrent>

Appendix D - References

1. Conover, Michael R. *Resolving Human-Wildlife Conflicts: The Science of Wildlife Damage Management*. Boca Raton, FL: Lewis, 2002. Print.
2. Reducing Deer-Vehicle Crashes <http://wildlifecontrol.info/wp-content/uploads/2016/04/Deer-Vehicle_factsheet1.pdf>
3. Evaluation of Electronic Frightening Devices as White-tailed Deer Deterrents <<http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1002&context=vpc18>>
4. D'Angelo, G. J., A. R. De Chicchis, D. A. Osborn, G. E. Gallagher, R. J. Warren, and K. V. Miller. 2007. Hearing range of white-tailed deer as determined by auditory brainstem response. *Journal of Wildlife Management* 71:1238–1242.
5. Zhuo, David & Lu, Anlang. (2016). Electronic Deer Warning System. <<http://digitalcommons.calpoly.edu/cpesp/214/>>
6. GNU ARM Embedded Toolchain. <<https://launchpad.net/gcc-arm-embedded>>
7. Texane's ST-LINK Tool. <<https://github.com/texane/stlink>>
8. Adafruit MMA8451 Breakout Board. <<https://learn.adafruit.com/adafruit-mma8451-accelerometer-breakout/overview>>