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Elephant detection using Geophones

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Abstract

In this report we have discussed our objective, approaches and experiments of our summer internship project on elephant detection near the railway tracks. We started by choosing the appropriate device for measuring the footsteps, then moved on to processing the received signal, extracting features from the data and finally trained and tested a ML algorithm.

1 Introduction

Elephant accidents near railway tracks are increasing year by year. The objective of the project is to detect the elephant's footsteps and raising an alarm to avoid the accident. The footsteps generate seismic waves in the ground in different patterns which can be used to classify the animals based on their footsteps. Our problem statement was to differentiate among elephants, humans, vehicles using the seismic waves generated by them.

2 Selection Of Instrument

Seismic sensors are the devices used to measure seismic vibrations by converting ground motion into a measurable electronic signal. To detect the seismic waves, we had to choose between accelerometer and geophone. Accelerometer measures ground motion in terms of ground acceleration and geophone in terms of ground velocity. Noise in accelerometer readings was much higher than that of a geophone. Accelerometer has much lower sensitivity than the geophones. Accelerometer required an extra power supply for its working whereas geophone is a passive sensor. As in the long run, a sensor requiring extra power supply will increase the maintenance charges, we decided to go with the geophones. Among the geophones we had to choose the one with the desired frequency. The resonant frequency and the spurious frequency of the geophones are the minimum and the maximum frequencies that the geophone can measure. As our footsteps data were in the range of 8 -100Hz, we chose to go with HG-6HS geophone.

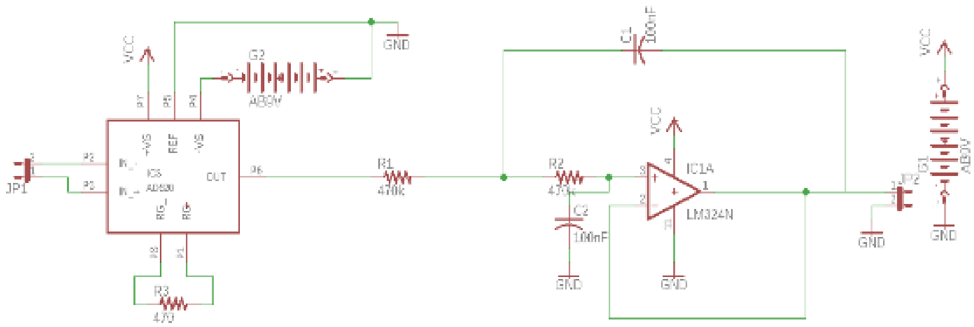
Specifications - HG-6HS Low Frequency Geophone

	A - Coil	B - Coil
Frequency	**Value**	**Value**
Natural frequency	4.5 Hz	4.5 Hz
Tolerance	±0.5 Hz	±0.5 Hz
Maximum till angle for specified Fn	0°	0°
Typical spurious frequency	140 Hz	140 Hz
Distortion		
Distortion with 17.78 mm/s p.p. coil-to-case velocity	<0.5%	<0.3%
Distortion measurement frequency	12 Hz	12 Hz
Maximum tilt angle for distortion specification	0°	0°
Damping		
Open circuit (typical)	0.284	0.58
Shunt for 0.6 damping	20000 Ω	560000 Ω
Shunt for 0.7 damping	14000 Ω	88700 Ω
Tolerance with calibration shunt	±5%	±5%
Resistance		
Standard coil resistance	3500 Ω	3500 Ω
Tolerance	±5%	±5%
Sensitivity		
Open - circuit Sensitivity	78.9 V/m/s	78.9 V/m/s
Tolerance	±5%	±5%
Moving mass	15 g	10 g
Max coil excursion p.p .	4 mm	4 mm
Physical Characteristics		
Diameter	25.4 mm	25.4 mm
Height	36 mm	36 mm
Weight	81 g	81 g
Operating temperature range	-40°C to 100°C	-40°C to 100°C

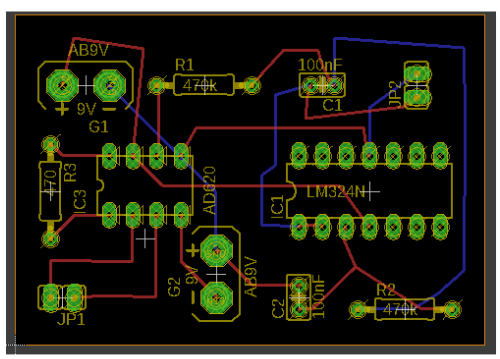
3 CIRCUIT DESCRIPTION

Output from the geophone sensor comes in ranges of microvolts. The circuit designed should be able to amplify the signal and filter out the noise. We used AD620 IC for amplification purpose.The AD620 is a high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000.The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 microvolts max, and offset drift of 0.6microvolts per degree Celsius max, is ideal for use in precision data acquisition systems. The amplified is then passed on to second order low pass filter using LM324 IC.

The geophone output is analog in nature. So, we cannot use a normal ADC to convert the signal to digital. So, we chose USB soundcards which had audio ADCs with range -2.5 to 2.5 volts instead of 0 to 5 volts.



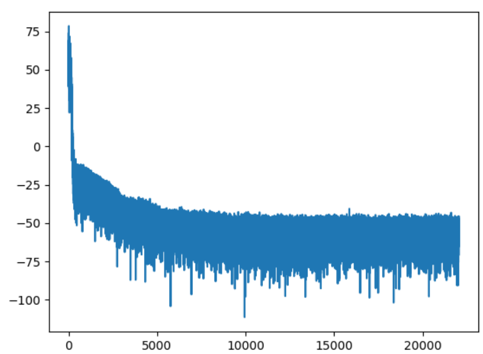
Circuit diagram



Final PCB design made using Eagle schematic software

4 DATA COLLECTION AND FEATURE EXTRACTION

We collected around 350 human footsteps data ,300 vehicle data. One of the major problems we faced was that we were not able to eliminate the noise completely by using single filter which we used as the filter's gain gradually reduced above the cut-off frequency. So, we made a software filter using python and filtered the signal multiple times in order to reduce the amplitude of the noise frequencies to a minimum level.



We saved the signal in the form of a .wav file. In order to extract the features from the audio signal to train the ML model, we used PyAudioAnalysis library which gave us around 68 features for a single audio file.

Feature ID	Feature Name	Description
1	Zero Crossing Rate	The rate of sign-changes of the signal during the duration of a particular frame.
2	Energy	The sum of squares of the signal values, normalized by the respective frame length.
3	Entropy of Energy	The entropy of sub-frames' normalized energies. It can be interpreted as a measure of abrupt changes.
4	Spectral Centroid	The center of gravity of the spectrum.
5	Spectral Spread	The second central moment of the spectrum.
6	Spectral Entropy	Entropy of the normalized spectral energies for a set of sub-frames.
7	Spectral Flux	The squared difference between the normalized magnitudes of the spectra of the two successive frames.
8	Spectral Rolloff	The frequency below which 90% of the magnitude distribution of the spectrum is concentrated.
9-21	MFCCs	Mel Frequency Cepstral Coefficients form a cepstral representation where the frequency bands are not linear but distributed according to the mel-scale.
22-33	Chroma Vector	A 12-element representation of the spectral energy where the bins represent the 12 equal-tempered pitch classes of western-type music (semitone spacing).
34	Chroma Deviation	The standard deviation of the 12 chroma coefficients.

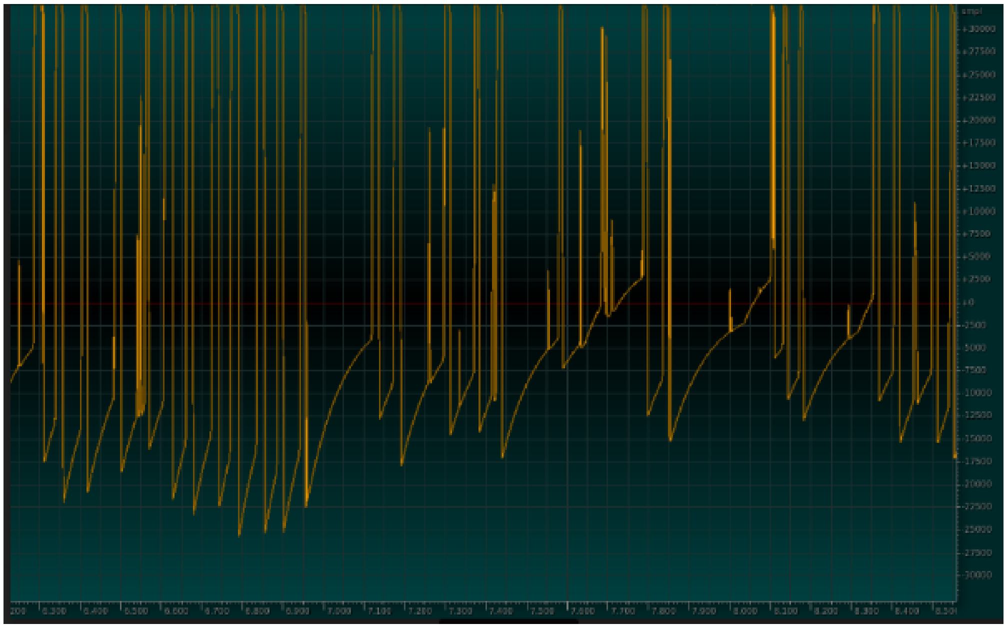
These 34 features are calculated for short term and midterm analysis which finally gives us 68 features.

5 TRAINING AND TESTING

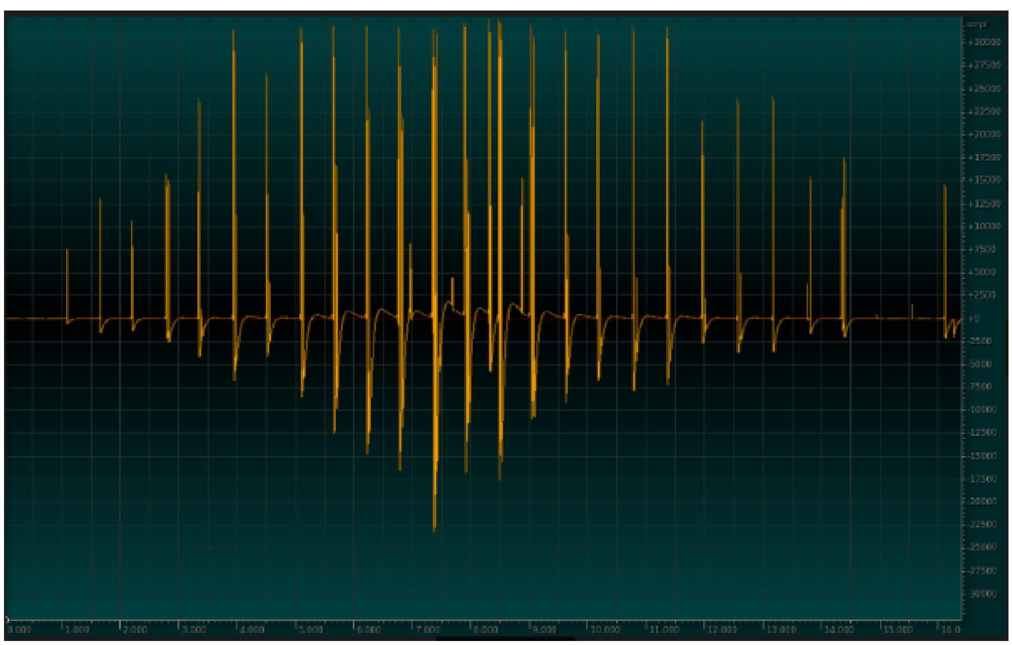
We trained a SVM and a Random forest ML model using the collected data along with some blank data as a separate category. We then tested both the models using our test data and found that SVM model gave us better results than Random Forest approach. So, we chose to go with the SVM model.

6 Implementation of SMART BORDER

We tried to test our model in real time by implementing a smart border using raspberry pi. We noted down the time during which human movement or vehicle movement was there. We then cross verified our results with the output of the classifier. One of the major drawbacks was that the classifier could not identify if vehicle and human movement occurred together and classified it as vehicle movement.



Wave file for vehicle data



Wave file for Human data

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