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PROJECT REPORT

On

" Acoustic Based Ambulance Arrival Detection and Direction Indication "

Project Report submitted in partial fulfillment of the requirement for the award of the degree of Bachelor of Engineering
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Electronics and Communication Engineering

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CERTIFICATE

This is to Certify that the dissertation work **"**Acoustic Based Ambulance Arrival Detection and Direction Indication**"** carried out by HRUSHIKESH.V [1CR16EC051], AKHILESH SINGH.B [1CR16EC010], HARSHANIKETHAN R KOTION [1CR16EC047] bonafide students of **CMRIT** in partial fulfillment for the award of **Bachelor of Engineering** in **Electronics and Communication Engineering** of the **Visvesvaraya Technological University, Belagavi,** during the academic year **2019-20**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

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1.

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ABSTRACT

In order to avoid the major accidents, and to avoid the delay of an emergency ambulance reaching its destination the smart ambulance detector is used. The inattention to the surrounding traffic and distraction such as FM or music or hands free communication with in the car cabin can make drivers unaware of nearby emergency vehicles, that can cause such issues. This can be solved using a smart detecting and indicating device.

The ambulance detector is a device that detects the arrival and the direction of arrival of an emergency vehicles like ambulance. **MACHINE LEARNING** is the technique used for detection and **TDOA** [Time Difference of Arrival] is the technique used for direction indication of an emergency vehicle.

This project studies the characteristics of siren **.Machine Learning** technique takes calculated features of a siren like mean, variance , kurtosis , skewness, energy etc… as an input , these features are trained using different machine learning algorithm like KNN , ENSEMBLE , FINETREE , LOGISTIC REGRESSION etc… and the results are tested after training for the best algorithm based on its efficiency . The most efficient algorithm's trained Model is stored and loaded back when needed for real time prediction of a similar featured data.

TDOA [Time Difference of Arrival**]** takes raw signal data from four similarly designed microphones as an input. TDOA performs Generalized Cross-correlation using Phase Shift technique on the four recorded signals. The output of the TDOA with least correlated value is the microphone that detect the siren first and thus the direction of arrival of siren sound.

The project includes both MATLAB and PYTHON based analysis of MACHINE LEARNING and TDOA algorithm which gives similar results on both WINDOWS and LINUX based operating system , The SIMULATION part is done using MATLAB software on windows , whereas the HARDWARE development is done using PYTHON on linux [RASPBERRY PI 3B+].

The **hardware components** are RASPBERRY PI 3B+, RESPEAKER HAT, ARDUINO UNO, LEDs. The respeaker hat which includes four similar microphones is attached to the microcomputer board raspberry pi 3b+ .The respeaker hat captures the sound signals around it and sends the digital data into raspberry pi where all the signal processing is done. The output is displayed by raspberrypi controlled arduino board, the siren detection and siren direction is displayed using LEDs which are connected to arduino board.

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Chapter 1

INTRODUCTION

Emergency vehicles use sirens and lights to alert nearby cars of emergency. Despite the use of lights and high level sound lots of road users are unaware of emergency vehicles in traffic.
This may be due to several reasons that mainly includes external noise of traffic and internal noise within the car cabin. Externally noisy car engines of old and cheaper cars, Internally the luxury of music, hands free communication system or personal debate that distract driver, that can make a driver inattentive towards the emergency vehicle coming towards him .
Also as the research is faster in all the fields of science, the sound proof materials are available now, many top end cars are made of such sound proof materials that resists the sound [siren / traffic noise] reaching inside the car cabin. This creates a serious problem when an emergency vehicle is rushing towards.
Therefore, the device is very helpful for human drivers, to alert the driver in the presence of an emergency vehicles with the sirens ON when it is approaching from a far distance itself. By automatically turning OFF or lowering the radio volume, the device creates awareness about the emergency. Making drivers alert of emergency vehicles help the ambulance flow smooth and fast without any crashes and collisions in the traffic.
Inspite of alerting the car drivers, the emergency vehicle face a serious problem of traffic signal, most of the delay is created at the traffic signal when the emergency vehicle is stuck in the middle of the traffic and the traffic light is red. This creates a requirement of a device that automatically detects the siren and its direction so that it can turn the traffic signal to green when the siren is approaching towards it in that particular direction.
By knowing the acoustic properties of the siren and the effects of it being emitted by a moving vehicle (The Doppler Effect), it is possible to determine the relative position and direction, thus alerting the drivers of the nearby emergency vehicle, so that they can act accordingly.

Chapter –2

1. Methodology used in project

This gives the clear information about how the model works or the principle of working model. Firstly the four similar microphones records the signals from external environment which are then band pass filtered, the band pass filter used here is a hardware type as the digital filters found to be reducing the efficiency of prediction by giving out similar values of signal features. After band pass filtering the filtered data is fed into Machine Learning algorithm, this algorithm includes feature extraction of the signal as the first step and training, testing the extracted features as the second step. The trained model is now used for real time prediction.

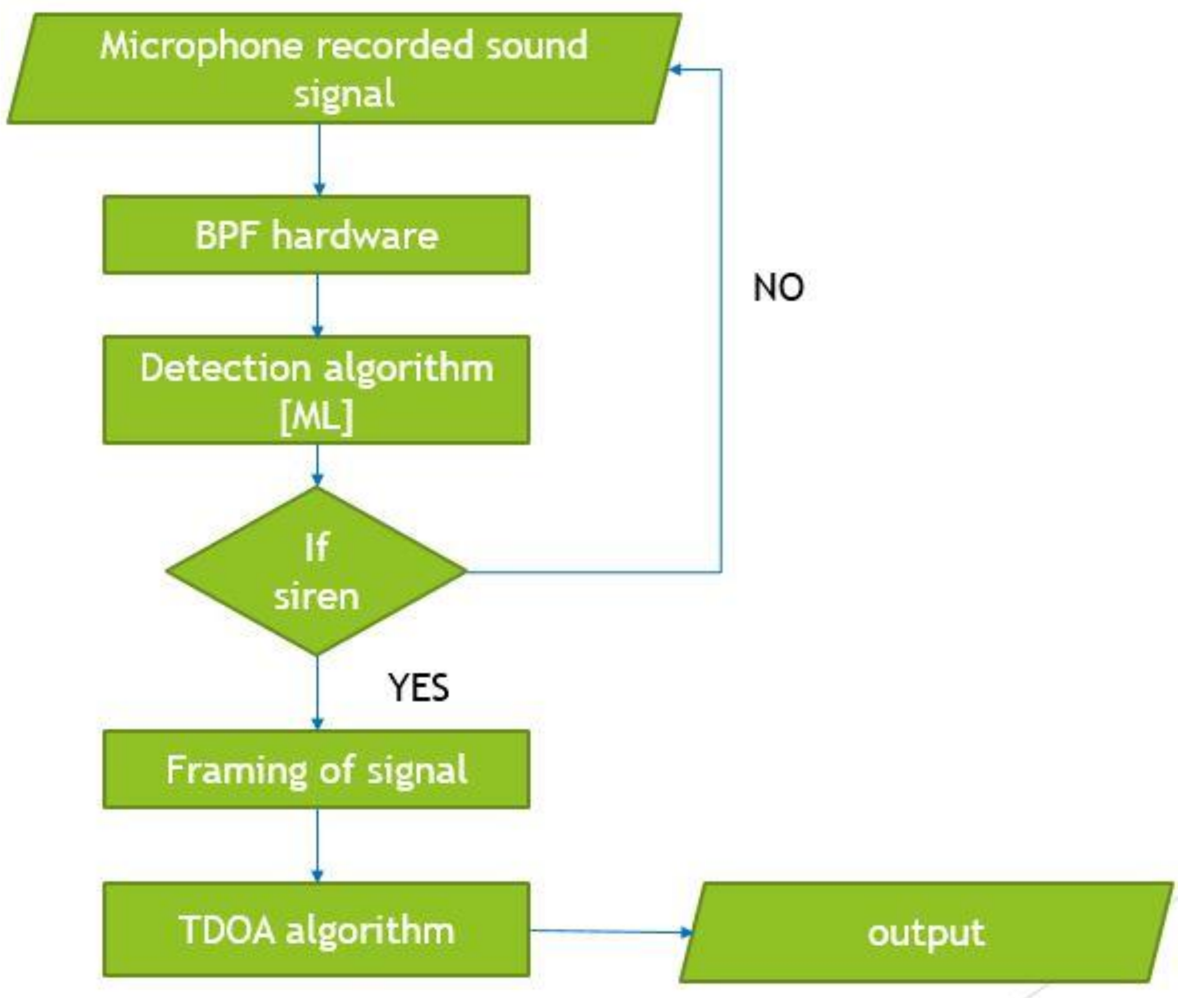


Fig 1: Methodology flow diagram.

The real time prediction is done by once again calculating the same features of the incoming new filtered signal and predicting using the trained model. If the predicted signal is a siren then the signal is sent for framing else the loop is set for new signal recording.

After framing of the signal the four signals recorded from four similar microphone are sent to TDOA algorithm that indicates the direction of arrival. Framing is done to reduce the delay of direction indication and also to increase its accuracy.

Chapter –3

LITERATURE SURVEY

3.1 Systems using acoustic sensors:

[1] Rohini Priya, Anju Joy Jose, Sumathy G, “Traffic Light Pre-emption control System for Emergency Vehicles,” SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE) –volume 2 issue 2 Feb 2015

This system uses acoustic sensor linked to the preemption system. Systems like this override the traffic signal when a specific pattern of wails from the siren of an emergency vehicle is identified. The most advantageous part of this system is that they are fairly inexpensive to implement it in our existing traffic signals and also the ability to use siren which is already installed in emergency vehicles – thus avoiding the need for installing any special equipment. But the complicated part is that the sound waves from the siren can be easily reflected by buildings and other large vehicles present at or near the intersection and this reflected wave may trigger a preemption event in the wrong direction. Yet another disadvantage is that the acoustic sensors can sometimes be sensitive enough to activate the preemption for a siren from too far away or from other unauthorized vehicle with a horn exceeding 120 dB All these systems offered many solutions to the problems from different perspectives. But still other problems are yet to be solved attached to various traffic light pre- emption systems. For example; the narrow range of communication for these systems and decision time based on that range, the repeatedly and unwanted waiting times for other vehicles’ drivers on intersections for the emergency vehicle to pass through and the effect of congested roads, especially during rush-hours, on various pre-emption systems.The automatic traffic light system is that, in case of emergency vehicles like ambulances and fire engines that want to pass by when the signal is red, an automatic voice sensor which is attached to the traffic light that recognizes the siren sound of the emergency vehicles and shifts the red signal to green. This is recognized from 500m distance from the signal. When it is green signaled for the emergency vehicle’s path the other three sides of the traffic is halted. The mechanism that can be used in the sound sensors is that in which the siren sound of the emergency vehicles reaches the maximum level when it is near the signal and then decreases after crossing the signal. When the sensor recognizes the decrease of the siren sound, the normal operation of the traffic light continues.

Voice detection system

The sound of any vehicle is absorbed by the voice IC APR9600 and sent to the microcontroller. As soon as the PIC detects that it is approach of an emergency vehicle the other voice ICs are set to the inactive state for a while till the particular EV passes that IC. It checks whether any of the voice that is absorbed by the voice IC matches with the already saved pattern of the siren. If the pattern matches it will instruct the control system to change the light system accordingly.

[1] Rohini Priya, Anju Joy Jose, Sumathy G, "Traffic Light Pre-emption control System for Emergency Vehicles," SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE) –volume 2 issue 2 Feb 2015

Consideration	Optical systems	Line of Sight System	Radio System	GPS	Sensor system	Acoustic System
Dedicate Emitter Required?	Yes	Yes	Yes	No	Yes	No
Susceptible to Electronic Noise Interference?	No	No	Yes	No	Yes	No
Clear Line of Sight Required?	Yes	No	No	No	Yes	Yes
Affected by weather?	Yes	Yes	No	No	Yes	No
Possible Preemption of Other Approaches	No	No	Yes	No	Yes	Yes
Possibility of Illegal Triggering of Preemption	Low	High	High	Low	High	High
Centralized Traffic Signal Monitoring	No	No	No	Yes	No	No

Fig 3.1 Comparison of Technologies.

3.2 Ambulance siren detector using FFT on dsPIC

[4] Takuya Miyazakia, Yuhki Kitazonoa, Manabu Shimakawab "Ambulance Siren Detector using FFT on dsPIC" Kitakyushu National College of Technology, 5-20-1 Shii, Kokuraminamiku, Kitakyushu, Fukuoka 802-0985, Japan Kumamoto National College of Technology, 2659-2 Suya, Koshi, Kumamoto 861-1102, Japan –issue 2013

Siren Sound to Be Detected

The siren sound of ambulance in Japan is defined by Japanese law. The siren sound repeats two tones. The tones are 960 Hz and 770 Hz, and these are repeated 1.3 sec period. The siren sound affected by the Doppler effect and varies its frequency. The frequency varies up to 1.178 times when ambulance and observer car are approaching at a speed of 100 km/h each other.

Analyzing Method

The siren sound of ambulance has two characteristics. One is that the sound has two different frequencies and the other is that each tone periodically sounds on and off. Using FFT, these two characteristics can be converted into numerical values.

This analyzing method consists of two steps. The first step is analyzing the pitch frequencies. The second step is analyzing the amplitude change frequencies about each pitch frequencies. Both of the two steps used FFT to analyze the frequencies. In first step, the input signal is sound pressure sampled by a microphone. It is sampled in the sampling rate of 2,400Hz and is applied 64 point FFT. Therefore the amplitudes and phases are obtained about each 37.5 Hz bandwidth. In second step, the input signals are numerical values of amplitudes obtained in first step. For each band, the amplitude is sampled in the sampling rate of 2.34 Hz and is applied 16 point FFT. Therefore the amplitudes and phases of amplitude change are obtained about each 0.14 Hz bandwidth.

Determination Method

By using the obtained numerical values, whether the input sound is siren or not can be determined. The characteristics of ambulance siren sound have three particular relations. They appear in the way shown in figure 5 from the reference as shaded areas. These areas have a constant gap of pitch frequency, a same amplitude change frequency, and an opposite phase about the amplitude change. These areas move under the Doppler effect within the square area enclosed by a bold line shown in figure 5 from reference. By checking whether this area contains the areas that satisfy the three relations, the input sound can be determined siren or not.

[4] Takuya Miyazakia, Yuhki Kitazonoa, Manabu Shimakawab “Ambulance Siren Detector using FFT on dsPIC” Kitakyushu National College of Technology, 5-20-1 Shii, Kokuraminamiku, Kitakyushu, Fukuoka 802-0985, Japan Kumamoto National College of Technology, 2659-2 Suya, Koshi, Kumamoto 861-1102, Japan –issue 2013.

3.3 Acoustic Based Safety Emergency Vehicle Detection for Intelligent Transport Systems.

[2] Bruno Fazenda1 , Hidajat Atmoko1 , Fengshou Gu1 , Luyang Guan1 and Andrew Ball1 1 Diagnostics Engineering Research Group, School of Computing and Engineering, University of

Huddersfield, Huddersfield, UK ::"Acoustic Based Safety Emergency Vehicle Detection for Intelligent Transport Systems" , available at :http://usir.salford.ac.uk/9390/ , published on 2009

ACOUSTIC DETECTION-SOUND SOURCE LOCALISATION

The detection of the travelling vehicle is based on acoustic detection of the siren. In order to detect this, a set of microphones are placed on the exterior shell of the passenger vehicle. Directional information is extracted using a microphone array formed of pressure transducers (Omni directional) with a known configuration – in this case a crossed array.

Time Delay Estimation Method

The time delay of arrival for the signal arriving at each microphone is extracted to determine the direction of the incoming source. The technique for determining the direction of a sound source is established using the generalized cross-correlation (GCC) methods as follows. The relative time difference or delay between microphones 1 and 2, for instance, is defined as

$$\tau_{12} = \tau_1 - \tau_2 \qquad (1)$$

The signal at each microphone is modelled as

$$x_i(n) = \alpha_i s(n - \tau_i) + \eta_i(n) \qquad (2)$$

Where τ_i is the propagation time from the unknown source s(n) to microphone i (i=1,2) and α is an attenuation factor due to sound propagation. $\eta_i(n)$ is assumed as an uncorrelated additive stationary Gaussian random noise. Equation (1) is solved by determining the cross-spectrum between signals x1 and x2 with a weighting function Φ(ω). The maximum value of the function coefficient is then extracted using Equations (3) and (4):

$$\Phi(\omega) = \frac{1}{|S_{x1x2}(\omega)|} \qquad (3)$$

$$\tau_{12} = \arg\max_{\tau} \left(\Phi(\omega) S_{x_1x_2}(\omega) \right) \qquad (4)$$

The weighting function Φ(ω) in this case takes the form of the phase transform (PHAT) which has been reported to have greater immunity to the effects of reverberation and performs more consistently for source signals that change over time.

Sound Intensity Method

An alternative method has been investigated comprising of a combination of the microphone signals to form a 2 dimensional orthogonal acoustic probe. This method extracts the incoming angle of a sound source by determining sound intensity vectors in the 2 orthogonal directions (Fig. 3.1). This can be done in the time-domain or using the direct method expressed as

$$I_r = -\frac{1}{2\rho_0 \Delta r} \frac{1}{T} \int_0^T (p_A(t) + p_B(t)) \int_{-\infty}^{t} (p_B(\tau) - p_A(\tau) \cdot d\tau \cdot dt \qquad (5)$$

Where I_r is the sound intensity at the point half way between the line connecting the two microphones A and B. Δr is the distance between microphones. ρ_o and T are the medium density and period of the measurement respectively. In this work, microphones A and B can either be microphone pairs M1/M3 or M2/ M4.

MEASUREMENT

Fig. 3.1 shows the microphone array configuration with a radius of 134 mm. The line connecting the pair M2/ M4 line is established as the array's primary axis - X. All source directions are determined referenced to this axis with angle increasing anti-clockwise.

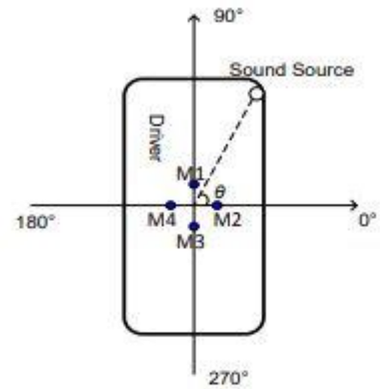


Fig 3.3.1 Plan view of crossed microphone array position and orientation on car.

Two types of sound sources, a random and a typical siren noise, were used for the experimental tests. The source was modelled with a small speaker of 60 mm diameter and its position was fixed at a known distance to the microphone array center point. The microphone array was rotated to acquire the emitted sound for 8 positions representing the main regions of interest. The acquired signals were then passed through the siren signal extraction process to separate the siren from the surrounding noise.

Detection of siren signal

To extract the siren signal, the so-called adaptive predictor noise canceller scheme employing the least mean squared (LMS) algorithm has been adopted and incorporated into the system. Fig. 3.2 demonstrates that the method is capable of extracting the siren signal (Fig. 3.2b) from the background noise.

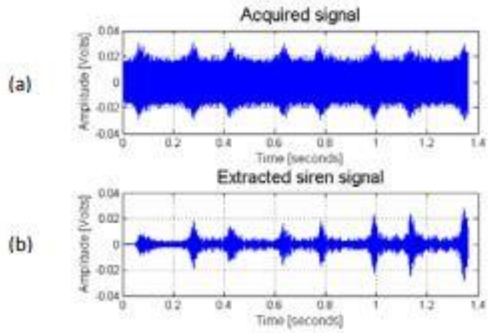


Fig 3.3.2 The acquired signal from the microphone array. (a) The raw signal and (b) Its extracted siren signal

The adaptation process was setup with the following parameters: 10 samples delay, 128 FIR filter taps and 0.25 adaptation step coefficient. Results show that with this particular setup the adaptation process has not fully converged until 1 second has elapsed. However, as the typical signal features of the siren are formed as early as 0.1 seconds, the adaptive method is sufficient to detect the siren source. The extracted siren signals shown were further processed to obtain the source directions using both the sound intensity and the time delay methods described in the following sections.

[2] Bruno Fazenda1 , Hidajat Atmoko1 , Fengshou Gu1 , Luyang Guan1 and Andrew Ball1 1 Diagnostics Engineering Research Group, School of Computing and Engineering, University of Huddersfield, Huddersfield, UK ::“Acoustic Based Safety Emergency Vehicle Detection for Intelligent Transport Systems” , available at :http://usir.salford.ac.uk/9390/ , published on 2009

Chapter –4

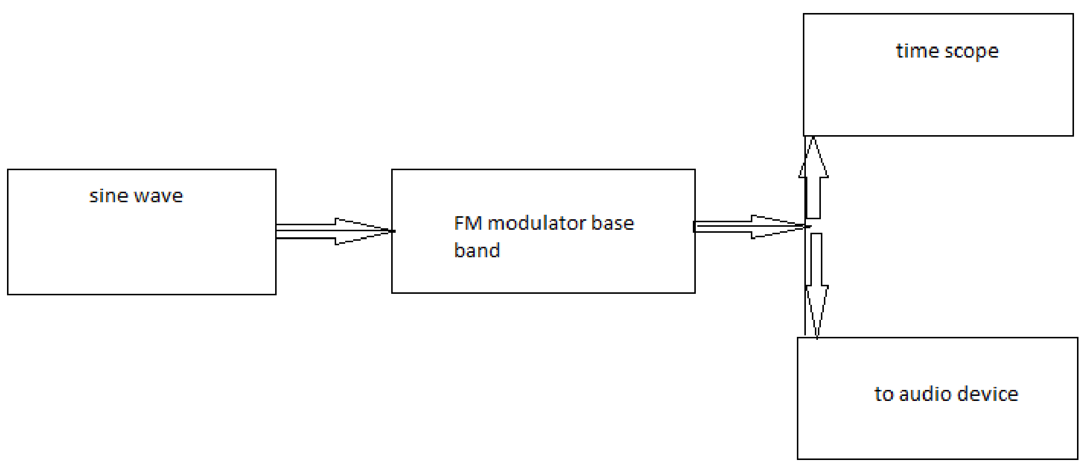
SOFTWARE SIMULATION

4.1 Siren specifications.

- The siren sound repeats two tones. The tones are 960Hz and 770Hz and these are repeated 1.3 seconds period
- The siren sound is affected by the Doppler effected and varies its frequency.
- The frequency varies up to 1.178 times when ambulance and observer car are approaching at a speed of 100km/h each other.

4.2 How to generate siren sound in Simulink and matlab

Siren sound can be generated using FREQUENCY MODULATION technique



Blocks parameters

Sine wave: T=1.3 second; f=1/T=0.769Hz; frequency =2*pi*0.769; sampling time=1/44100;

frequency modulation – fc=865Hz, fd = 95Hz. fc + fd =960 Hz ; fc - fd=770Hz.

MATLAB

y=fmmod (x, fc, fs, deviation) is the matlab function used to generate siren sound of desired frequency range. Basically there are 4 types of ambulance siren sounds .All 4 types can be generated by varying time duration(T) .So that message signal(sine wave) can be changed accordingly , and thus the desired siren type can be obtained.

4.3 Instantaneous Frequency calculation

Basic idea

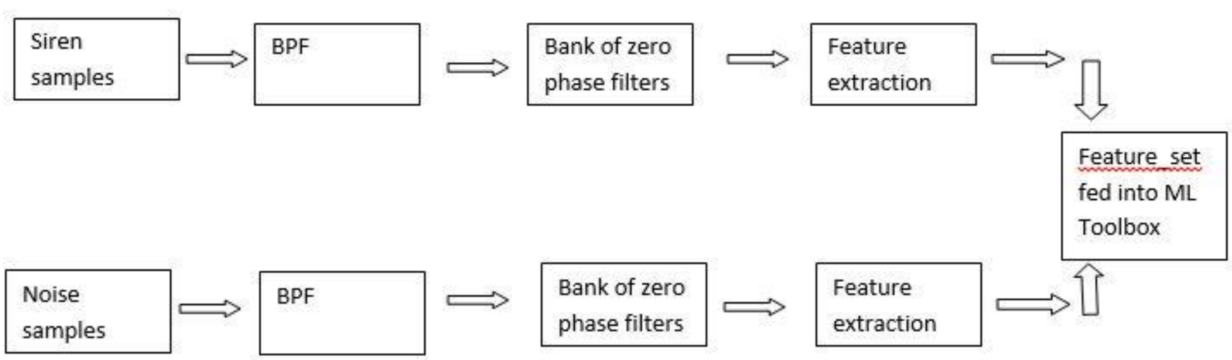
The siren sound from the real world is recorded using recording devices, and fed into the matlab computation that includes instantaneous frequency algorithm. The frequency at every instance of time of a time domain signal can be obtained.

Since the amplitude of the siren is higher compared to the external noise, a threshold amplitude can be set empirically and the frequency value above that particular amplitude can be obtained and verified.

If such obtained frequency satisfies the standard siren frequency specifications we can conclude that it’s a siren, else it is not a siren.

4.4 MACHINE LEARNING TECNIQUE OF SIREN SOUND DETECTION

Machine learning basically sets a threshold i.e., machine learning sets the boundaries between N features sets. Here we collect two sample sets, siren in traffic and noise samples which are passed through filters and features like MEAN, VARIANCE, ENERGY, SKEWNESS, KURTOSIS, of the sample sets are extracted and fed into machine learning Toolbox (it includes all machine learning algorithms).



- First we extract features of siren in traffic noise, so the data is read and passed through a FIR filter using windowing technique. Next is the Decomposition function which is a bank of zero-phase filters.
- The various features like MEAN, VARIANCE, SKEWNESS, KURTOSIS, ENERGY are calculated and fed to form a feature matrix.
- Similarly the feature matrix is developed for the noise samples and both siren feature matrix and noise feature matrix are fed into machine learning toolbox as a feature set.
- The toolbox trains the sampled data and stores the trained model in a classifiers [later this classifiers can be imported], and tests the samples to provide the following outcomes.

4.5 Ambulance arrival direction indication using Time Difference of Arrival technique

TDOA [time difference of arrival] is estimated using generalized cross-correlation with phase transform weighting function [GCC_{PHAT}] because of its significant accuracy for this purpose and its robustness against reverberation.

In GCC technique, spectrum of the cross correlation is divided by its magnitude where the result shows the phase information only. This help in solving the reverberation error that occurs due to the reflections of signal from the solid surface. GCC_{PHAT} for two time domain signals $x_i(n)$ and $x_j(n)$

$GCC_{PHAT}(f) = (X_i(f) . [X_j(f)]^*)/ (|X_i(f). [X_j(f)]^*|)$

$X_i(f)$ and $X_j(f)$ are spectra of signals $x_i(n)$ and $x_j(n)$

Matlab code:

Matlab has a inbuilt function called [**tau,R,lag]=gccphat(sig,refsig,fs)** this computes time delay **tau** between signal **sig** and reference signal **refsig .** To estimate the delay, gccphat finds the location of the peak of the cross-correlation between sig and refsig . The cross-correlation is computed using the generalized cross correlation phase transform algorithm [GCC_{PHAT}].

tau = time delay , R = cross-correlation values , lag= correlation time lags .

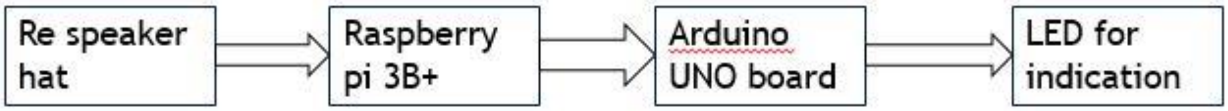
Here 4 signals are taken as input from 4 different microphones of same specifications, out of 4 signals any 1 signal is taken as a reference signal.

The number of cross correlation channels equals to the number of channels in signal [NxM] , N=number of time samples ; M = number of channels in a matrix.

Chapter 5

Hardware Development

5.1 Hardware setup



The sound waves strike on to the four similar microphones present on the re-speaker hat. The re-speaker hat mounted to the GPIO pins of raspberry pi sends the four channeled signal as the input data to the raspberry pi.
The raspberry pi has the machine learning algorithm in python language that starts computing the input data in real time.
The output after computation is displayed using the arduino board and the LED lights connected to the arduino board.
Raspberry pi communicate to arduino board via serial communication protocol using PyFirmata program installed both in raspberry pi and the arduino board.

Fig 5.1.1 Hardware connection.

Raspberry pi and arduino board are connected through usb port and programmable port respectively using a cable as shown in figure 5.1.1

5.2 Used libraries, Software and Hardware.

Hardware: Re-speaker Hat, raspberry pi 3B+, Arduino UNO board, 5 LEDs, USB power cable.

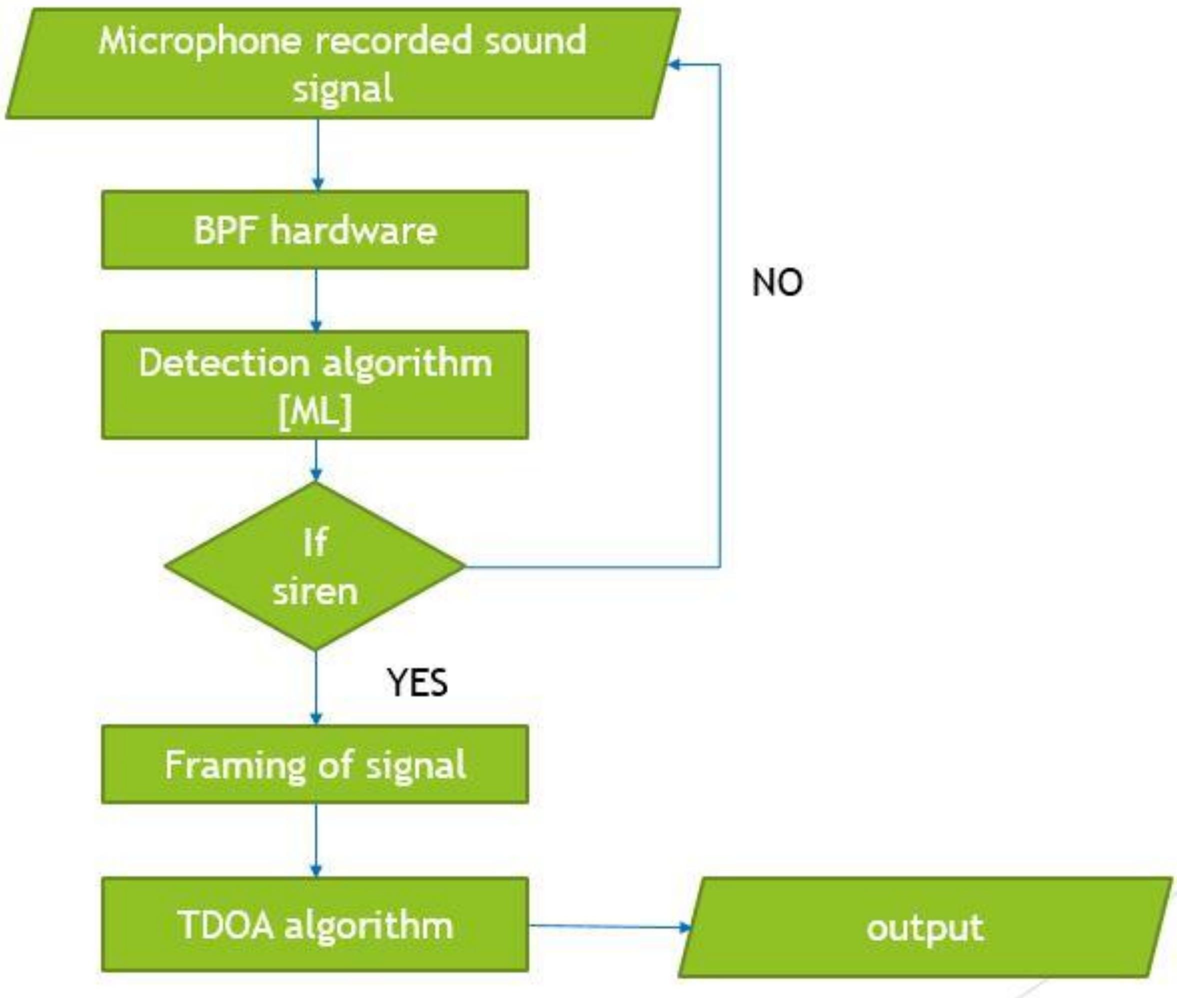
Coding languages: python for raspberry and, C for arduino.

Operating system: Linux based OS for raspberry pi.

Libraries used in raspberry pi: numpy, pandas, sklearn, pickle, scipy.

PyFirmata is python program which can be installed in Arduino and pi to allow serial communication b/w raspberry and arduino.

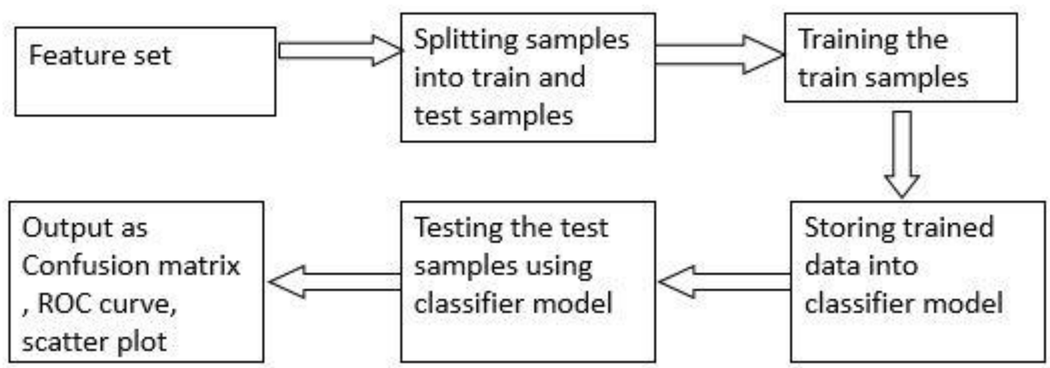
5.3 Methodology



Firstly the four similar microphones records the signals from external environment which are then band pass filtered, the band pass filter used here is a hardware type as the digital filters found to be reducing the efficiency of prediction by giving out similar values of signal features.

After band pass filtering the filtered data is fed into Machine Learning algorithm, this algorithm includes feature extraction of the signal as the first step and training, testing the extracted features as the second step. The trained model is now used for real time prediction.
The real time prediction is done by once again calculating the same features of the incoming new filtered signal and predicting using the trained model. If the predicted signal is a siren then the signal is sent for framing else the loop is set for new signal recording.
After framing of the signal the four signals recorded from four similar microphone are sent to TDOA algorithm that indicates the direction of arrival. Framing is done to reduce the delay of direction indication and also to increase its accuracy.

5.4 Machine learning operation using python



The calculated features of the input signal are used to form the feature set. These feature set are split into training and testing samples. The train samples are now passed through machine learning algorithm like linear regression, KNN, fine tree, logistic regression etc. After the completion of training the trained model can be stored, and this trained model can be loaded back for real time prediction.
The testing samples can be used to test the accuracy of training. Out of 100 samples 70 samples can be set for training and 30 can be set for testing.
To predict the new signal if it a siren or not, similar features of the new signal has to be calculated again and the trained model is loaded for real time prediction.

5.5 TDOA algorithm for direction of arrival indication.

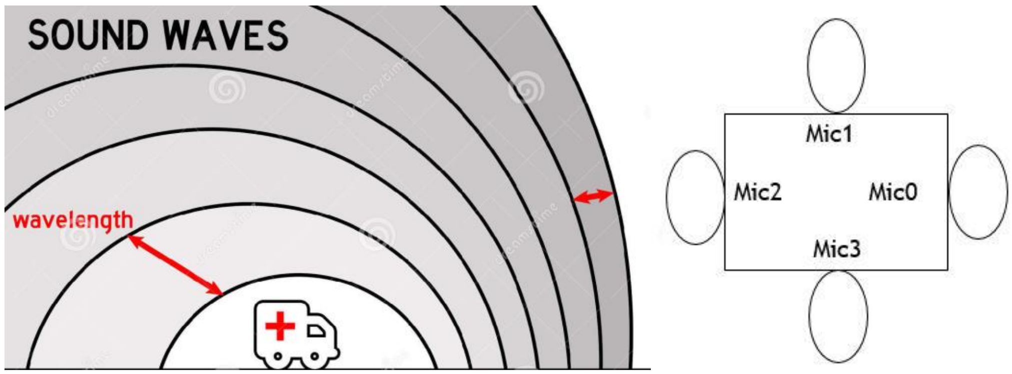


Fig 5.5.1 TDOA [Time Difference of Arrival] demonstration.

Same principle and technique that we used in matlab simulation is used in python language for the direction indication. That is generalized cross correlation using phase transform method.

As we know this algorithm requires one reference signal out of N signals. From figure 5.5.1 out of four signal recorded from four similar microphones at the same time, signal from microphone 1 is taken as reference signal which is auto-correlated with itself to give zero as output and cross-correlated with other three signals to give corresponding negative and positive values.

Chapter 6

RESULTS AND CONCLUSION

6.1 Generated siren sound.

The siren sound is generated using matlab codes. The power spectrum density of the particular sound is obtained as shown below.

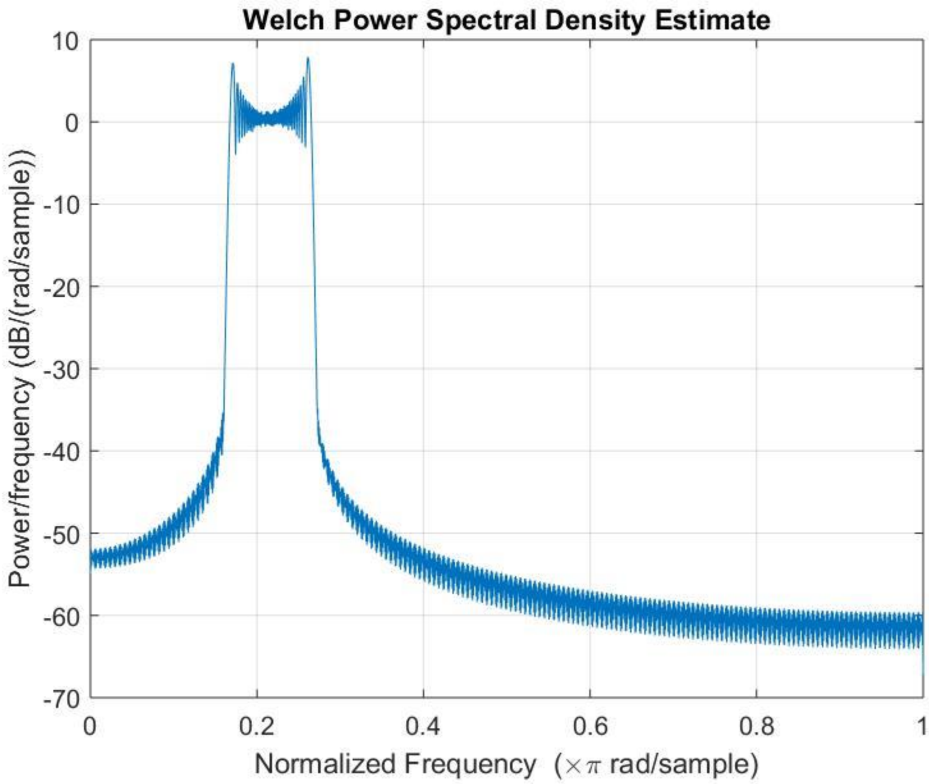


Fig 6.1.1 Spectrum of a Siren of static ambulance

The two frequencies of siren (960 Hz, 770 Hz) are clearly detectable, that can be obtained from Y axis values using the following equation.

x=value at Normalized Frequency

F=(x/half of max frequency)*(fs/2)

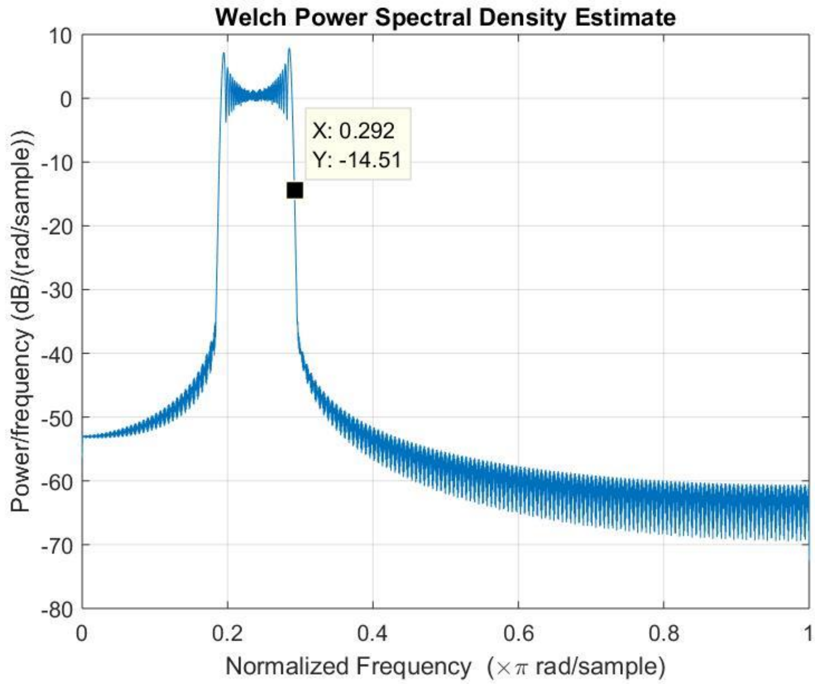


Fig 6.1.2 spectrum of siren of moving ambulance at 120 km/hr.

CONCLUSION

For a stationary ambulance the siren frequencies where in range (960 Hz, 770 Hz) . But when ambulance starts moving the frequency as started changing. Thus frequency of siren sound changes due to Doppler Effect. This creates difficulty in fixing the frequency range to detect siren sound.

Since the sound lies in all frequency range .PSD technique does not give desired output.

So there is a need of algorithm that calculates frequency at every instance of time and amplitude at every instance of time, so that the frequency above certain amplitude value can be obtained as siren sound is highly intense.

6.2 Instantaneous Frequency calculation

Results:

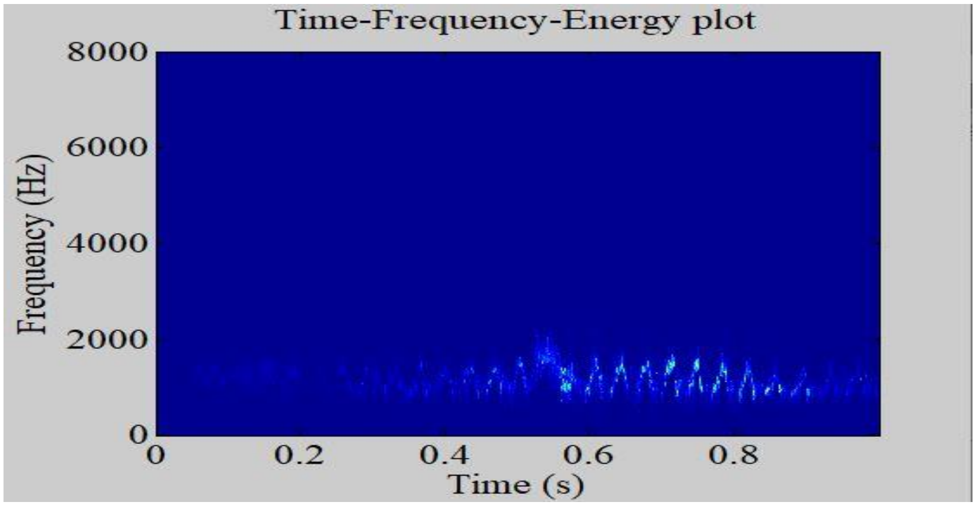


Fig 6.2.1 Recorded siren sound that includes siren sound along with traffic noise. With Output: fmax=1863hz ; fmin=787hz .

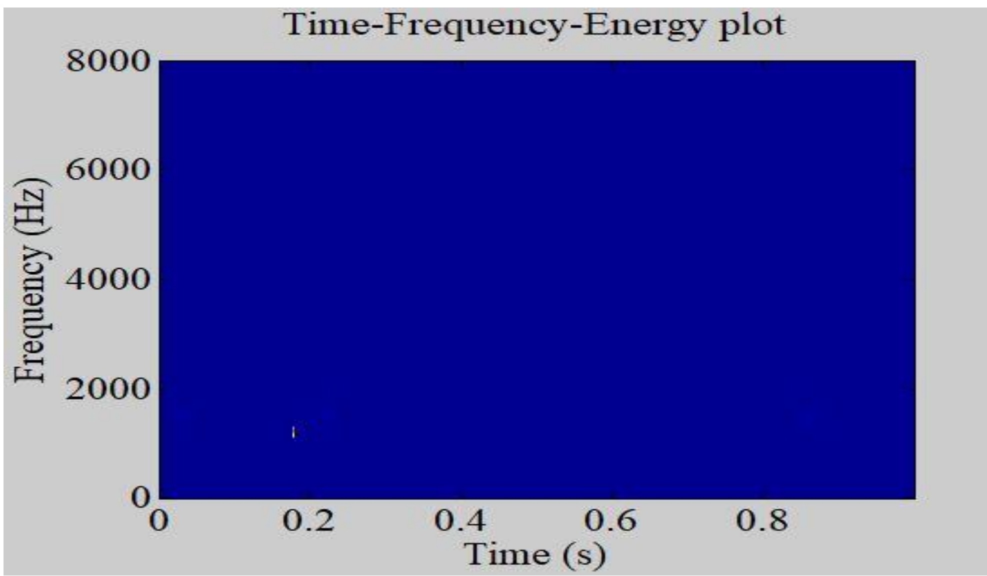


Fig 6.2.2 Recorded siren sound where noise dominates siren sound. With Output: fmax=1639hz fmin=1029hz .

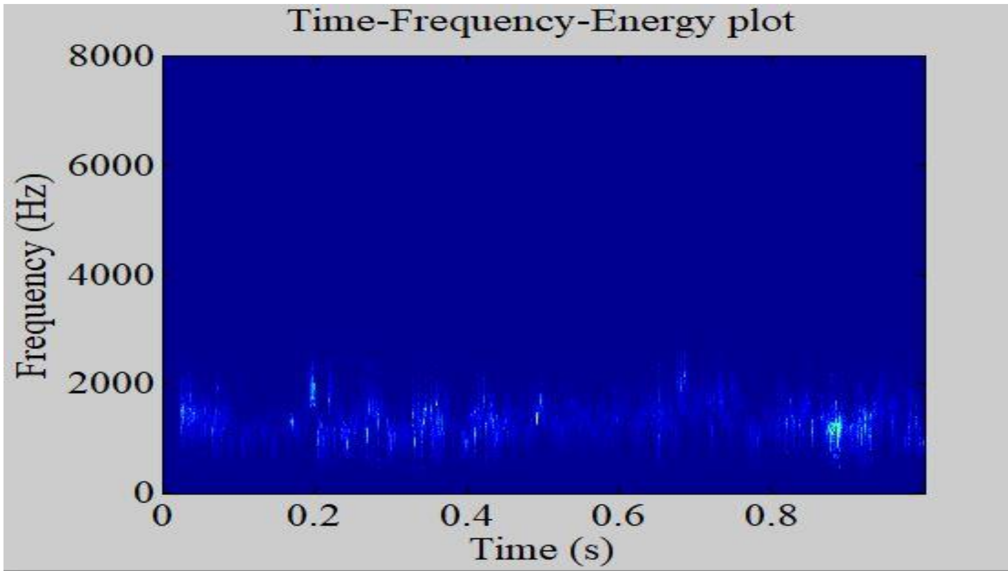


Fig 6.2.3 Recorded noise that included no siren sound. Output: fmax=1475hz ; fmin=815hz.

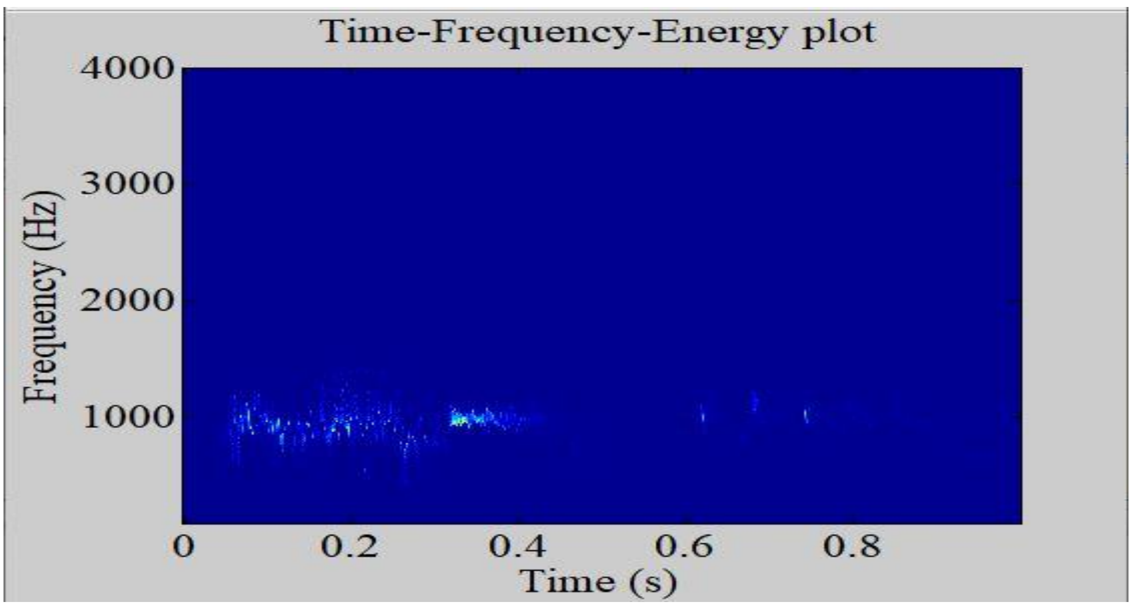


Fig 6.2.4 Real time recorded data with no siren in it. Output: fmax=1063hz ; fmin=822hz .

Conclusion:

- The bright region in the graph indicates the higher amplitude signals. The siren has higher intensity of sound and its amplitude is higher compared to the noise in the traffic, a cutoff for amplitude is set empirically so that above that amplitude the maximum frequency and minimum frequency is obtained.

- For a **matlab synthesized siren sound** the output maximum and minimum frequency where same as that of generated siren frequency. The added noise could easily be removed on passing the data through filter. The output frequency was in desired range, thus the siren sound was easily detected.
- For the **real world recorded siren**, when siren dominated noise the output frequency was in range of standard siren frequency. When noise dominates siren sound the output frequency was out of range of standard siren frequency. Also for some recorded sound with high siren sound than noise the output frequency was not in range of standard siren frequency. This creates difficulty in setting up the threshold (ratio of max and min frequency).
- When the real time sound input is taken to the system and applied with instantaneous frequency algorithm the output frequency was almost same for the data with siren and without siren this may be because the noise is present at all frequency. So this technique does not predict the siren sound. So we must move to machine learning technique.

6.3 MACHINE LEARNING TECNIQUE OF SIREN SOUND DETECTION

Results:

1) Fine tree algorithm giving 100% accuracy.

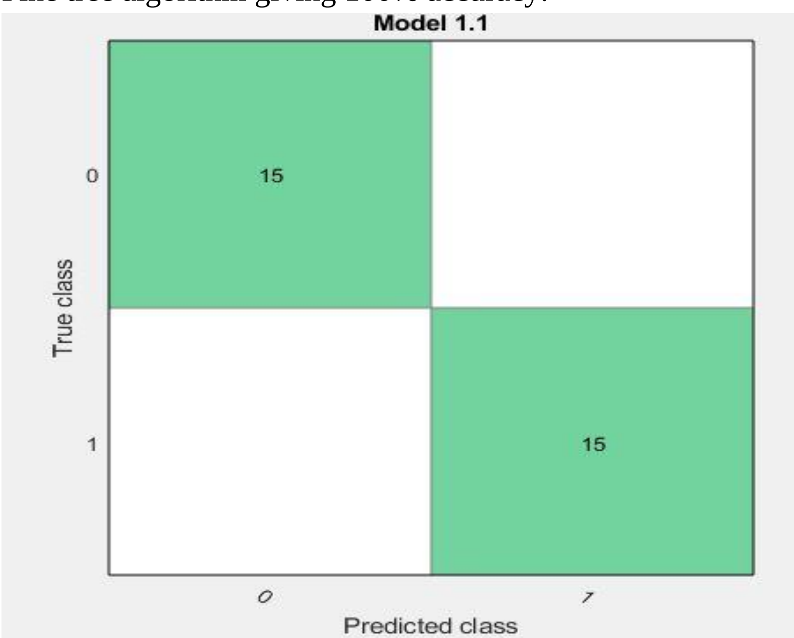


Fig 6.3.1 Confusion matrix

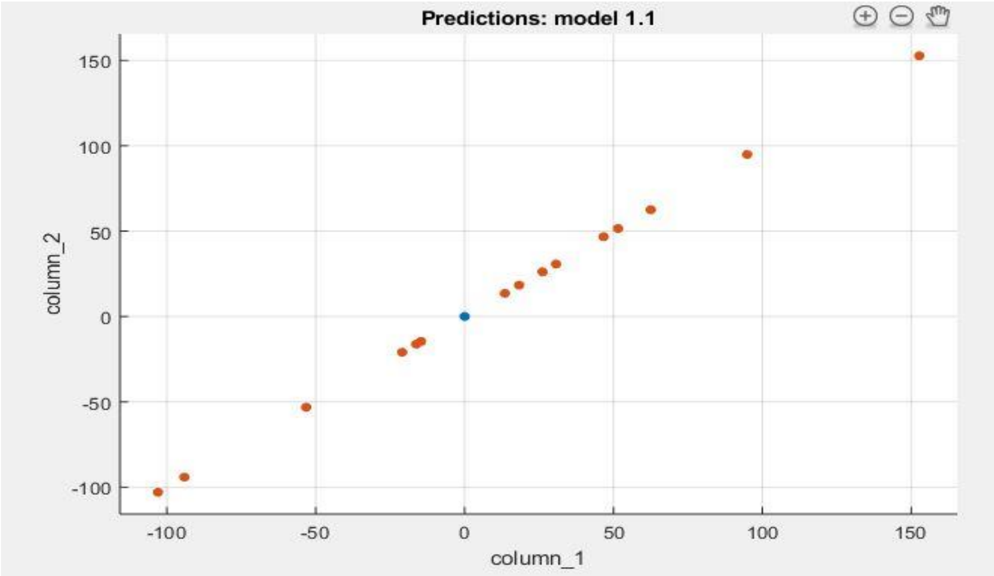


Fig 6.3.2: Scatter plot

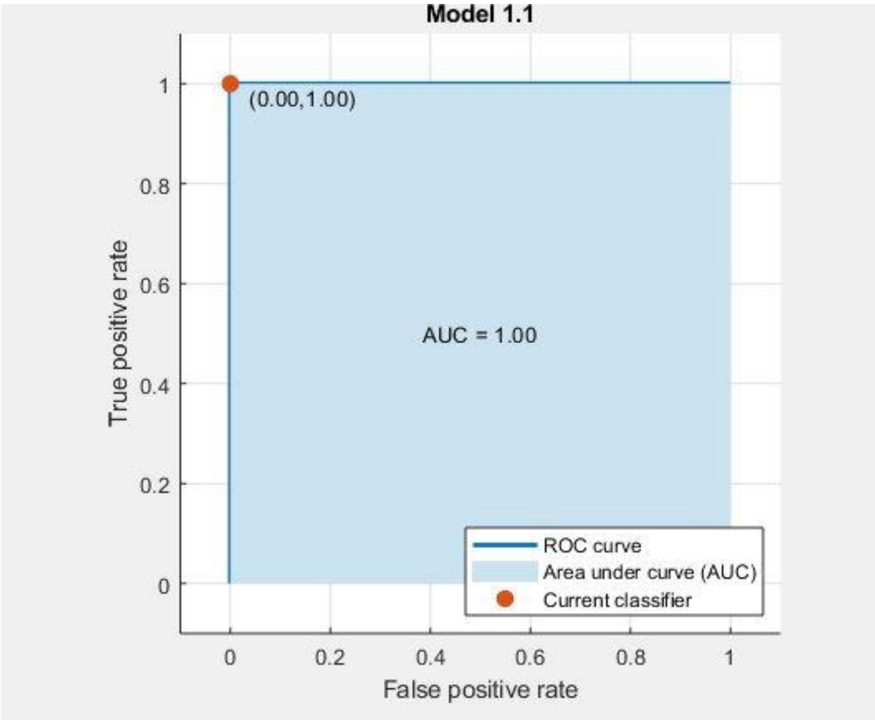


Fig 6.3.3: ROC curve.

2) Logistic Regression algorithm giving 86.7% accuracy.

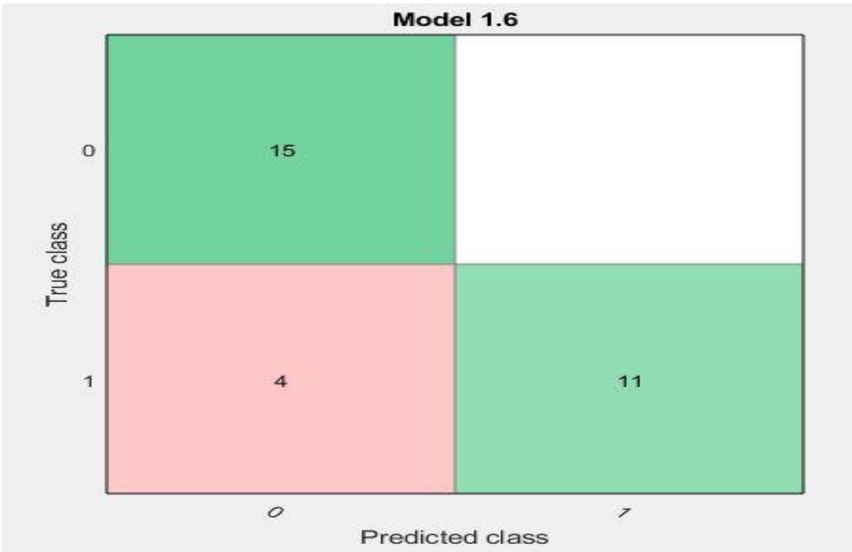


Fig 6.3.4: confusion matrix.

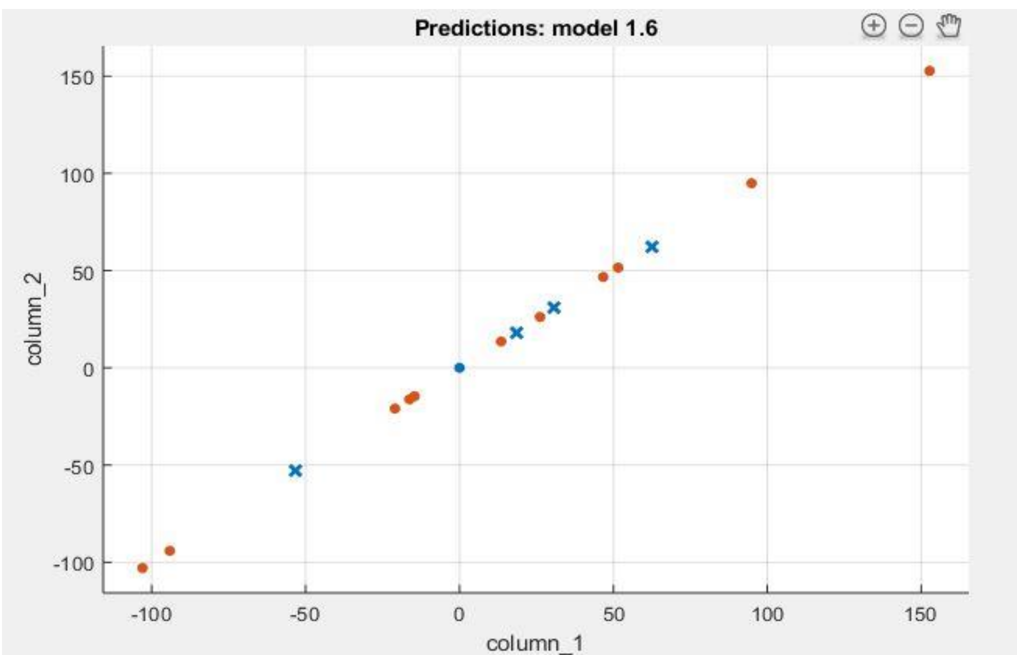


Fig 6.3.5: scatter plot.

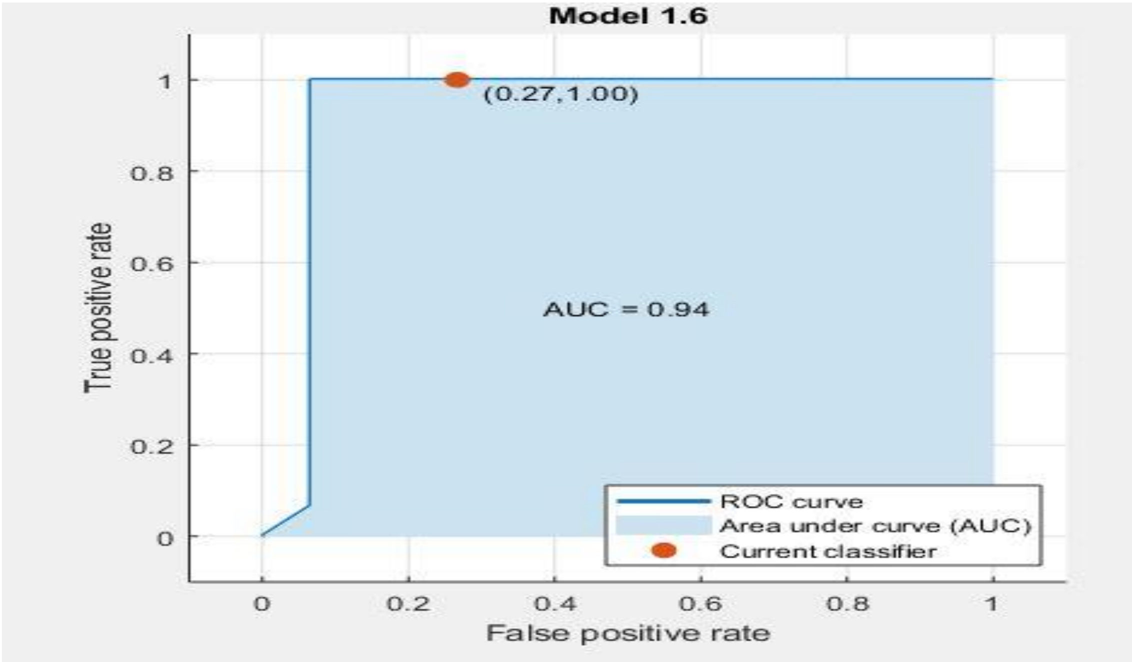


Fig 6.3.6: ROC curve.

Conclusion:

- Figure 4.4.4: Here 0 is siren and 1 is not a siren/noise, out of 15 siren samples all the 15 samples are correctly identified as siren by the algorithm, and out of 15 noise samples 11 were identified as noise and rest 4 samples were falsely identified as a siren.
- Figure 4.4.6: Here 0 is noise/not a siren and 1 is siren (0.27,1.00), It shows[0.27 , 1.00] the 100% chance of identifying it as a siren for siren samples added to it , 27% of chance of identifying it as a siren and 73% of chance to identify it as a noise for the noise samples added to it . Finally the algorithm is 86.7% accurate.
- As the number of input samples increases the accuracy of siren detection also increases. Figure 4.4.1-4.4.3 give an example of 100% accuracy.

6.4 Ambulance arrival direction indication using Time Difference of Arrival technique

Results:

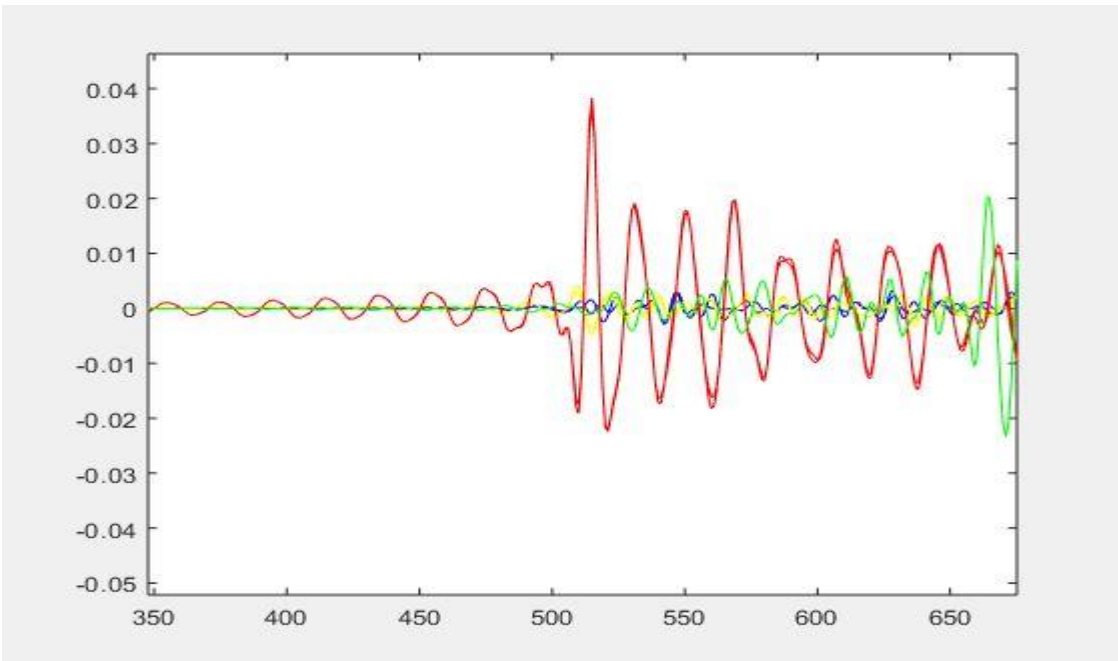


Fig 6.4.1 Signal waveforms of four signals.

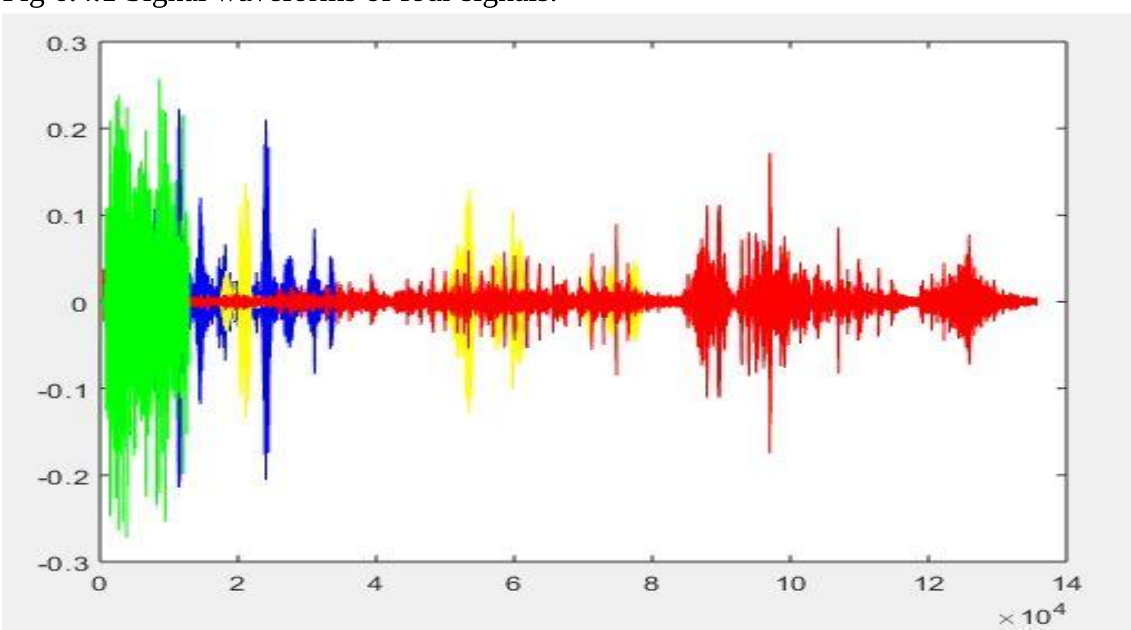


Fig 6.4.2 Four input signals

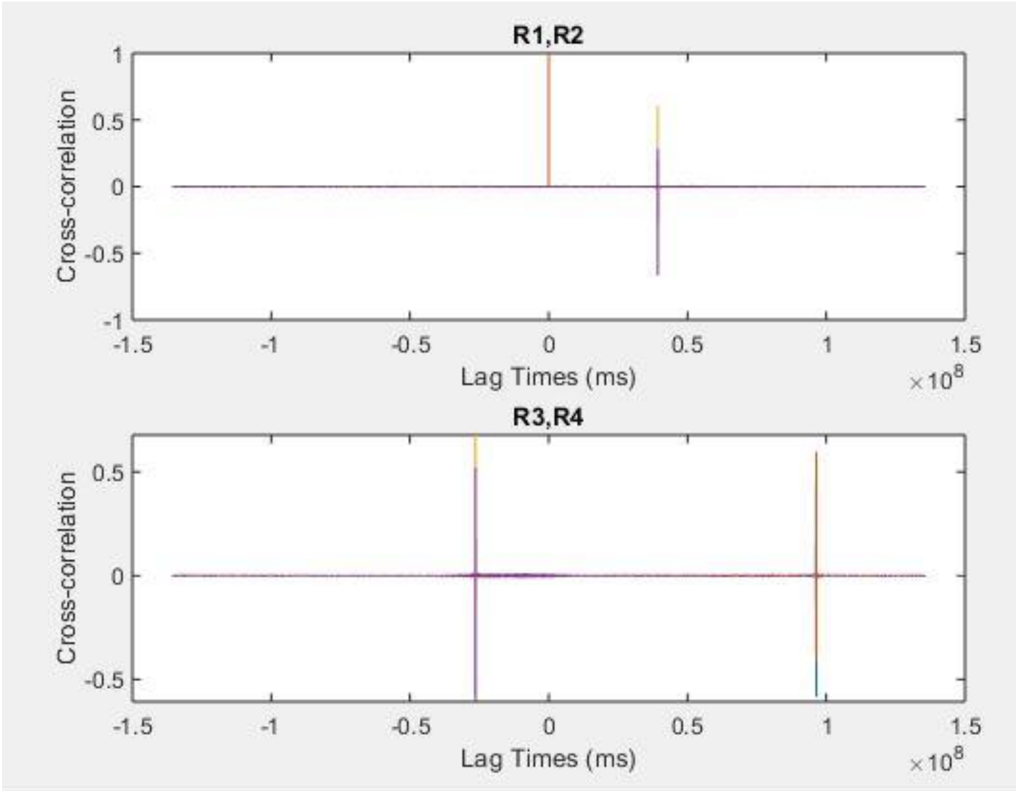


Fig 6.4.3 Cross-correlation [R] plot

Conclusion:

One of the four signals is taken as a reference signal, reference signal is cross correlated with other three signals and auto-correlated with itself to give a bell shaped curve at the particular lag times as shown in the graph. The signal from the respective microphone gives its time delay value as output, and the signal with least time delay value is the microphone that receives the sound first out of all four microphones, and thus the direction is determined.

6.5 Hardware part results

Conclusion of logistic regression ML algorithm

Confusion matrix obtained after machine learning training and testing has the accuracy of 82.4%. The classifier model is stored and used when necessary for real time prediction.

Conclusion after TDOA computation

Mic0= 2.375

Mic1=0.0

Mic2= -0.9375

Mic3 = 1.5625

Sound signal strikes at mic2 first and hence the least correlated value. The mic with least correlated value determines the direction of the source. So we can conclude that the emergency vehicle is approaching in the direction towards which the mic2 is placed.

To avoid false detection from initial stage framing is done after siren recognition.

Chapter 7

APPLICATIONS AND ADVANTAGES

The created device can be modified to many *Applications* like

- The automatic gate open and close system when the siren move towards and away from it , which can be used in remote place with harsh climatic conditions where humans cannot work effectively.
- An autonomous vehicle that can guide itself without human conduction pave the way for future systems where computers take over the art of driving. Such systems require a component that guides it to move towards safe direction when emergency vehicle approaches towards it.
- A person lacking the power of good hearing who may be a car driver or a traffic police can carry a device that indicate the presence of an emergency vehicle at his surroundings .
- Integrating traffic signal along with such a device help to reduce the delay created in the traffic for an emergency vehicle in reaching its destination.

Chapter 8

CONCULSIONS AND SCOPE FOR FUTURE WORK

The software model obtained has 100 percent accuracy, But when it is developed as a hardware model it is seen that the machine learning algorithm is having 82 percent accuracy. This accuracy can be improved by using high sensitive microphones so that very characteristic of a sound can be obtained. Also the voice recognition features like mfcc , cepstrum , zerocrossing kind of feature analysis help in improving accuracy.

The device can be upgraded by interfacing with different components in master and slave mode that can be used in N different applications.

Chapter 9

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