IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727
PP 43-48
www.iosrjournals.org

Sensing, Processing and Analysis of Low Frequency Sound and Footfall Vibration for Detection of Intruding Elephants

Dibin G.
Department of Electronics and communication Engineering
Government Engineering College Wayanad
Thalappuzha, Wayanad-670644, Wayanad, India
Email: dibingangadharan007@gmail.com

Dr. Thajudin Ahamed V. I
Department of Electronics and Communication Engineering
Government Engineering College Wayanad
Mananthavady-670644, Kerala, India
Email: thajudin@gecwyd.ac.in

***Abstract*—In this literature review, discussing several methods to detect elephants before they are entering to human vicinity to prevent the Human-Elephant Conflict (HEC). Here focusing on the detection of elephants producing lower frequency sound and their foot-fall vibrations. There have different feature extraction methods such as Greenwood Function Cepstral Coefficients (GFCC), Mel-Frequency Cepstral Coefficients and Fourier Bessel Cepstral Coefficients (FBCC), etc. Aim of this literature review is to identify better feature extraction method for identifying elephant rumbles and foot-fall vibrations from the practical noisy environment. This paper also discussing about different classifiers using such as Artificial Neural Networks (ANN), Support Vector Machine (SVM), Hidden Markov Models (HMM) and Linear Predictive Coding (LPC). If we can detect the sound and vibration of the elephant it will be the best solution for HEC. Considering the sensor network concept to improve the accuracy and the coverage area of the system. Here also considering the possibility of self-thinking ARFID based Radio Collars to improve the life span of it.**

***Index Terms*—Rumbles, Foot-falls, Feature extraction, GFCC, MFCC, FBCC, ANN, SVM**

I. Introduction

Man animal conflict is a huge problem faced in the villages and other places bordering the forest. We are focusing on man elephant conflict in Wayanad where our college situated. Elephant, wild boar, gaur, sambar deer, spotted deer and bonnet macaque are major crop raiders. Elephants, wild boars and tiger attacks causing human causalities and death. Elephants were responsible for 75.85% of the crop raiding and human death in Wayanad. We cant predict the arrival of elephants[17]. Primary need is for an alarm system to inform people when an elephant is straying towards a village. There are several instances in Wayanad of elephants causing damage to crops and property and attacking people. If a system can raise an alarm when elephants are crossing a particular forest limit, then people can take precautions. There have several techniques for avoiding human elephant conflict but nowadays they are not working properly or elephants are destroying it with their intelligence [18]. The Indian elephant (Elephas Maximus Indicus) is one of three recognized subspecies of the Asian elephant and native to main land Asia. Indian elephant reach 2 and 3.3 meters shoulder height and between 2,000 and 5,000Kg weight[21]. As both the hind foot and front foot are of the ground at same time. This gait has been likened to the hind legs and frond legs taking turns running. They start this run at only 8Km/hr. Elephants can reach speeds up to 40Km/h all the while using same gait [21].

About 10,000 people living inside the pockets inside the sanctuary. There are different types of existing methods to overcome the Human Elephant Conflict (HEC). Passive solutions like electric fencing and trenching are more expensive and nowadays damaging by elephants. Active solutions like motion sensor and IR cameras have less coverage area and they are using only in some particular locations where elephants come most often. Most efficient method is the radio collar technique; it can provide the location of the elephant in a particular interval of time. But it is the most risky technique. radio collar can set to an elephant only after capturing it and also tranquillizing an elephant may cause to the death of it. So government needs to give special permission for attaching a radio collar to elephants. Because of these disadvantages of the HEC solutions we are trying to detect the presence of elephant using the features of them. Elephants are large mammals and they are making lower frequency sounds and also have infrasound components which can travel several kilometers. Rumble is the sound which producing by elephants most often. Rumble sound frequency range is 5-500 Hertz, with 85 to 90 decibels magnitude. Spectrogram [6][9] of the rumble is shown in figure 1, and we can see that it have a curve shaped features of high energy in a frequency range of 5-500Hz roughly. Many papers are based on the feature extraction of Rumble sound produced by the elephants. Elephants are also making vibrations on their footfalls because of their weight. Detection of this vibration is very difficult, but if possible to detect it will be a better detection model. Each material has its own natural vibration frequency. Vibrations produces harmonics and some of them will loss due to the distance travelling and the medium properties.

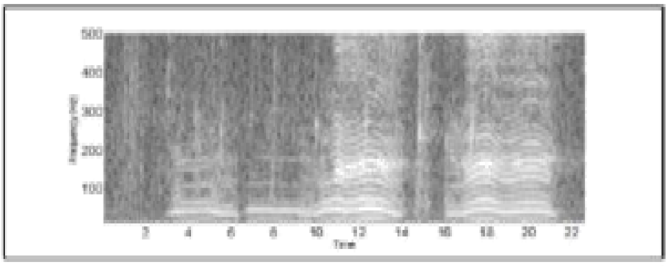

Fig. 1. Spectrogram of rumble

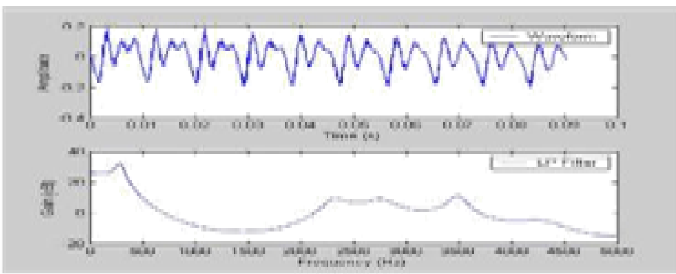

Fig. 2. Time domain signal and corresponding formant frequencies

II. RELATED WORKS

Formant analysis method is mainly using to extract features from the sound signals produced from vocal tract[4]. Considering the elephant rumbles, vocal cords vibration makes sound and it travels through the cavity of the skull and trunk of elephant. V. Wijayakulasooriya is discussing about the formant feature extraction in his paper. Elephant calls can be recognize by analyzing the resonant frequency of vocal track which is called Formants. Figure 2. shows the time domain signal and its corresponding formant frequencies.

From experiments using elephant calls revealed that the near formants are nearly stationary or they are overlapping. The features f1 and f2 can be calculated by

$$f_1 = \mathrm{STD}\left(\frac{F1}{F0}\right)$$
$$f_2 = \mathrm{STD}\left(\frac{F2}{F1}\right)$$

One of the most commonly method for voice feature extraction is the Mel Frequency Cepstral Coefficients (MFCC). In several papers discussing about the MFCC, and it is the extended cepstral coefficients extraction method by including the property of human ear[7]. A Mel Frequency filter bank is using to correct the human ear perceives sound intensity dependence on frequency by converting the f[Hz] into the f_{mel} [mel], which is based on human hearing. The relationship is

$$f_{mel} = 2595 \log_{10}\left(1 + \frac{f}{700}\right)$$

Figure 3. shows the behaviour of the function

Mel Frequency filters have linear scale in the triangular shape with overlapping as shown in figure 4.

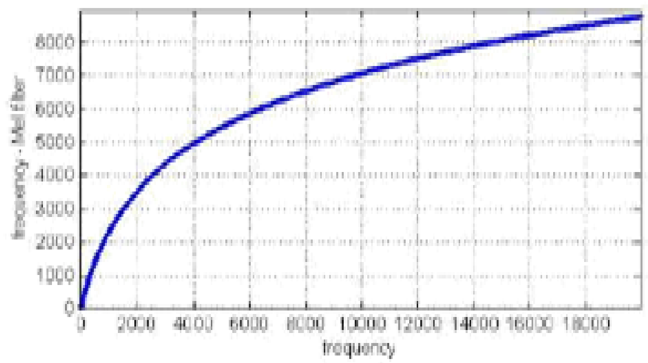

Fig. 3. Characteristic Mel-frequency [mel] and frequency [f] domains

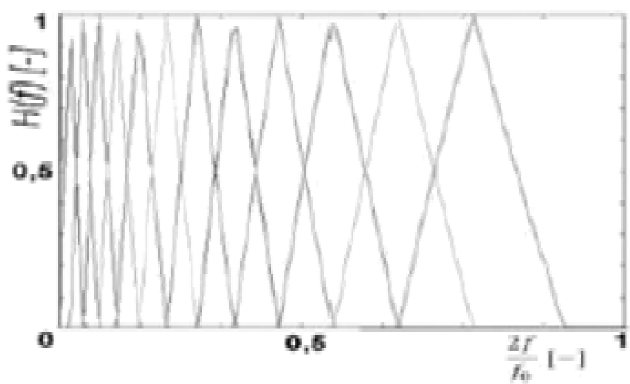

Fig. 4. Mel filter bank

In the MFCC feature extraction the signal is framing using a moving window and Pre-emphases it. After that the signal passes through a Mel Frequency Filter bank and takes its logarithm. The Discrete Cosine Transform (DCT) is using to bring the higher energy coefficients to the top.

Greenwood Function Cepstral Coefficients (GFCC)[1][2] is a well using feature extraction method for mammal's sound recognition. Greenwood states that mammals perceived frequency on logarithmic scale along the cochlea. And also modelled a relationship by the form of equation

$$A\left(10^{ax} - k\right)$$

where a, A and k are species-specific constants and x is the cochlea position. For the case of elephants the x is found as 0.88 from experiments using a number of rumbles. GFCC can be implemented by replacing the Mel Frequency filter bank with using the Greenwood frequency filter bank. All other procedures are same for the MFCC and GFCC.

In some voice recognition applications Fourier Bessel cepstral Coefficient (FBCC) method replacing the MFCC. Bessel function is considering for the damping model signals and voice or sound signals are considered as such damping signals. In the FBCC the difference between MFCC is, in FBCC the framed signals are transforming to corresponding Fourier Bessel Coefficients instead of performing Discrete Fourier Transform (DFT)

Artificial Neural Network (ANN) is one of the most commonly using classifiers[2]. Classifiers are using for training the system by giving test data features of true and false samples of the object. The ANN consists of input, output and hidden layer neurons. In ANN classifier training time we need to set 1 for the rumble sound and 0 for the false data. The Neuron Network can be construct using the MATLAB 2013. In ANN the given test data is passes through feed forward neural network for training the network using back propagation algorithm. Efficiency of ANN increases with the increase in the number of Samples.

Hidden Markov Model (HMM) can be used for classifying the features[2]. Hidden Markov Model is a doubly stochastic process of N number of finite states $P=(P_1, P_{2...}P_N)$ which can be observed through another stochastic process set which makes M number of observed symbols $R=(R_1,R_2,..R_M)$. The HMM ($\lambda=(A,B,\pi)$) consists of three probability models, State transition probability distribution (A), observation symbol probability distribution (B) and initial state probability distribution. Support Vector Machine (SVM) is an another classifier[2] which is supervised learning model with associated learning algorithms that analyze data used for classification and regression analysis.

For detecting and sensing the foot-fall vibrations of elephants first need to select a good geophone or vibration sensor. MFCC and Envelop shape features can be considered as the feature extraction method for vibration detection. Small cost piezoelectric sensor[16] and MEMS based accelerometers[15] are used for vibration detection in some other applications. Some harmonics of the vibration will lose due to the distance between sensor and object and due to the medium absorption.

Current radio collar techniques facing a main challenge of less life span of the collar. Current GPS/GPRS collars can active only 6 times in a day to get a life span of 2years[22]. If the collar is only activating when the elephant is near to our vicinity we can improve the battery life.

III. SUMMARY OF FINDINGS

Most of the referred papers are considering noiseless sound signal and not applicable to the practical noisy environment. From these papers we can conclude that the sensor part is the most challenging in the sound and vibration based animal tracking. For elephant rumble detection the GFCC is more useful than using the Mel frequency filter bank. If we are using more features we can increase the accuracy but it may reduce the speed of the system. If we can detect the sound or vibration of the elephant using a high sensitive sensor, there have a large possibility to do this system as practical. If we have more number of samples then ANN or its updated classifier techniques are most suitable. When considering a sensor network the system can improve the accuracy and the detection area.

Fig. 5. Rumble sound detection system placement

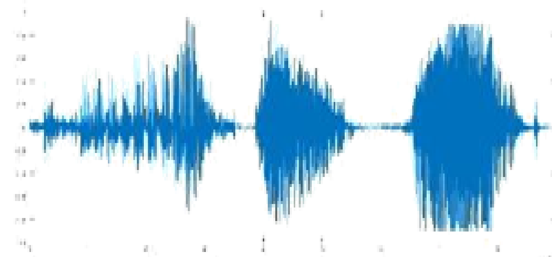

Fig. 6. Rumbling sound

IV. EXPERIMENTS

A. *LOW FREQUENCY SOUND DETECTION*

We have information about the low frequency signal in the elephant rumbles which can travel some kilometers. At the starting of our experiments we collected some samples of elephant rumbling sounds to verify the higher energy frequency components of elephant rumbles. By using the Fourier transform calculation of each rumbles we verified that the higher amplitude frequency components or pitch of the rumbles is in between 5 to 500Hz. Because of the lower frequency detection application in the noisy environment we need to identify the better microphone. Desired frequency range is 5 to 500Hz which combines both the infrasonic region and audio signal region.

Our ordinary microphones are designed for audible frequency which is 20Hz to 20 KHz. For the desired frequency range either we need to use both infrasonic microphone and ordinary microphone parallel or design and make one for the particular range.

For the elephant rumbling detection from the noisy environment we are using the Fourier Bessel cepstral coefficients (FBCC) of the sound frames. At first we are framing the audio signal to 30Sec with 50

For these each frames calculating the Fourier transform version by using FFT. In this we can see many frequency components other than the lower frequency range.

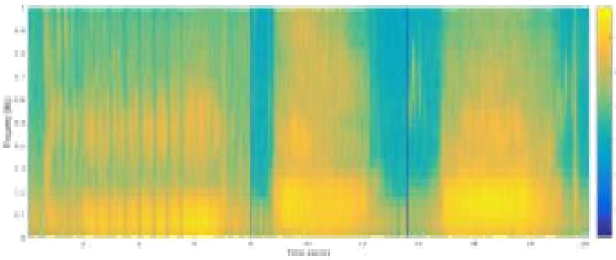

Fig. 7. Spectrogram of rumbles

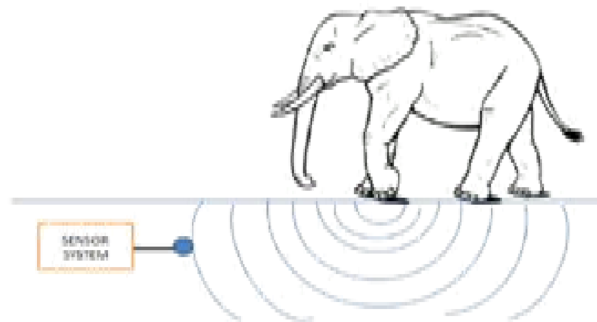

Fig. 8. Footfall vibration detecting system placement

Now we are going for the spectrogram of the signal to obtain the relation among the energy, frequency and time. Here we can see that the more energy containing frequency components are low frequency, and also noticeable that the rumbling sound is in the shape of logarithmic scale in the spectrogram.

Next step is, to enhance the spectrogram to filter the higher energy components. Here we are finding the gradients of the spectrogram and some enhancement processing like smoothing, tensoring, and finding Eigen values and weighting these values. The tensor is defined

This enhanced spectrogram is passing to the greenwood filter bank. The greenwood filter bank is designed as the elephant vocal tract with specific coefficients. Greenwood found that each mammal has its own difference in the producing sound frequency in logarithmic scale along their cochlea. And he modelled the relationship with the equation.

$A(10^{ax} - K)$

Here a, A and K are species specific constants and x is the cochlear position. With using this equation define a frequency warping through the following equations for real frequency f and perceived frequency f_p.

$F_p(f) = (1/a) log10 (f/A + K)$

The constants a, A and K are the frequency cochlear position data which is available. Here greenwood tells that the value of K for elephants is 0.88. With using the known information about the minimum and maximum frequency of the elephant rumbling sound he derived equations to determine the constants a and A. The hearing range of $(fmin fmax)$ determines the a and A.

A = fmin/1 - K

a = log10 $(fmax/A + K)$

This filter bank will filter out the signal more selectively in less frequency region than higher. For computation of cepstral vectors we are taking the Discrete Cosine Transform (DCT) of the logarithm scaled version of the enhanced spectrogram sequence.

The aggregated features of the known rumbling sound and known noises are using for the training of the system. Rumbling sound is giving as the positive class and the noise samples as negative class. The numbers of background noise samples are more than the number of information samples. We have chosen the State Vector Machine (SVM) as detector for the following reasons.

1) SVM is computationally efficient for novel data detection application and for an automatic detection.
2) We have fewer samples of the elephant rumbles than the noise samples.

B. FOOT-FALL VIBRATION SENSING

There are many literatures talking about the ability of elephants to communicate using the footfall vibrations, and sensing of other elephants path by identifying the footfalls. There is no specified data about the footfall vibrations other than it is a low frequency signal. Because of the higher attenuation rate of soil we need to use a highly sensitive vibration sensor at the end.

The first experiment is to identify the better vibration sensor from the available. We checked piezo electric sensor, accelerometer, SW-420 vibration module switch and disc type piezo electric sensor. We used the all sensors in the same work bench surface and produced same amount of knock and observed the output. Finally we verified that piezo electric sensor using in 8105 hydrophone is better sensor among them.

Hydrophone Type 8105 A small spherical transducer for making absolute sound measurements over the frequency range 0.1 Hz to 160 kHz with a receiving sensitivity of 205 dB re 1 V/Pa. It is rugged, being capable of withstanding pressures of up to 107 Pa (100 atm.; 1000 m (3250 ft.) ocean depth). This hydrophone has excellent directional characteristics; at 100 kHz, it is omnidirectional over 360 in the x-y (radial) plane and 270 in the x-z (axial) plane.

Now we are going for object and position identification using this piezo electric sensor. Before going to the field work we are going for identify the known object from the vibrations through test bench. Here we used a wood table as the vibrating surface and some known objects as free falling vibration source. At first we will use only one object from different height and distance by taking one as constant to calculate the amplitude of the vibration from different heights.

From the experiment observed that, if the height of the object falling increases the amplitude of the amplitude of the

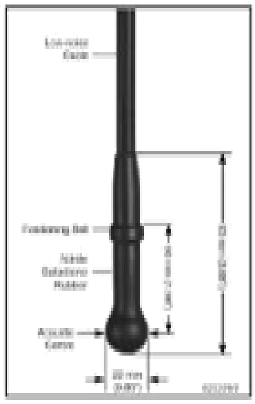

Fig. 9. 8105 hydrophone

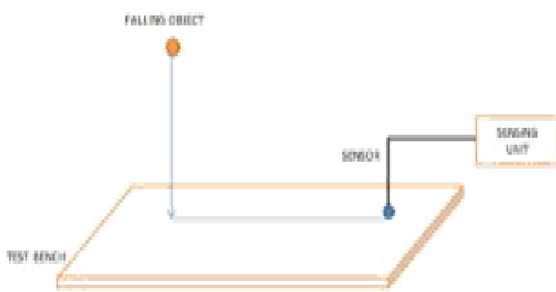

Fig. 10. Table based experiment setup

vibrations increases proportionally. When the distance of the object falling point increases, the amplitude of vibrations are decreasing proportionally.

Now we collected the output data of the sensor by using the free fall of different objects in different heights and distances. Then converted these signals to frequency domain using the Fast Fourier Transform (FFT). And observed that all the frequency components are in less frequency range. If the distance is increasing some frequency components are changing and disappearing. For all material and object falling time, one frequency component is common in higher amplitude, which is in the 39Hz (approximately). When the falling material is changed in the same wood table some frequency components are changing. So we are assuming that 39Hz may be the natural frequency of the wood table. And more frequency components are with respect to the vibrating falling source. And also there have some frequency components shifting when the area of impact is changing. Here we came to a conclusion that if we can understood the vibration noise frequency and natural frequency of vibrating body we can filter those frequencies and there have a chance to identify the object information. And also with using more than 3 sensors we can determine the direction of the source iff we got the correct relationship between height, distance and mass of the object.

Vibration through one material will pass through the neighboring material in contact. Here this material may act as frequency convertor. And also the vibration will transfer to all the area of the second material in contact. If a vibrating material is placing under the earth surface vibration through more paths will get to the second material.

C. REAL FIELD TEST WITH ELEPHANT FOOT FALL

We did an initial real field work in Muthanga Wild Life sanctuary Wayanad, tried to sense the captured elephants foot fall vibrations. Here we are assuming that 2000Kg weight of the elephant is distributing to its four legs and one footfall weight as 500Kg, and also the height of the footfall considering as very less as below 15CM. Used both piezo electric sensor and water column based sensor for vibration sensing. Before the elephants arrival we checked and verified both of the sensors output by producing impacts to the ground. But after some time the sensitivity of the water column based sensor is reduced significantly and it became very poor sensitive after some hours. Checked and identified that the soil which initially in contact with the water column became dry and produced air gapes in between the earth and the water column. That became the reason for the less transmission of the vibration.

When the elephant is walking the piezo electric sensor produced very many noises which are unknown to us. This noise may be from other unwanted vibration sources through earth. Here we came to an conclusion that Elephants foot fall is less impact than expected. So we need to use either more sensitive vibration sensor or additional system for filter the desired signal from the noise and amplify it. Piezo electric sensor continuously monitoring some time varying noise components, which are sometime coming to higher values. These noise signals are related to the type and structure of the soil or earth. So if we need to set an sensor for obtaining the footfall vibrations of the elephant first we need to study the type and structure of the soil and its model. Then we can use that model to cancel them from the receiving signal. And then need to analyze the relationship between frequency and distance of falling from the sensor if there have from the practical situation. And also we can use this vibration sensing method to analyze the soil type and its structure.

V. CONCLUSION

Low frequency rumble sound is detectable from the surrounding noise if it has high loudness than same frequency noise. Using FBCC makes the system more accurate and also more slow. Elephants never make rumbling sound often. So we need fast algorithm, as checking is done every 30ms. Elephants footfall vibrations are very less in amplitude. If we need to pick up them clearly we need good sensors and a specified soil model and correct position for sensor under soil. In order to calibrate the sensing system, we need to study the characteristics of the vibrating material (soil). Need to make a model of material to filter out the components with respect to the falling object (elephant footfall). Need to analyze the relationship between frequency and distance of falling from the sensor if there is.

REFERENCES

[1] Matthias Zeppelzauer, Angela S. Stoger and Christian Breiteneder,"Acoustic Detection of elephant presence in noisy environments,"*MAED Barcelona Spain*,2013.

[2] Arpit Sourav Mohapatra, Sandeep Singh Solanki, "An automatic method to Detect the presence of Elephant,"*IEEE International Conference on Advanced Communication Control and Computing Technologies ICAC-CCT*,2014.

[3] Janaka.V. Wijayakulasoorya "Automatic Recognition of Elephant Infra-sound Calls Using Formant Analysis and Hidden Markov Model ,"*6th International Conference on Industrial and Information Systems, ICIIS 2011*,2011.

[4] Lalith Seneviratne, g. Rossel W.D.C Gunasekara, "Elephant Infrasound Calls as a Method for Electronic Elephant Detection,"2012.

[5] Angela S. Stoeger, Sean Hensman, "Visualizing Sound Emission of Elephant Vocalizations: Evidence for two Rumble Production types ,"2012.

[6] Patrick J. Clemins, Kundoro Adi, Jidong Tao, "Generalized Perceptual Features for Vocalization Analysis Across Multiple Species,"*IEEE journal ICASSP 2006*,2006.

[7] Chinthaka M. Dissanayake,Bill Moran and Peter Farell, "Propagation Constrains in Elephant Localization Using an Acoustic Sensor Network ,"*IEEE ICIAfS12*

[8] Rolf Bardeli, "Similarity Search in Animal Sound Databases "*IEEE transaction on multimedia*, Vol. 11, No. 1, 2009.

[9] David K Mellinger, "Recognition of transcient low-frequency whale sounds by spectrogram correlation ,"*Acoustic society of america*, 2000

[10] M.P.J Dharmaratne, P.C Magaderamgamage,"Human-Elephant Conflict and solutions to it in Srilanka ,"*Young researchers forum- PGIS* vol 1. 2014,

[11] Ing. Ladislav Ptacek,"Multiple instance learning based birdsong classification using unsupervised recording segmentation ,"2012.

[12] Xin Zhang,Ronghui Huang,SenJing Yao, Xu Dong "Finite Element Analysis and Vibration Control of the Substation Charged Maintenance Robot,"*IEEE* 2016.

[13] Yukitoshi Kashimoto, Manato Fujimoto, Hirohiko Suwa, Yutaka Arakawa, Keiichi Yasumoto, "Floor vibration type estimation with piezo sensor toward indoor positioning system,"*International Conference on Indoor Positioning and Indoor Navigation (IPIN), 47 October 2016, Alcal de Henares, Spain*,2016.

[14] P. Kotter*, B. Callan-Bartkiw+, M. Boesing*, K. Wegener, J. Berkemer+, O. Zirn, "Noise-Vibration-Harshness simulation of ultralight vehicle traction drives based on a universal modelling approach ,"*Third edition*, Prentice hall, 2014.

[15] Javier Rivas, Ralf Wunderlich and Stefan J. Heinen, "Road Vibrations as a Source to Detect the Presence and Speed of Vehicles ,", *IEEE sensors*,2016.

[16] Varun P. Gopi, Pavithran M., Nishanth T., Balaji S., Rajavelu V., P. Palanisamy, "Using seismic sensors to detect elephants and other large mammals: a potential census technique Journal of Applied Ecology 2005"

[17] STUDY ON MAN WILDLIFE INTERACTION IN WAYANAD WILDLIFE SANCTUARY, KERALA/ P.S. Easa.S. Sankar/KERALA FOREST RESEARCH INSTITUTE PEECHI, THRISSUR/April 2001

[18] http://www.thehindu.com/news/national/kerala/man-suffers-grievous-injuries-in-elephant-attack-in-wayanad/article7094717.ece

[19] https://www.youtube.com/watchv=Yd0MRjq37uwindex=5list=PLWQUOoMTT6SwS-NgjgtHPj-LBh1NJwpd

[20] https://www.youtube.com/watchv=tX6nHUrL1Xsspfreload=10

[21] https://www.elephantvoice.com/elephant-communication/acoustic/communication.htmlid=631 tmpl

[22] Vinayan (Officer in World Wildlife Fund)/pa.vinayan@gmail.com