Research Paper

AN EFFICIENT SURVEILLANCE SYSTEM TO DETECT ELEPHANT INTRUSION INTO FOREST BORDERS USING SEISMIC SENSORS

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ABSTRACT

Human-Elephant conflict is the major problem in the forest borders with large elephant herds. In this paper, an automated system to detect the intrusion of elephants into the human habitat in forest borders is proposed. The seismic signals generated by the movement and other sounds made by the elephants are received by the system and is transmitted to the central processor along with the GPS position of the receiver node. The received signals contains some noise and it is should be removed using algorithm. After removing the noise signal is matched with the database patterns. On match of a stored pattern, the system generates a SMS to forest authorities. The proposed is very efficient with good computation power and low cost.

KEYWORDS: Human – Elephant Conflict Seismic Sensors

INTRODUCTION

Indian sub-continent is diverse in biological and non-biological aspects. The diversity in the flora of the forest areas in the country attracts a wide range of animals to have it as the habitat. One of the most prominent species in the Indian forest is the elephant. India is the major habitat for 60 percent of the Asian elephants (Elephas Maximus) of the total estimated population of 40,000-50,000. Asian elephants lose their habitat as the forest areas are rehabilitated to human settlements, industries and agricultural lands. These conversions lead to the increased shortage of the natural food and water resources needed by the herd of elephants. Shortage and fragmentation of habitat makes the herd of wild elephants to enter into the human habitat in the forest borders and roadways. There exists a severe damage to crops, human lives and also the elephants. The crop damage is costlier as the herd damages the larger portion of the vegetation when it moves into the farm lands. This loss by elephants can be mitigated by taking precaution measures on intrusion of the herd. But the detection and tracking of the herds is hard due to their size and complex nature of the movement. The elephants are considered endangered species as it faced heavy loss of lives by poachers. The poaching for ivory of the elephants, attacks made by humans to protect their farm lands, captivation of baby elephants and accidents are some common reasons of the reduction of elephant population. This paper is structured as follows: In section 2 of this paper, an analysis of the previous works on elephant detection with various techniques has been elaborated. Section 3 discusses the study area of the system. Section 4 formulates the problem statement and motivation for the proposed system. Section 5 describes the proposed methodology of the problem statement. Section 6 discusses the experimental results of the system. Section 7 gives the conclusion of the proposed work.

RELATED WORK

Based on the study of the previous research works and the field research the factors contributing for the intrusion of elephants along the forest borders are summarized below:

a) Vegetation on farm lands with no protection fences attracts the elephants.
b) Damage of fences constructed in the forest borders either by humans or natural ailment.
c) Shortage of food resources in the forest perimeter.
d) Degradation of climate in the forest region.
e) Artificial water resources constructed near the habitat of the elephants.
f) Occupying traditional migration paths of elephants by human constructions.
g) Trenches constructed improperly, damaged or not maintained.
h) Periodic migration of the herd to other comfortable habitats.
i) Forest fire causing all the wildlife to lose its habitat.

With these factors contributing the intrusion there are several systems and initiatives developed to reduce human-elephant conflict around the globe. Some of the traditional, conventional and experimental methods proposed by the humans are discussed below:

1) Air guns: Air guns produce sudden shock waves on air producing burst sounds that annoys elephant herd.
2) Non - electric fences: Simple fencing technique used to block the path of the expected intrusion.
3) Electric fences: Electric fences uses low voltage AC power supplies to avoid the intruding animals into habitat.
4) Chilli rope fences: Two stringed fences are constructed around the vegetation or habitat with the mixture of dry chilli powder and engine grease applied on the strings.
5) Loud alarms: Alarms producing loud noise triggered by a trip wire is used to defer the elephants back into forest.
6) Chilli smokes: Animal dung's and/or red hot chillies mixed and burnt to produce pungent smoke clouds blown in the direction of the elephants to raid them.
7) Watch towers: Watch towers of certain height is constructed and used for surveillance of elephant's intrusion to avoid the damage caused by them.
8) Solar powered torches: Solar torches are specially designed to produce powerful light and are used to raid elephants in the forest borders.
9) Trenches: Trenches of considerable width and depth is constructed in the forest borders to prevent the intrusion of the elephants.

10) Fire: A considerable amount of fire is burnt on the expected intrusion path of elephants to defer them back into forest.
11) Fire crackers: Crackers producing loud noise is used on intrusion of elephants to raid them.
12) Throwing arrows / stones: On intrusion of elephants, sharp objects on considerable mass like arrows or stones are thrown on them to raid the herd.

With these manual intervention methods, there are several automated system as a result of scientific advances are developed to detect the elephants. Some of them are discussed below:

The authors, C. Arivazhagan and B. Ramakrishnan presented a paper on the conservation of elephants with the focus on connectivity of elephant's habitat[1]. The authors aimed to increase the population of elephant and protect the habitat of elephants from degradation and fragmentation. The study was done in southern part of the Indian sub-continent.

Pieter I. Oliver *et. al.* discussed a method to detect the elephants using the dung[2]. With the dung decay rates and distance sampling techniques, they have detected and estimated the population size, age group in Southern Mozambique region.

Prithviraj Fernando et. al. proposed a solution to track elephant movement patterns in their habitat by direct observations to conserve elephants and to avoid human-elephant conflict[3]. They have used radio collars to get GPS locations of elephants every 4 hours. Data received from the individuals are interpreted in an Excel sheet with statisticXL 1.8 add-in. The data is then mapped on the toposheets to visualize the collected data.

Tucker Balch has proposed a methodology for animal tracking using RFID system[4]. The RFID tags are detected and interpreted by a control hub and the locations are determined. It has a drawback of short range detection and it has low update rate of the locations.

S J Sugumar and R Jayaparvathy have proposed an analytical model for surveillance and tracking of elephant herds using a three - state Markov chain[5]. The design gives the migration pattern of elephants and behavior of the elephants over the whole year in different climatic periods of three villages near forest borders. The study is conducted in the Coimbatore Forest Division which falls in the dense forests of the Western Ghats of India. The intrusion detection system is developed based on pattern of movement of the herd to detect the intrusion of the elephant herds into the locality or habitat of the humans. On intrusion of the elephants the system warns the forest officials with an alert message. The system is hardware implemented as a prototype to detect intrusion of elephants into the forest borders.

Ramkumar R *et. al.* has developed a simulation model called ASRET to reduce the Human-Elephant Conflict (HEC)[6]. This system generates early warning to prevent conflict between humans and elephants. The system is a simulation model simulated in MATLAB Simulink with the central processing unit, primary unit and secondary unit. The signals from the sensor nodes are processed by the central processing unit and the secondary unit is responsible for the transmission of signals to and from the sensor nodes. Since the system is a simulation model the results of the real time implementation model is not elaborately discussed.

Ranjit Manakandan *et.al.* presented a case study on the dispersal and movement of the elephants between the Hosur – Dharmapuri Forest Division and Koundinya Wildlife Sanctuary[7]. The migration of the elephants is due to the various parameters like vegetation, scarcity of shade, scarcity of grass, water scarcity, forest fires and human elephant conflicts. The study also concluded that the aforementioned conservation issues there is a decline in population of the elephants in KWS as most of the elephants have translocated to the Hosur – Dharmapuri Forest Divisions. The authors also suggested evaluation and restoration of the forest division to improve the elephants count in the forest region.

James D. Wood *et. al.* presented a technique to estimate the population of the elephants in Central Africa where it is hard to enter the dense forest[8]. Since the forest is very denser aerial surveys are not possible so they developed a system using seismic sensors to estimate the total population of large mammals in a specific region. The seismic detection system has successfully detected large mammals with higher accuracy.

S J Sugumar and R Jayaparvathy presented a system to detect elephant intrusion along the forest borders using real time imaging[9]. The proposed system is an automated unsupervised elephant image detection system that reduces human elephant conflict in the context of elephant conservation. The elephant's image captured in the forest border areas and is sent to a base station for processing the image using Haar wavelet and image vision algorithm. The system also proposed an optimized distance metric for lesser retrieval time compared to Euclidean and Manhattan algorithms. A paper on a low cost infrasonic recording system is proposed in the year 2013[10]. The system is built to record the infrasound calls made by elephants. With the recorded infrasonic calls the elephants can be detected efficiently with low cost compared to other systems. The system also records infrasounds generated by other sources of the environment which can be used for research purposes.

STUDY AREA

The Krishnagiri and Dharmapuri districts of Tamil Nadu hold Hosur Forest Division and Dharmapuri Forest Division. The forest divisions lies very much closer to the electronic hub of India- Bangalore. Developmental activities of these regions have severe impact on the forest area which includes the construction of roads, railways, human settlements and commercial constructions like special economic zones[11].

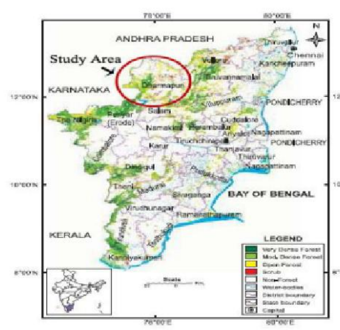

Figure1. Study area of Krishnagiri and Dharmapuri District of Tamil Nadu, India

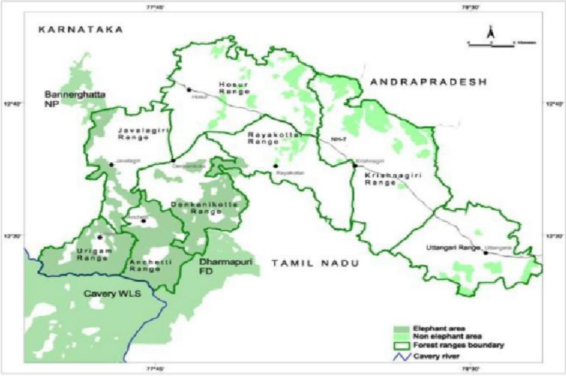

Figure 2. Enlarged map of the study area showing detailed range of forest divisions and elephant intrusion areas.

The two forest divisions of Hosur and Dharmapuri have most of the reserve forests of the state, including Sanamavu Reserve Forest, Melumalai Reserve Forest, Anusonai and Udedurgam Reserve Forest, Veppanahalli Reserve Forest, Rayakottai Reserve Forest depicted in figure 1 and figure 2.

The forest area of the Krishnagiri district is 2, 02,409 ha which constitutes 9.6% of the state and the forest area of the Dharmapuri district is 1, 64,177 ha which constitutes 7.8% of the state. The forest division is an extension of the Bannerghatta National Park which lies to its north and also Cauvery Wildlife Sanctuary to its south. The Forest division also covers the Sathyamangalam forest range and extends well to the Nilgiris. The Forest division serves as a meeting point of the Western Ghats and Eastern Ghats forming a vital link to the elephant's movement between the greatest forests of South India.

The Krishnagiri and the Dharmapuri districts have forest cover of 3,034 km^2 of the total geographic area 9,622 km^2, which constitutes 241 km^2 of very dense forest, 1,078 km^2 of moderately dense forest and 1,715 km^2 of open forest[12]. The forest range lies at an elevation of 300 m to 1400 m above the mean sea level and most of the forest region lies between 11º 12' N to 12º 49' N latitude and 77º 27' E to 78º 38' E longitude. There is a greater diversity in the climatic conditions due to the varied altitude of the various regions of the forest division (It is recorded that the eastern and western part of the forest regions experiences completely contrast climatic conditions).

The forest division falls in the chain of Eastern Ghats and the areas in and around Denkanikottai has been declared elephant reserve due to large number of elephant's death in the past decade. The crucial elephant crossings over human habitations lie at different regions of the forest divisions. These forest divisions hold most of the roads and rail lines to connect various towns, cities and the district headquarters through the forest, also most of the villages are positioned near the forest boundaries and the forest ranges. The major elephant crossings in the roadways and rail lines are Hosur to Denkanikottai of length 29.7 km, Hosur to Kelamangalam of length 20 km, Kelamangalam to Uddanapalli of length 14 km, Denkanikottai to Anchetty of length 24.8 km, Jawalagiri to Anchetty of length 40.2 km, Hogenakkal to Urigam of length 58.2 km. These regions are crucial to get affected by the elephants and there exists loss of lives of both humans as well as elephants. The vegetation of the forest borders and the natural elephant habitat acquired by humans attracts elephants to enter into habitat of humans the forest borders. It is reported that around 20 people are killed by elephants in the span of three years from 2013 to 2015[13]. Also there are unreported deaths which show the fact that above 40 people loses their lives by elephant attack.

As the transport ways of roads and rail lines connecting major cities to the villages lies in the crucial elephant crossing regions there exists frequent accidents when the elephants try to cross these paths. The railway track from Hosur to Dharmapuri of length 75 km is the major section of the Southern Railways experiencing elephant accidents. The number of elephant's death by train hits in this section in the year of 2015 is reported as 4. Also the people in the forest borders go into forest to collect logs, fire sticks, medicinal plants, fruits, cattle grazing and to collect natural honey where there is a higher risk of elephant's attack. There is a yet another risk of elephant attack while the farmers try to ride elephants from their farm lands. There are unreported deaths by both of the above mentioned situations.

PROBLEM FORMULATION

The objective is to detect the elephants trying to intrude the human habitat in the forest borders. The system uses seismic sensors to detect the seismic signals generated by the movement of the elephants. The signals are processed; features are extracted and are matched with stored patterns of elephants in the database. Also the signals are filtered to an extent using the FastICA algorithm. The signals are visualized to see the processed and filtered seismic signals using the spectrogram. From the processed signals, only a segment of the seismic data detected is used for match. The segment is called as window. On successful match of the recorded pattern, the central processor will generate an alert message with the GPS position of the sensing node.

Let S_n be the segmented seismic record sample where n = 0, 1, 2… N – 1, and recorded seismic segments ranging from x= 1, 2, 3… X. Then the signal produced along with the noise can be given as follows:

$$S_n = \omega_n + \sum_{x=1}^{X} P_n^x$$

where ω_n be the noise signal added to the original signal. The P_n^x is the signal generated by the recorded seismic segment and the corresponding seismic record sample. Since the noise signal is not easily predictable it is kept separately.

MATERIALS AND METHODS

Independent Component Analysis for Noise Removal:

The Independent Component Analysis is an effective and efficient signal processing technique that can separate noise signals from the original source signal. The ICA splits set of independent sources based on their statistical independency from a noisy signal. In the mathematical model, it can be represented as:

$$x = A(s + n) = A\tilde{s}$$

where $x=[x_1, x_2,…,x_n]^T$ is observed signal, $s=[s_1,s_2,…s_n]^T$ is the source signal, A defines the m x n mixing matrix and n is the noise signals mixed up same as intrinsic components.

The ICA algorithm takes linear transformation of the equation to estimate the source components based on assumption of independency.

$y = w^T x = w^T A\tilde{s} = zT\tilde{s}$

where z=A^Tw, w is the estimator of the row matrix A^{-1} and y is the best estimation of the source signals. With the efficient processing power of ICA, the FastICA algorithm is based on the fixed-point algorithm that can process independent components. The FastICA algorithm is shown in the following steps:

1) Center the data $x(t)$ to make its mean zero:

$x = x - E(x)$

2) Calculate the covariance matrix $E\{xx^T\}$

$E\{xx^T\} = EDE^T$

Where E is the orthogonal matrix of the eigen vectors of $E\{xx^T\}$ and D is the diagonal matrix of the eigen values, $D = diag(d_1, d_{2,\dots,}d_n)$

3) Whiten the data $x(t)$ to produce the whitening vector z

$z = Vx$

Where V is the whitening matrix, $V = ED^{-1/2}E^T$

4) Choose an initial vector w_0 of unit norm

5) Update w_{k+1}

$w_{k+1} = E\{zg(w_k^T z)\} - E\{g'(w_k^T z)\}w_k$

6) Normalize w_{k+1}

$$w_{k+1} \overset{2}{\leftarrow} w_{k+1}/||w_{k+1}||$$

7) Check convergence, if not converged, go back to step 5

8) If converged, calculate the independent component $y = wx \approx s$

Fuzzy Logic to analyze Elephant Migration based on Resources and Climate:

Availability of comfortable environment and resources demands the elephant herd to decide whether to migrate to other region or not. It is a complicated analysis to predict the availability of resources and environment as the habitat perimeter of the herd is very large. To analyze the availability of the resources and good environment fuzzy logic is used. Although the Hosur – Dharmapuri forest divisions have better climate and food resources for the elephants there is a shortage of food resources at various periods of the year.

The availability of the resources is based on the two factors: rainfall and climate. The logic takes these two factors as input parameters and the resultant or the output variable is the decision of migration. The rainfall and climate is chosen as parameter as these factors influences the availability of food resources in the forest like greens, trees, fruits.

The input variables, rainfall and climate are grouped to form the variable terms: Very Less: Hot, Less: Dry, Average: Moderate, High: Cool, Very High: Cold.

The Migration will be based on the variable terms formed above. E.g. For the variable terms Very Less: Hot, Less: Dry the migration probability is very high and for the other variables there is a least probability of migration. i.e.,

IF (Very Less: Hot) is 1 THEN Migration is TRUE

IF (Less: Dry) is 1 THEN Migration is TRUE

IF (Average: Moderate) is 1 THEN Migration is FALSE

IF (High: Cool) is 1 THEN Migration is FALSE

IF (Very High: Cold) is 1 THEN Migration is FALSE

The figure 3 shows the migration logic based on the availability of the food resources and comfortable environment. For the logical variable term Very Less: Hot is 1, it shows that the rainfall is very less and climate is very hot: on this state the elephant has higher probability of migration. For the logical variable terms less: Dry is 1, it shows that the rainfall is less and climate is dry: on this state the elephant has higher probability of migration. . For the logical variable terms Average: Moderate, High: Cool, Very High: Cold is 1, it shows that the rainfall is normal and has good climate: on this state the elephant has zero probability of migration.

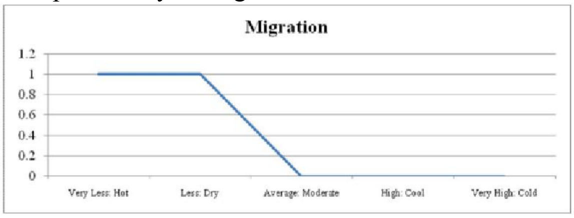

Figure 3. Migration analysis of elephants with respect to the available resources and climate.

The Table 1 depicts the possibilities of the migration situation on existence of variable combinations of climate and rainfall. As rainfall and climate are major parameters for the availability of food for the herd.

Table 1: Analysis of Expected Migration State

Climate / Rainfall	Hot	Dry	Moderate	Cool	Cold
Very Less	TRUE	TRUE	TRUE	FALSE	FALSE
Less	TRUE	TRUE	FALSE	FALSE	FALSE
Average	TRUE	FALSE	FALSE	FALSE	FALSE
High	FALSE	FALSE	FALSE	FALSE	FALSE
Very High	FALSE	FALSE	FALSE	FALSE	TRUE

Analysis of Elephant Migration on the whole year using Mobility Markov Chain:

The analysis of migration of the elephant herd during various periods of year will help to alleviate the Human Elephant Conflict by taking counter measures precisely. In general, the whole year can be divided as Hot, Dry, Moderate, Wet and Cold Seasons. To analyze the movement of the herd previous records of movement of herds to various regions of the Hosur – Dharmapuri Forest Divisions are collected.

Mobility Markov Chain (MMC), a probabilistic automaton is used for analyzing the migration regions called Point of Interest (POI) [14]. The Mobility Markov Chain is build with:

- A set of states, representing the POIs where frequent intrusions are recorded in the villages or regions along the forest borders. Here the set of states is P={DRF, SRF, KRF, JRF, URF, KORF, ARF, URRF, PRF, OTHER} where DRF represents the Dharmapuri Reserved Forest, SRF represents the Sanamavu Reserved Forest, KRF represents the Kelamangalam Reserved Forest, JRF represents the Jawalagiri Reserved Forest, URF represents the Uddanapalli Reserved Forest, KORF represents the Kollatti Reserved Forest, ARF represents the Anchetty Reserved Forest, URRF represents the Urigam Reserved Forest and

PRF represents the Pennagaram Reserved Forest, the last state represents the other infrequent POIs of migration.

- A set of transitions, representing the movement of herd from a region to another region. The set of transitions is T={$t_{1,1}$, $t_{1,2}$, $t_{1,3}$, …,$t_{i,j}$}, where $t_{i,j}$ corresponds to the probability of moving from a state of POI to the other. For a path with no transition, zero probability is marked and is not shown in the graph. For the transitions from a state to other state the sum of probability of all the transitions should be equal to one. i.e.,$\sum P(i,j) = 1$.
- The weights are associated with the states in the form of the integer. The weights are assigned to a state based on the duration and total counts of migration events happened in the POI. The last state OTHER has no weight assigned as it contains only the infrequent regions other than the frequent POIs. The probability of the migration is computed on the basis of the number of migrations occurred on average in the last five years. With the transition probabilities computed the figure 4 is drawn.

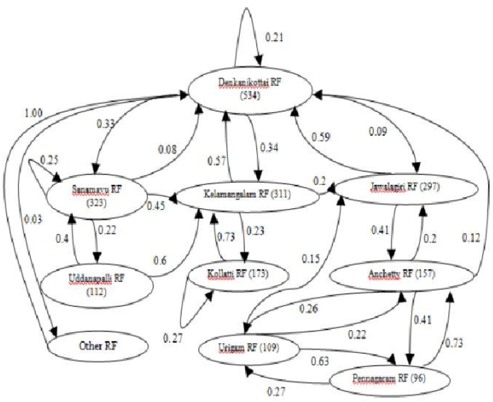

Figure 4. Mobility Markov Chain for Elephant Migration analysis in Hosur – Dharmapuri Forest Division

The state diagram is designed in the decreasing order of the weights assigned. The higher weights represent the frequent POIs of the elephant herd. The figure 4 shows the transition probabilities of the herd migration throughout the year. Here the probability of moving from DRF to SRF is 0.33, but the probability of the vice- versa will not be the same, as there exists different migration counts from and to the POIs. The Denkanikottai RF is the major habitat of the elephants as they roam in and around the forest regions. The herd moves to the other forest regions with the probability of 0.33 for Sanamavu, 0.34 for Kelamangalam, 0.09 for Jawalagiri, 0.03 for other forest regions, and 0.21 for Denkanikottai RF itself. The sum of probabilities leaving the DRF will be 1.00, as the probability should be exactly equal to one for any event. The probability that a herd migrates from SRF to KRF is maximum compared to all other regions which is marked as the frequently used path. The probability of movement from KRF to DRF might be larger but during dry seasons the herd moves from Hosur Forest Division to Dharmapuri Forest Division.

The path extends from KRF to PRF through JRF, ARF and URRF. The herd moves and stays in ARF for longer durations if there appears a comfortable climate. The elephant herd rolls around the forest ranges of ARF, URRF and PRF often as these forest ranges lies closer to each other. The probability of the elephant herd moving from the DRF to other forest regions is 0.03 which is comparatively lesser compared to all other migration probabilities showing that the elephants have lesser chances of migration to those POIs. The transition matrix in table 2 depicts the transition probabilities depicted in the Mobility Markov Chain State Diagram. With the analysis of the data, it is found that there are different paths of migration of the herd between Hosur and Dharmapuri Forest Regions. There are multiple migration paths: (i) DRF > SRF > URF > KRF > JRF > ARF > URRF > PRF (ii) DRF > KRF > KORF (iii) DRF > JRF > ARF > URRF > PRF (iv) DRF > SRF > KRF > JRF > ARF > URRF > PRF (v) DRF > KRF > JRF > ARF > PRF. There are other paths that a herd can use to migrate between the forest ranges, but they are used in very lesser frequencies. The figure 5 shows the block diagram of the proposed detection system.

Table 2: Transition Matrix for Migration Analysis of the Elephant Herd in Hosur – Dharmapuri Forest Division

	Next State									
Current State POI	DRF	SRF	KRF	JRF	URF	KORF	ARF	URRF	PRF	OTHER
DRF	0.21	0.33	0.34	0.09	0.0	0.0	0.0	0.0	0.0	0.03
SRF	0.08	0.25	0.45	0.0	0.22	0.0	0.0	0.0	0.0	0.0
KRF	0.57	0.0	0.0	0.2	0.0	0.23	0.0	0.0	0.0	0.0
JRF	0.59	0.0	0.0	0.0	0.0	0.0	0.41	0.0	0.0	0.0
URF	0.0	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KORF	0.0	0.0	0.73	0.0	0.0	0.27	0.0	0.0	0.0	0.0
ARF	0.12	0.0	0.0	0.2	0.0	0.0	0.0	0.26	0.41	0.0
URRF	0.0	0.0	0.0	0.15	0.0	0.0	0.22	0.0	0.63	0.0
PRF	0.0	0.0	0.0	0.0	0.0	0.0	0.73	0.27	0.0	0.0
OTHER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

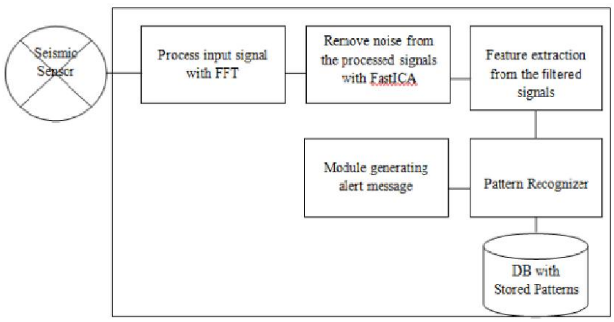

Figure 5. Block diagram of the detection system

EXPERIMENTAL RESULTS AND DISCUSSION

A simulation model is developed to detect the elephant intrusion along forest borders. The system takes input from the seismic sensor in the form of raw seismic waves produced as a result of movement in surface of the land. The received waves are processed using a signal processing module developed as a part of the simulation model. The module covers various levels of processing to detect the target pattern in the recorded waves. The target pattern is the seismic signals of the elephant herd. The received signals are processed with Fast Fourier Transform (FFT) and Fast Independent Component Analysis (FastICA). The FastICA algorithm mitigates noise signals in an efficient manner. With the use of FastICA algorithm, the raw signals received from the seismic sensor can be filtered. The filtered signals are passed to the next level to extract the features in the signal. The extracted features will have the original patterns of the footfalls of an elephant or the herd. The signals are segmented to form records of variable length. The variable length records are given as input to the pattern recognizer that matches stored patterns of the elephants in the database with the Dynamic Time Warping Algorithm (DTW) (300 samples of preprocessed seismic signals of footfalls of the elephant herd and elephants are stored in database). If the pattern recognizer produces positive interrupt then the alert message generator generates alert message to the stored GSM numbers. On negative interrupt from the pattern recognizer the system flush the received signals and wait for the next seismic wave to be processed. The figure 6 depicts the seismic signal produced by the footfall of the elephant. Table 3 presents the true positive rates evaluated after 150 tests.

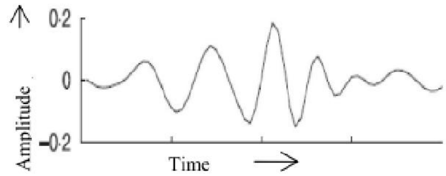

Figure 6. Time series of single foot fall of the elephant at a sampling rate of 200Hz

Table 3: Test for True Positive Rate

Samples	Actual Test Signals			
	Elephant		Other Objects	
	TPR	FPR	TPR	FPR
50	42	8	0	0
100	89	11	0	0

CONCLUSIONS

A seismic surveillance system was designed for the recognition of large mammals like elephants. The focus of the study was to analyze the usability of seismic features for effective detection of the seismic waves generated by the movement of the pachyderms. Several sampling of the records were carried out in order to find suitable geophone configurations and to establish good samples of seismic record pattern in the database, which will afford reliable results. An analysis algorithm based on Mobility Markov Model (MMM) was implemented, which is able to locate a herd. Further performance increase is achieved by exploring differences in position and the climatic conditions, as the implemented algorithms mainly use climate and environment to track the herd. With this system the detection rate of the elephant is higher than any other techniques with the detection rate of 93.75 percent.

Further study will involve feature normalization, and feature classification with the help of Principal Component Analysis algorithm. The algorithm will lead to classification of different species on move.

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