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"*eleAlert*"-A Sensor for Detecting Elephant Intrusions at Boundary Villages

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Abstract: Human-elephant conflict (HEC) takes hundreds of human and elephant lives, every year. Though there are many techniques and systems deployed in African and Asian countries to mitigate this conflict, none of them have provided efficient solutions. The success of a modern HEC mitigating system heavily depends on its capability to detect the presence of an elephant. In most of the existing systems, their superior accuracy of detecting an elephant's presence is limited by certain conditions such as the ability to capture a good quality image containing the elephant. In this paper, we propose an alternative elephant detection system which uses odour of elephant urine and the ear-flap sound as detection parameters and also a support vector classification for decision making. The proposed system can produce higher accuracies in detecting wild elephants present in a 35m radius, under all conditions. Thus, the proposed system is much more superior over the existing elephant detection systems and will be an effective tool to mitigate the HEC.

Keywords: Human-elephant conflict (HEC), Intrusion detection, Odour of urine, Ear-flap sound, Support vector machine

1. Introduction

ElephasMaximus, commonly known as the Asian Elephant, is one of the three living species of the largest land animal on earth [1]. As well as the other two species, the Asian elephant is also an endangered species. Its habitats range from South Asia to Southeast Asia. Asian elephant is tightly linked to the history, culture, religion and mythology of many countries in South and Southeast Asia for over 2500 years. Tamed Asian elephants have been used in the transportation and agriculture, in the past. However, the majority of the Asian elephant population is still limited to the wild.

As a result of recent human activities such as deforestation, excessive farming, large scale land and infrastructure development and segmentation of elephant habitats have paved the way to the downfall of this giant. Elephant population in Asia has been reduced from around 100,000 to 40,000 in the duration of a few decades [2, 3]. Furthermore, limiting the elephant habitats and habitat segmentation in Asian countries have not only fuelled the demise of elephant population but also the harmony between humans and elephants has been hindered during the recent years. In Sri Lanka, the large-scale infrastructure projects such as Mahaweli accelerated project in 1980s and the highway network expansion projects during the last two decades have worsened the conflict between humans and elephants.

As a result of loss of habitats and food, elephants have constantly intruded the human populated areas destroying not only the farmlands and properties, but also valuable human lives. Every year, hundreds of human lives are lost due to elephant attacks. On the other hand, shooting and use of poison, to protect farmlands from elephant attacks is very common in Asia. Thus, many elephants are killed by humans every year.

Nevertheless, it is our duty to protect this magnificent giant for the future. Every possible measure should be taken to protect the Asian elephants and consequently, there is a burning requirement to minimize the human elephant conflict (HEC). Thus, many Asian countries have enlisted "decreasing the human-elephant conflict" as one of their millennium development goals [3].

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There are a variety of techniques used in Asia for minimizing the HEC by restricting elephant access to human occupied areas [3]. However, since the elephants too have lost their habitats, restriction methods had not been very fruitful. On the other hand, the elephant being a very intelligent mammal, finds ways of breaching the protections and intruding into human populated areas. Consequently, recent attention has been focused on alerting elephant intrusions in advance to avoid potential conflicts [4]. With a timely alert, people can either retrieve to safety or take necessary actions to drive the elephants away, without harming them. This in turn saves the valuable lives of both humans and elephants. Motivated by this directive, in this paper, we present the development of an elephant intrusion alert sensor.

The rest of the paper is organized as follows. In Section 2 we present a survey of existing elephant repelling and restricting mechanisms used in the world today. In Section 3, the design of the novel elephant intrusion alert system is described. Section4elaborates on the classification mechanism employed in the intrusion detector while Section 5 presents the prototype implementation details and the testing results. Finally, Section 6 concludes the paper highlighting the directions for future improvements.

2. Elephant Intrusion Minimizing Mechanisms

There are many elephant intrusion restricting mechanisms used in the world today. They can be broadly classified into two groups. In one group, the techniques are to directly restrict the elephant intrusion. Electric fence is one of the very popular techniques used around the world to restrict elephant intrusions into human populated areas [4]. A metal wired fence is supplied with an electrical voltage high enough to produce a shock to the elephant. The electric shock is not fatal to the elephant, but it is a psychological barrier to cross. However, the electric fences are quite expensive to implement and operate, having a capital cost ranging around Rs.300,000 per one kilometre. On top of this capital cost, it incurs an operational cost for electricity used in energizing the fence. Thus, in many developing countries, the usage of electric fences is limited to only the critical areas. On top of all these, it has been reported that elephants place tree branches on the electric fence to break the fence.

Elephants have an inherent fear of bees and of the scent of chilli. Though the reason for this behaviour has not been scientifically explained yet, in parallel to the electrical fences, beehive and chilli pot fences are also employed in African countries to restrict the elephants from intruding into villages [5, 6]. In these fences, either the beehives or chilli powder pots are hung spaced by several meters. Though this technique provides promising results against the African elephants, the technique has not proven to be very efficient against the Asian elephant. On the other hand, the maintenance of beehives and the chilli pots are very difficult tasks under tropical climates of South and Southeast Asia. The elephant intrusion restricting systems may also cause a limitation on elephant movement which can erupt as an intrusion at some other place.

Apart from these elephant restricting systems, there are several elephant intrusion detection systems employed in Asia and Africa. They use either the images/videos captured [7, 8] or the infrasound calls generated by elephants [9, 10] to detect the presence of an elephant. Nevertheless, the vision-based systems need to have a good visibility of the area without foliage cover which cannot be guaranteed in tropical Asian countries. On the other hand, elephants may not emit infrasound calls always, hence using infrasound calls as the detection mechanism is not always successful. Thus, in this paper, we propose an elephant detection system based on multi parameters, namely the odour of elephant urine and the ear-flap sound made by elephants. To the best of our knowledge these two parameters have not been used before for elephant detection. Furthermore, with the use of a multi parameter intrusion alert system and a support vector classification to classify the sensor reading to “elephant present” and “no elephant/elephant absent” categories, we expect a much more accurate intrusion detection than a single sensor-based detection.

3. Design Methodology

The proposed elephant intrusion detection and alert system named as *eleAlert* is meant to be employed at the boundary of human populated areas and it consists of several important subunits as depicted in Figure 1.

3.1 Elephant Urine Odour Sensor

On average, an elephant urinates more than fifteen times a day and the amount of urine passed at a time may range even up to nine litres [11]. It is also observed that during urinating, a considerable amount of urine is stuck on the elephant's body parts. Hence, even when the elephant moves to a different location, the elephant emits a considerable odour of urine.

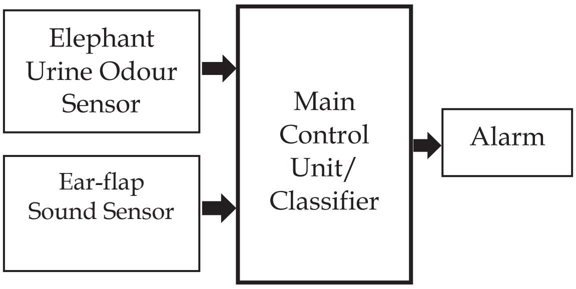


Figure 1 - System Block Diagram

The main chemical substance in the urine of any mammal is Ammonia which is very high in elephants compared to other mammals [11].
In order to verify the response of an Ammonia sensor to animal urine, several tests were conducted at Dehiwala and Pinnawala zoological gardens using MQ137 integrated Ammonia sensor module. Results of the tests to measure the strength of the urine odour at different distances from the animal are shown in Figure 2 for six different animals which are commonly found around boundary villages. It is clear that the odour of urine is very much high in elephants than all the other animals, having a considerable odour even at the maximum tested 35 m distance.

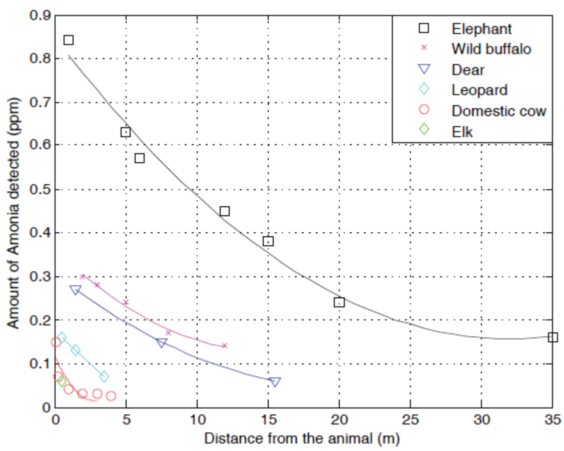


Figure 2 - Ammonia Odour Variation with the Distance to the Animal

3.2 Ear-Flap Sound Detector

Having a body mass ranging up to five tons, elephant's body generates a very high amount of heat. In the absence of sweat glands, the primary mechanism of the elephant's excess heat dissipation is through the ears [12]. Elephant ears are equipped with a large surface area and an extensive vascular network to facilitate this process. Thus, the elephant periodically flaps the ears which generates a periodic sound signal, and it can be heard even at a considerable distance away. The ear-flap sound has been identified to be in the frequency band 300 Hz-500 Hz [12]. As the second parameter measurement, we develop an ear-flap sound capturing circuit. The aforementioned circuit consists of three principal components, namely, the microphone (Mic), low noise amplifier (LNA) and the band-pass filter (BPF) as shown in Figure 3. To cater for the specific frequency range under consideration, we selected a special Mic module, MAX4466, which has a good response in the frequency band of interest and also a very high load resistance of 100 kΩ [13].

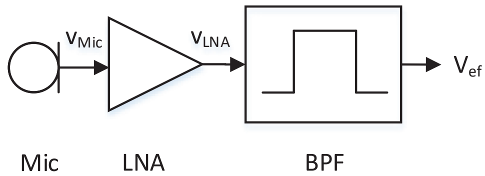


Figure 3 - Ear-Flap Sound Detector

3.2.1 Low Noise Amplifier

Low noise amplifier takes an input signal from the microphone in the range of microvolts to millivolts and amplifies the same to a volts range without much added noise. For this purpose, we selected an ultra-low noise operational amplifier AD797 in the circuit configuration shown in Figure 4 [14].

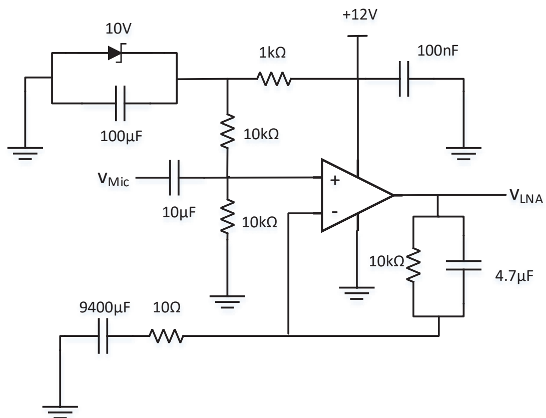


Figure 4 - Low-Noise Amplifier Circuit

3.2.2 Band-Pass Filter

The filter is the most critical component in the ear-flap sound detector as it allows the demarcation of the ear-flap signal from other noises. For this purpose, we employed a two-stage cascaded filter which has a bandpassfilter response in the 300-500 Hz frequency range as shown in Figure 5.

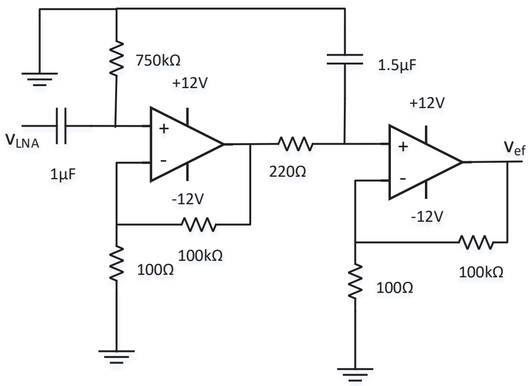
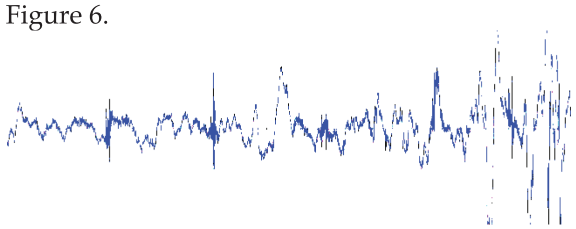


Figure 5 - 300-500 Hz Band-pass Filter Circuit

The input and the output signals for a sample elephant ear-flap sound detection is shown in Figure 6.



(a) Before filtering

(b) After filtering

Figure 6 - Band-Pass Filtering

3.2.3 Efficiency of Ear-flap Sound detection

Though the ear-flap sound is a possible parameter to detect the presence of an elephant, in the dry zone outdoor environments where most of the elephant intrusions occur, the other surrounding noises such as wind sound is at a relatively high level. An experiment was conducted with the presence of an elephant to determine the V_{ef} variation with distance from the elephant. Furthermore, a test at the same premises was conducted in the absence of an elephant. Results of the aforementioned tests are shown in Figure 7, which clearly depict a direct current V_{ef} output in the range of Volts in the presence of an elephant. The signal can be clearly detected over noise, up to a distance of 10 meters, approximately. Since the sensor nodes are placed at the boundary of a perimeter to be protected, this range is adequate in practical applications.

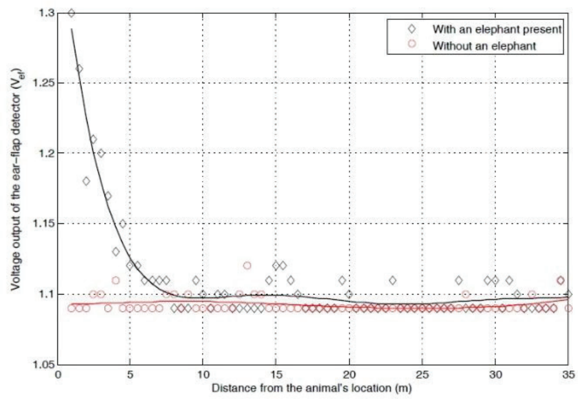


Figure 7 - Ear-Flap Detector Output Variation with the Distance from the Elephant

3.3 Main Control Unit / Classifier

The main control unit of the *eleAlert* system considers the inputs from the urine odour sensor and the ear-flap sound detector and makes an intelligent decision, whether an elephant is present or not. If an elephant is present, the control system energizes an alarm siren.

The training data set is limited in this particular application; hence we use a support vector machine (SVM) supervised learning to determine a boundary between the "present" and "not present" ranges. Use of SVM classifier is expected to produce better results with the limited training data set, than any other classifier [15].

4. Support Vector Classifier

SVM is a supervised learning technique for classifying a set of test data into two groups. For simplicity of notation, let us denote V_{ef} by x_j and Ammonia sensor ppm output by y_j, corresponding to a $j-$thtest instance. Let $\{(x_1, y_1, z_1), (x_2, y_2, z_2), ..\}$ represent a set of training data points where z_j is the class to which each test instance belongs to (*e*.g.elephant absent or present), $z_j \in \{-1,1\}$. The task is to calculate the maximum margin of separation between the two classes such that two parallel straight lines dividing the two classes maintain the maximum distance between them. The maximum margin boundary line is,

$$wx + w'y - b = 0 \qquad ...(1)$$

where$w, w'$and b are to be determined to maximize the separation between the two parallel straight lines $wx + w'y - b = 1$and$wx + w'y - b = -1$[15]. The value $\frac{2}{\sqrt{w^2+w'^2}}$ defines the distance between the two parallel straight lines. Hence, the training process can be stated as a constrained maximization of $\frac{2}{\sqrt{w^2+w'^2}}$ under the constraint: for each j,

$$\begin{Bmatrix} wx_j + w'y_j - b \geq 1 \text{ if } z_j = 1 \\ wx_j + w'y_j - b \leq -1 \text{ if } z_j = -1 \end{Bmatrix}$$

Hence,

$$z_j(wx_j + w'y_j - b) \geq 1 \qquad \ldots(2)$$

As in [15], w, w' and b can be determined and the classifier can be given as,

$$f(x,y) = \text{sign}(wx + w'y - b) \qquad \ldots(3)$$

5. Prototype Implementation & Test Results

As already mentioned in Section 3, the urine sensor and the ear-flap sound detector were implemented to measure the two parameters in the presence and absence of an elephant. The classification algorithm was hosted in an Arduino Uno controller board. Moreover, the setup was powered using two Li-Iron sealed type batteries of 12 Volts each. Note that, in these experiments we used a comparison between the two scenarios, thus did not require to calibrate the two sensors to read the absolute values of the two measured parameters.

Then, the pairs of measurements were taken for the known cases, where an elephant was present within a 35 m distance in 31 samples and the elephant was not present in another 20 samples, which are plotted in Figure 8. We consider five support vectors given by,

$$\begin{pmatrix} 0.27 \\ 1.09 \\ -1 \end{pmatrix}, \begin{pmatrix} 0.29 \\ 1.09 \\ -1 \end{pmatrix}, \begin{pmatrix} 0.28 \\ 1.01 \\ +1 \end{pmatrix}, \begin{pmatrix} 0.23 \\ 1.08 \\ +1 \end{pmatrix} \text{ and } \begin{pmatrix} 0.25 \\ 1.05 \\ +1 \end{pmatrix}$$

to determine the decision boundary by calculating the values of w, w' and b as in [15]. Figure 8 also depicts the straight line of decision boundary,

$$y = -1.52x + 1.45 \qquad \ldots(4)$$

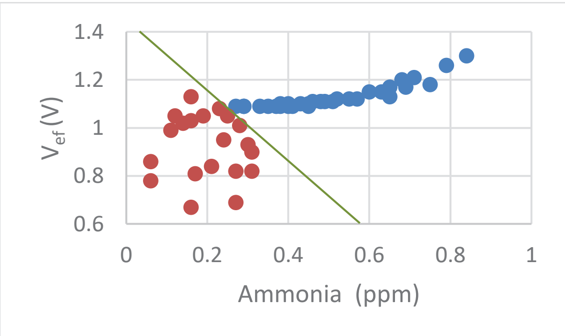


Figure 8 - Decision boundary

determined under a SVM classification in [15]. Note that the decision boundary will vary based on the selection of support vectors and we have selected the support vectors to minimize the overall error in classification.

A further set of 20 samples belonging to the two classes were also tested using Equation (4) for the classification. The results of classification where the estimated class of each test sample k is given by $\hat{z}_k$ is listed against the actual class z_k, in Table 1 and also in Figure 9. Test results show a 90% accuracy in the classification.

Table 1 - Estimated Classes for Test Cases

x_k	y_k	z_k	$\hat{z}_k$
0.14	0.93	-1	-1
0.15	0.96	-1	-1
0.11	0.78	-1	-1
0.16	0.76	-1	-1
0.23	0.78	-1	-1
0.22	0.77	-1	-1
0.20	1.11	-1	-1
0.24	1.16	-1	+1
0.09	0.75	-1	-1
0.25	1.18	-1	+1
0.66	1.15	+1	+1
0.35	1.11	+1	+1
0.71	1.2	+1	+1
0.38	1.08	+1	+1
0.43	1.12	+1	+1
0.48	1.12	+1	+1
0.57	1.11	+1	+1
0.72	1.21	+1	+1
0.36	1.1	+1	+1
0.55	1.11	+1	+1

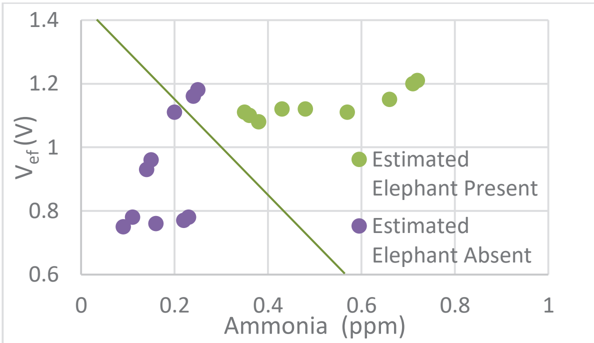


Figure 9 - Accuracy of Classification

Misclassifications are all false-positive cases, and are mainly contributed by the erroneous noisy readings given by the ear-flap sound sensor.

For comparison purposes we consider the classifications based on a single parameter at a time (either the V_{ef} or Ammonia concentration). When a single parameter is considered, it is clearly not feasible to find a SVM separating boundary between the two classes for the given training data set. One of the techniques we may use in such situations is the selection of a set of support vectors, eliminating the outliers. However, in this classification, we need to eliminate a large number of test points as outliers. Therefore, for a single parameter-based classification, we selected a nearest neighbour (NN) classifier [15]. The results of the single parameter NN classification using the same data set is given in Table 2. As claimed, use of a joint classification based on multiple parameters has improved the accuracy.

Table 2- Single parameter NN classification results

	Average in elephant present test cases	Average in elephant absent test cases	NN boundary	Accuracy
Ammonia (ppm)	0.50	0.22	0.36	85% (17/20)
V_{ef} (V)	1.14	0.92	1.03	85% (17/20)

We also compared the accuracy of classification with those of other similar elephant detection systems in Table 3. It is apparent that the proposed elephant detector is having a similar order accuracy as the other existing elephant detection systems.

Table 3 - Comparison of Elephant Detection Accuracies

Method	Accuracy (%)
Image based [7]	92
Video based [8]	92.83
Infra-sound calls based [9]	88.2
Proposed	90

6. Conclusion

In this paper, we presented the design and implementation of a novel wild elephant intrusion detection system which uses the odour of elephant urine and the ear-flap sound to determine the presence of an elephant in the vicinity of 35 meters. Due to the limited number of test samples available, a support vector based supervised learning process was conducted and the overall elephant detection system produces an accuracy of 90%, under the tested conditions. It is also verified that this accuracy is superior to those of the single parameter-based classifications. Though the alternative elephant detection systems available in literature provide higher accuracies in detection, it is important to note that the image/video-based systems obtain this high accuracy only when an image/video of the elephant is available, while proposed detection system does not require the visibility of the elephant. At the same time, the infra-sound calls-based elephant detector achieves the tabled accuracy only up to a 10m distance. Hence, the proposed detector is much superior over the existing alternative elephant detection systems.

The proposed system will be of immense value to mitigate HEC existing in many parts of the South and Southeast Asian countries.

Other possible further improvements include interconnecting all geographically spaced *eleAlert* nodes to form an internet of things based wide area elephant intrusion monitoring system with which the relevant authorities can remotely monitor a large potential threat area with ease. Moreover, combining vision-based and the proposed techniques can be expected to have an improved accuracy elephant detection.

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