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Elephant Intrusion Detection, Deterrence and Warning System ("Tusker Alert")

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Abstract: The Human-Elephant Conflict (HEC) is a serious socio-economic problem in Sri Lanka. Many methods including traditional electric fence systems to novel technological approaches are being used to minimize the HEC. Each method has its limitations, complications, and disadvantages. To prevent and overcome them, a wireless sensor network-based detection system combined with a warning system, and an artificial bee sound-based deterrence system was proposed in this research. With the help of PIR and infrared sensors, intrusion can be detected, while by emitting recorded bee sound, deterrence can be accomplished. By combining those two aspects with a communication network, a warning system was developed to alarm relevant authorities such as the wildlife department, railway authority, and police stations through SMS alert system, mobile app, and warning light system while a database is also being updated regarding the intrusions which can be used for further analysis and predictions. Application of the system covers wider aspects of detecting and warning of elephant intrusions such as on village forest boundaries, rail tracks, and on roadsides (possibly on expressways) with a tested and proven result of 92% detection rate from controlled environment testing.

Keywords: Human-Elephant Conflict, Detection, Warning, Wireless Sensor Network

Introduction

The relationship between elephants and the Sri Lankan cultural value is significant and unique, hence Sri Lanka plays an important role in the conservation of Asian elephants. Sri Lanka has the highest Asian elephant density of 10% of total Asian elephants within 2% of land extent, as well as a higher human density among the regional countries Therefore, the steps were taken toward conservation and mitigation of human-elephant conflict obviously set an example for other countries too.

A. Human Elephant Conflict

The human-elephant conflict (HEC) in Sri Lanka is not a modern problem. It has been there since man started cultivation and settlements near the habitats of elephants. Mainly farming communities in dry zones and poor people in underdeveloped areas near forest boundaries suffer severely due to elephant attacks. crop raiding, village raiding and destroying houses to find salt and rice, sudden attacks on the roads are the main types of attacks. When considering the deaths of elephants due to human activities, between 2005 and 2010 the total number of 1154 elephants had been killed where 574 were gunshots. 105 deaths caused by electrocution and 90 were caused by train accidents. (Fernando, et al., 2011) later from 2010-2018, 69 more elephants were dead due to train accidents. (Fernando & Usgoda arachchi, 2018). Annually about 71 human deaths are recorded due to elephant attacks and many more damages on the property. According to (Santiapillai, et al., 2010) most of the crop raids were carried out at nighttime between 1900-0400hrs where villagers are totally unaware of elephant intrusions even by breaking electrical fences and entering fields. When considering train accidents, many were occurred due to the unawareness of the presence of elephants on the railway tracks mostly at night.

Many of the farming communities have been ignored or beyond the reach of the department of wildlife conservation. Farmers in such areas are therefore left with the responsibility of defending their crops, goods, and houses from wild elephants by themselves by shooting or poisoning while keeping trust in the electric fence without even knowing the condition of it. Therefore, there is a need to find localizes detection deterrent and warning systems that are not only simple in application but also affordable and long-lasting to deter elephants.

B. Literature Review

Various methods and systems had been developed throughout the years to address the HEC. Electric fence act as both physical as well as a psychological barrier to elephants. But it did not eliminate the issue nor offer a stand-alone solution for HEC. (Gunaratne & Premarathne, 2006) . Intrusion detection and alerting system for electric fences (eleAlert) were designed and implemented by (Wijesinghe, et al., 2011). However, eleAlert system consists of a major limitation of the physical access to the system for repairing and maintenance after an intrusion. (Fernando et al,2012) presented a method to track elephants using radio collars to get GPS locations of elephants (Fernando et al,2012) has proposed a system for detecting elephants using RFID system. It has a limitation of short-range detection and it has low update rate of the locations. Moving to systems with visual and image processing approach, (Sugumar & Jayaparvathy, 2014) introduced a system to recognize elephant intrusion along the forest borders with the use of real-time image capturing. A vision-based system has been developed by (Dua et al,2015) with the aid of a video camera with 85% detection rate. the detection system is developed by (Ramesh, et al,.2017) which used to identify elephants using image processing. These methods dynamically learns from the trained images with different backgrounds, distances and light conditions. (Ramesh, et al., 2017). Vision-based systems had limitations with the light condition, camera angle and field of vision. to detect elephants they often need reference images to identify the object. A method that uses geophones to sense the vibrations of elephants were presented by (Suganthi, et al., 2018) and (Nakandala, et al., 2014) developed a WSN system that acts as a virtual boundary around a village using PIR sensors and IR sensors. Vibration sensors, geophones, and seismic sensors would not be effective near railway tracks since the train itself generates a considerable amount of vibration around the area which might lead to false identification, further the vibration sensors placed underground, and their wiring could be damaged and maintenance would be difficult. A research conducted in Laikipia country, Kenya by (Graham, et al.,2012) came up with a conclusion that cell phones can enhance communication and decrease human-elephant conflict with a place there is excellent mobile coverage. A research has been conducted in Udawalawe National park by using a disturbed Asian honeybee buzzing sound, elephants responded by moving considerably additional aloof from their resting areas. Further (King, et al., 2007) states that elephants are not only moving away from buzzing bee sounds with unique low frequency rumble that warns other elephants in the area to retreat from the threat (King, et al., 2010). This important finding of the fear of elephants to buzzing bee sound is used in the proposed system to deter and drive away from the elephants.

C. Significance of Research

Considering the facts, the main reason which causes such damage has been found out as the unawareness of elephant intrusions to human habitats and railway tracks. Thus, the need for an improved integrated system for detection, early warning, and deterrence with a reliable data acquisition method has emerged.

If an early warning could be provided, relevant authorities could take action on elephants while people in affected areas could avoid direct confrontations with elephants. Motivated by this idea, the designed system will serve to minimize the HEC in rural areas and railway tracks by detecting and warning of elephant intrusions while deterring and driving them away from vicinities until long term strategic plans and habitat management, enrichment policies establish to overcome HEC completely.

Methodology and Approach

A. Modular Design

Design contains 4 modules.

i. Detection module- Dual IR beam detectors 100m range and PIR sensor 12m range.
ii. Deterrence module - contain 8ohm 4W speakers and mp3 module to play buzzing sound of bees.
iii. Warning and DAQ module- signal lights connected by NRF24 RF module for wireless communication up to 1 km, GSM module to generate SMS and GPRS data to ThingSpeak data base platform which can be accessed by ThingView open source app.
iv. Power module – Operation 3A and standby 1mA is required. The system is required to work at least 24 hours without solar charging. Hence,12V 7Ah 20HR Sealed Lead Acid battery,20W solar panel with 14.5V 10A Solar charger controller is used.

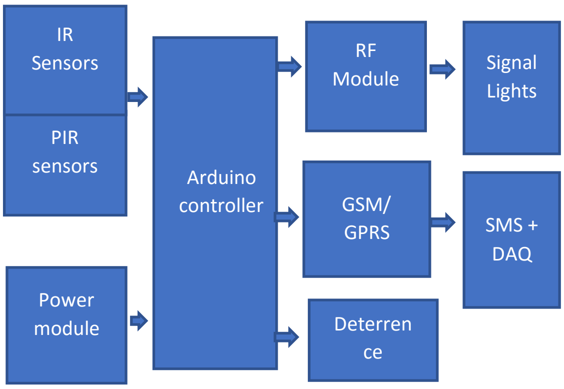

Figure 1. Modular design of system

B. Operation of the System

Primary detection was done by the Dual-beam IR sensors up to 100m. If both IR sensors set HIGH for 1.5 seconds delay (set to tackle the average walking speed of an elephant), Then the signal modules activated by RF signal until they are turned off by the observers. (In case of street signal lights, the signal modules will be activated with reference to the PIR Sensors). Simultaneously, the GSM module will execute AT commands for SMS and GPRS databases. When the Database gets updated it will notify on the mobile application.

On all occasions, the deterrence module is activated with the PIR signal to repel elephants from the nodes in order to protect the nodes. On railroads and roadsides, the deterrence module will be associated with the IR signal too. On Implementations to village boundaries, the deterrence module will not be activated with the IR signals (elephants may deter and run inward).

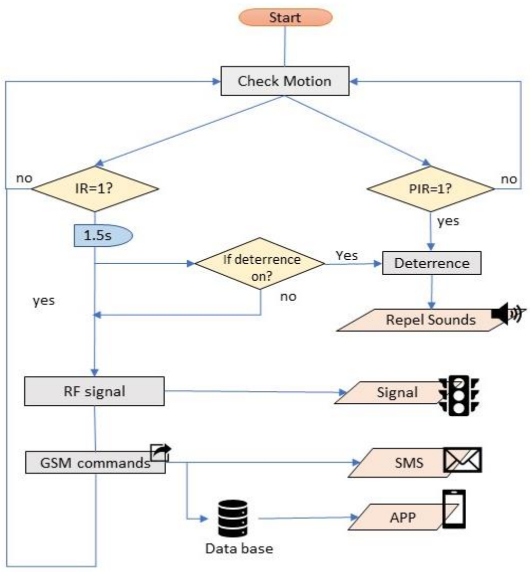

Figure 2. Operation of system

C. Detection Nodes Optimization

In optimizing the detection module, we have assumed that juvenile and baby elephants do not move alone without herd and if moved, the threat from baby elephants is minimum. Based on that assumption the optimized height of sensor placement is done for the worse case of detecting an intrusion of an isolated juvenile male elephant

According to (Chelliya Arivazhagan and Raman Sukumar, 2008) the mean Height for male juveniles 208 cm and for female juveniles is 229.7 cm. According to (Fred Curt and Janak C. Kumarasinghe, 1998) 200cm – 240cm for ages 10-20 years for Male elephants and 182- 215cm for juvenile female elephants. After measuring heights of 4 juvenile male elephants a mean height value of 212.5 cm obtained and compared with previous references. A general height value based on our assumptions was taken as 210cm by keeping a factor of safety 1.0. hence the topmost sensor placed at 210 cm and a lower sensor placed at 160cm, keeping 50cm body detection space.

A horizontal distance of 50m was marked along the elephant moving the path and marked spots. Then using video footage time taken to move was measured for randomly selected samples and hence speed is calculated. The average speed of an elephant of walking normal phase was found out to be 1.5 ms-1 with a range from 0.8 ms^{-1} – 2.1 ms^{-1}.

Ambiguates of references with the measured speed showed the unpredictability of the speed of individual elephant. Therefore, the maximum limit of (6.9 ms-1) range was set in the sensor so that any movement less than that could be detectable to the sensor. Keeping a factor of safety of 4.6

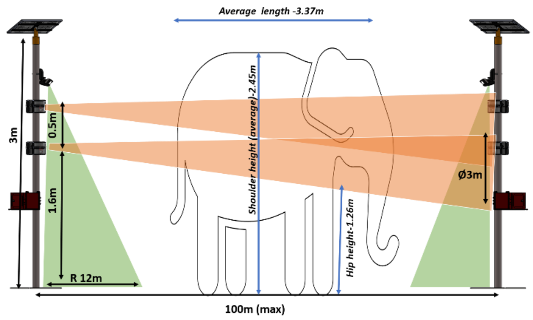

Figure 3. Dimensions of Detection system

D. Warning Module

Warning messages were supposed to be issued about elephant intrusions for its users. 4 types of users were targeted.

i. Users with normal mobile phones
ii. Users with Smart mobile phones
iii. Users with the Mobile application installed phones with GPRS
iv. Users who don't have mobile phones

To address all 4 users 3 variations of warning methods were used.

i. Alert SMS system with a google map link
ii. Online database and Mobile application
iii. Warning Light module

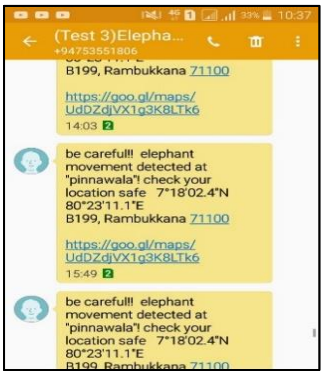

Figure 4. SMS warning with google map link

Alert SMS with google map link will notify the normal phone users as well as smartphone users. These users can directly check the time and location via google map link or SMS itself. This warning method was tested along with the Test 3a. The current module only uses up to 5 numbers and

could be maximized if combined with an 'SMS Gateway'. SMS could be sent to respective forest officials, police stations, railway stations or any other relevant authority and

the warning light module using RF signals has a range of 1000m. These modules can be implemented on railway tracks and roadsides as signal lights as well as in houses and assembly places to notify users about elephant intrusions. The designed module lights up until the user turns off the switch hence getting an acknowledgment from the user.

E. Monitoring Center

The monitoring centre of the tusker alert system is developed using the ThingSpeak IoT platform. Data is sent using HTTP POST requests using the GPRS module to the ThingSpeak channel. The saved data on the IoT data base could be extracted as .CSV .XML or .JSON file types for further analysis. Using MS Excel extracted data was analyzed and visualized. This channel further allows analysis and visualization of the recorded data using MATLAB

The IoT channel is accessible through mobile app named ThingView and it was customized to view all the fields of the channel in graphical form. ThingView mobile app allow several analytical and visualization functions such as time pre-set analysis, custom comparisons, etc.

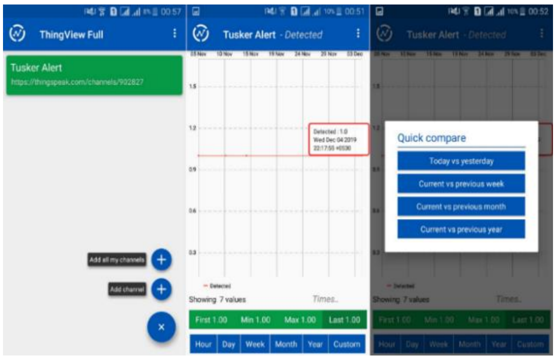

Figure 4. Thing view data monitoring app

F. Safety of System

The safety of the system was considered in 3 aspects. elephants, human and harsh environmental conditions

1) To prevent damage from elephants: the following methods are suggested when implementing the system in the real world. Driveaway elephants by emitting deterrence sound at 12 m. Using bio fences such as short lime vegetations around the system for 10m radius and embedding the system into a solid concrete structure.

2) To prevent the system from human threats: such as thieves following options followed; Implanting control box at 2.7m above ground beyond the reach of an average human. Using sensor tamper output signal and safety switch at the control box to generate a security alarm SMS on unauthorized breaching and using a community-based approach for awareness on maintaining and inspecting the system.

3) To prevent from harsh Environmental conditions: International protection rated sensors were used in the system. Dual-beam IR sensors (IP66) were protected from total dust ingress, protected from high-pressure water jets from any direction and limited ingress. PIR sensors

(IP44) protected from tools and small wires greater than 1 millimetre and protected from water spray from any direction. The validity of the ratings was also been tested by keeping the apparatus under heavy rain for 3 hours and no moisture was found inside. Embedding into a concrete structure in real world implementation would also increase the protection. Clearing the overhead trees and branches to ensure the maximum performance of the solar panels.

Test and results

This system was subjected to 4 tests. Node placement varied from 9m to 30m while nominal distance was stated as 100m

A. Test 1 – Detecting vehicles at KDU

Test1 was done as a control test with vehicles and a 100% detection rate of vehicles taller than 2m was obtained at KDU. Small trucks, trucks, buses, and lories are taller than 2.1m hence they are detectable while car bikes and vans are at undetectable height.

B. Test 2a and 2b – Elephant detection at Dehiwala Zoo

These tests were done using 6 sample elephants in the Dehiwala zoo. Test was conducted by keeping detection nodes 30 m apart and when elephant walk through.

Table 1. Sample Characteristics for Test 2

Name	**Number of tests**	**Detected**	**Detected rate %**
Namali	2	1	50
Madhavi	3	3	100
Bandula	3	3	100
Total	**8**	**7**	**-**
Average	**-**	**-**	**87.5%**

1) Test 2a: Individual elephant detection was tested at Dehiwala Zoo and a 95.45% detection rate was obtained.

Table 2. Results of Test 2a

Name	**Number of tests**	**Detected**	**Detected rate %**
Devi	2	2	100%
Khema	4	4	100%
Indi	2	2	100%
Namali	6	6	100%
Madhavi	8	7	87.5%
Total	**22**	**21**	**95.45%**

2) Test 2b: Done with an inclined path of 12° to simulate a situation of inclined railway crossing path. 87.5% of the detection rate was observed. It must be noted that test 2b was done using a sample of 3 elephants and for 8 times. Hence this result is not significantly accurate

Table 3. Results of Test 2b

Name	**Gender**	**Age**	**Shoulder height**
Bandula	M	52	297 cm
Devi	F	30	245 cm
Khema	F	36	242 cm
Indi	F	32	235 cm
Namali	F	17	230 cm
Madhavi	F	14	225 cm
Average			245.7 cm

C. Test 3 – Detecting Elephants & Herds at Pinnawala Elephant Orphanage

Test 3 was done at Pinnawala Elephant Orphanage. There a more realistic elephant behavior could be observed. Individuals, Adult Herds, and Herds with Juvenile elephants were present.

Table 4. Sample Characteristics for Test 3

Age (years)	Mean Height(cm)	Male	Female	Total
10-20	210	17	13	30
20-40	235	2	22	24
>40	240	3	4	7
Total	**220**	**22**	**39**	**61**

Table 5. Results of Test 3

Type	Number of Events	detected	rate%
Single	14	12	85.7%
Adult Herd	6	6	100%
Juveniles herd	8	8	100%
Total	**28**	**26**	**92.85%**

92.85% of Detection rate was observed with 100% Herd detectability.

Figure 4. Test 2a at Dehivala zoo. (Prototype is on right corner)

PIR detection within a 12m range of sensor nodes was also tested for activation of Deterrence. (But Deterrence sounds did not activate due to uncertainty, safety and reactions) there a 100% Detection for deterrence module also been observed.

To get a general idea of the performance of the Detection Module, a General Detection Rate is calculated (excluding test 1)

$$General\ Detection\ Rate = \frac{\boldsymbol{Sum\ of\ Result\ of\ (Test2a, 2b\&3a)}}{\boldsymbol{number\ of\ tests}}$$

General Detection rate of 91.93% was achieved with the primary detection system.

Application and Implementation

The designed system for detecting deterring and warning of elephant intrusions has a wider scope of applications where Human-Elephant Conflict is possible. Such identified applications are,

i. On Village Forest boundaries
ii. On elephant corridors at railway tracks where train elephant collisions are possible.
iii. On elephant corridors at roadsides where elephant presence is frequent

On each application, the system needs to undergo slight adjustments according to the terrain.

A. On Village Forest Boundaries.

On implementing the system in village boundaries following considerations need to be followed. Under-layer vegetation should be cleared and planted with plants like orange, lime or lemon which elephants have no appetite. Then the WSN transceiver nodes need to be implemented strategically behind the electric fence. Each house is equipped with an alarm system and each villager is getting an SMS or warning to the smartphone app. Centralized node with deterrence and warning modules need to be strategically placed in the boundary area so that any unnoticed person can be warned, and elephants can be deterred away. This centralized node could be used as a base station and all the detection signals from detector nodes could be collected in RF and converted into a GSM signal. (This will eliminate the GSM signal issues).

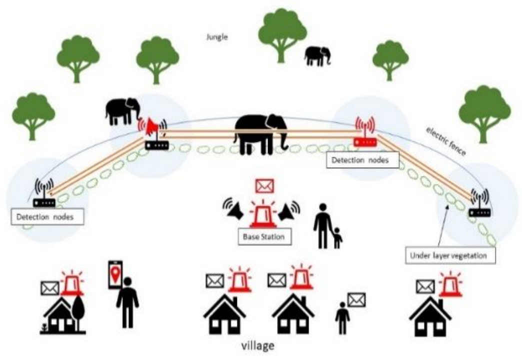

Figure 4. Implementation on village forest boundaries

B. On Railway Tracks and Roadsides

The receiver and transmitter modules are places parallel to the track (2-5m away). The maximum line of sight distance is 100 m. The signal lighting system is placed 1km away from the corridor and this distance can be increased using directional antennas to transmit RF signals. When an elephant passes through the sensors an alert SMS will generate as well as an RF signal sends to the signalling modules simultaneously the deterrence modules are activated. If an elephant reaches or moves beyond the limits along the track a special caution alarm will be generated with the signal. The warning modules can be placed in the engine room of the train if the train comes to the range of RF signals automatic warning will be given to the driver.

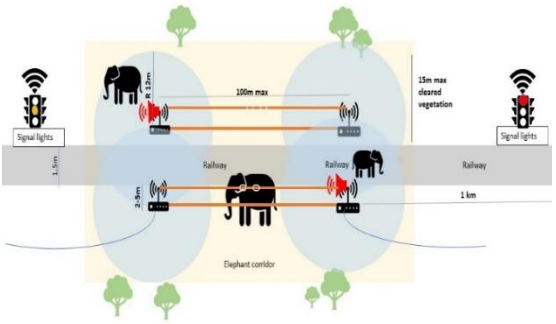

Figure 5. Implementation on Railway tracks/Roadsides

On implementing roadsides, the sensor placement is like that of flat/inclined rail tracks, but in case of a longer elephant corridor, the number of transceiver nodes would be increased. The vehicle drivers are alerted using warning signals as well as through the mobile application.

Future Improvements

Future improvements for this system are suggested as to carry out a pilot project with the wild elephant in a threatened area. Designing a circuit integrating all components (PCB) for commercial production. Integrating a SMS gateway portal for bulk SMS with subscriber options and Develop the prototype of the app. Integrate more IR beam sensor arrays and enhancing PIR to develop a Fuzzy logic controller to identify even juvenile elephants more accurately. Develop the monitoring IoT platform for better analysis and visualization performances. This design is already updating its data to a ThingSpeak cloud database in the MATLAB environment. By analysing the collected data for a long time and by identifying behavioural patterns of elephants, it is possible to manipulate this data for better visualization options as well as to implement a prediction algorithm. Finally providing opensource system access to the community for its developments and improvements.

Conclusion

Human elephant conflict is known to be a major socio-economic problem in Sri Lanka causing fatal damage for both humans and elephants. Protecting the lives and properties of people as well as conserving elephants was the focus of this project. Thus, the elephant intrusion Detection Deterrence and Warning system named "Tusker Alert" was successfully designed as a possible effective solution to minimize HEC. The design is Solar powered and uses IP (Ingress Protection) rated IR beam and PIR sensors for detection and GSM/GPRS for alerting along with RF warning light system used for warning. Buzzing bee sound and Elephant rumbles were used to deter and drive away from the elephants. The detection system was tested and observed a general detection rate of 91.9%. The application of implementation was enhanced to a wider range of applications such as for village boundaries, for railways and for the roadsides. This system is further enhanced by adding an IoT Things Speak database for monitoring functions of the node and a mobile application prototype to warn the users about elephant intrusions. Database and apps are suggested to be improved up to an advanced visualization and prediction algorithm along with the other future works. Finally, a possible solution for minimizing human-elephant conflict in rural areas of Sri Lanka and as well as an aid to the DWC and Railway department efforts on minimizing train elephant collisions were provided as the outcome of this project.

Acknowledgment

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