Design of a Vibration Sensor Based Train Arrival Detection System to Prevent Elephant-Train Accidents in Sri Lanka

Nuwantha. D. KULARATHNA[1], Sisaara PERERA[2]

(1. *Institute of Engineers Sri Lanka College of Engineering*;

2. *Department of Electrical and Computer Engineering, The Open University of Sri Lanka*)

Abstract: At present, Sri Lanka is home to about 5,000-6,000 wild elephants roaming over close to 70% of the country's land. Despite this blessing, around 150 elephants die each year due to many reasons. The main reasons for the altercations between humans and elephants are the drastic increase in the human population, human encroachment upon elephant territory for agriculture and settlements and unplanned development and transportation efforts. Elephants are long lived herbivores, and their survival depends upon regular migration over large distances to search for food, water, and social and reproductive partners. According to the Sri Lanka railways the average number of elephants that get killed due to elephant-railway accidents is about 9 per year. As a solution for this problem, we have proposed a novel system to pass a signal to indicate the train arrival. The proposed system detects the vibration of the locomotives and after detecting the vibration, alarm system will generate a high frequency signal within the frequency range, where the elephants are sensitive. The proposed system is a low cost device and this can be placed anywhere at any time. Moreover, this project aims to protect elephants from being harmed which usually happen due to various human activities.

Key words: Herbivore, Sri Lanka Railway, Locomotives

1 Introduction

Expansion of human settlements and agricultural fields across Asia and Africa has resulted in widespread loss of elephant habitat, degraded forage, reduced landscape connectivity, and a significant decline in elephant populations relative to their historical size and overall range [1]. As their habitats shrink, elephants are progressively forced into closer contact with people, resulting in more frequent and severe conflict over space and resources with consequences ranging from crop raiding to reciprocal loss of life.

Elephants are long lived animals, and their survival depends upon regular migration over large distances to search for food, water, and social and reproductive partners [2]. As a mammoth herbivore, a regular elephant consumes a maximum of 150 kg of forage and 190 L of water daily [3]. Meeting these basic needs requires a large foraging area to provide a variety of grasses, shrubs, and tree leaves, roots, and fruits. Moreover, typical family herd of Sri Lankan elephants (5–20 individuals) has a home range size of 100–1,000 km^2 [3]. As they range and feed, elephants affect the surrounding biodiversity. Researchers have found that when the elephants in shaping surrounding landscapes through feeding activities that damage tree canopies, uproot small trees and shrubs, and disperse seeds etc. [3] Moreover, due to unplanned development projects and large scale infrastructure developments such as roads and housing schemes that are built within elephant corridors and adversely affect the elephants who have been using these corridors for generations to migrate [4][5].

In Sri Lanka, around 250 elephants have been killed a year, but unfortunately prosecutions are relatively low. According to the Census and Statistics reports wildlife Conservation Department of Sri Lanka [9], approximately 48 persons and 200 wild elephants died due to human elephant conflict every year. Moreover, 75 of the elephants died by shooting, 20 elephants by getting caught in traps laid by farmers and a considerable number of elephants are being killed through traps laid with food containers packed with explosives has increased considerably. Also, the jaw bombs which are usually known in colloquial language as 'hakka patas' is a big threat to elephants [6] [7]. Attached to a pumpkin or pineapple, this device detonates once an animal bites it, badly wounding and ultimately killing it.

Besides, elephant train accidents are heavily affected to decline the elephant population over the last couple of years in Sri Lanka. According to the recent Census and Statistics, 10 elephants have been died by train accidents per year and which is a considerable amount. On the other hand, it has been found that the possible reasons for these accidents are highly depending on man-made activities. For example, the elephants usually run to the railway track when they are chased from Chena cultivation lands, plays a major role in elephant accidents. If this happens just when a train is passing by, the train cannot be stopped instantly when the elephant is seen a few yards ahead. On the other hand, the cargo train locomotives have about 15 compartments and it may not be possible to stop a train at an instant with a heavy load. Usually, the elephants are travelling in herds; the group follows the path that is taken by the matriarch of the herd. These animals behave in a closely knit manner and it reflects in their herd behavior. Only when the matriarch crosses, do the other animals follow her. The whole herd does not move away even if one elephant is left behind. They always want to keep their herd together all the time. This is why most of the time about two or three elephants gets killed due to these collisions.

However, in an effort to prevent the elephant-train accidents, the Department of Wildlife Conservation (DWC) in Sri Lanka has tried several methods, namely elephant translocation, setting up an elephant holding ground in mass elephant drives (Horowpathana) and the installation of electric fences. Electric fences are useful in addressing the aforesaid issue only as a psychological barrier. Because once the elephant breaks the fence, it learns and adapts to break it continuously. Therefore, it is mandatory and a crucial task to select the right geographical locations to install these fences. Elephant drives are another tactic to relocate many elephants to existing parks, sometimes 100-200 elephants at a time, but again the problem is unresolved because 95% of them consist of innocent females and their juveniles which means that the problem causing elephants are left behind. Moreover, use of 'ali wedi' or huge firecrackers to scare the elephants away from the lands has also become a futile effort, because while it may scare away the female elephants and cubs and even it will only aggravate and annoy the male elephants and due to that more damage will inflict.[5-6].

As stated above, according to the Census and statics of Sri Lanka railways, the average number of elephants that get killed due to elephant-railway accidents is about 9 per year [8]. In order to cater this issue, we have proposed a novel system to transmit a signal to indicate the train arrival by means of a vibration sensor and which is further elaborated under the section 'proposed methodology'.

1.1 Possible Reasons for Elephant Accidents

In the 1960's an elephant-railway collision was actually a rare phenomenon, although it has almost become a common occurrence along the '*Gal Oya'* train track. The major reason for this occurrence is that the human settlements in the '*Mahaweli*' areas and *Chena* cultivation activities have forced the elephants to change their routes. However, when these elephant herds are constantly chased away or if they cannot enter their usual grazing grounds the elephants tend to take other routes which have altered the previously identified elephant corridors. Thus, the train driver cannot expect at which point elephant herds would cross the railway track. This uncertainty and change in the locations where elephants cross railway tracks, elephants do not visible in bends, due to the misty weather conditions etc. have rendered it difficult for the train drivers to slow down the locomotive with a heavy load of other compartments and to be cautious about possible elephant movements.

In Sri Lanka, to date up to 324 trains running across number of 320 stations island wide. Not only the Department of wildlife conservation, but also the Ceylon Government Railway (CGR) also has taken some preliminary actions to prevent elephant train collisions. On the other hand, CGR provides transportation for 300000 passengers daily. Thus, their responsibility is to provide trusted and safe services to their passengers. As a result of this, CGR and the Department of Wildlife Conservation (DWC) have introduced several programs to minimize the elephant-train accidents. For example, as a precautionary measure, the DWC has appointed an officer from the department to sit in the train driver's compartment to spot elephant movements. But this has also proved ineffective in some cases if the elephant is spotted too close to a moving locomotive, it may not be possible to stop it suddenly. The only thing what railway officers can do is to limit the speed of a train within certain areas. Within warning areas, the speed limit is around 35kmph-1, So that the drivers can stop within 100m distance.

1.2 Recently Reported Incidents

According to Department of Wildlife conservation's 'Elephants Conservation Unit', the number of elephants killed and fatally injured on account of being hit by trains within the last three year is the highest number recorded so far [10-12]. Fifteen jumbos, including number of female elephants and calves were found to be dead on rail tracks bordering the national parks. Usually the elephants face fatal collisions as they get trapped between the shrubbery and steep embankment on either side of the track. During the recently reported accident, one elephant was killed and two others were badly injured in Anuradhapura district, which is about 160km (100 miles) away from north of the capital Colombo. According to the senses report of CGR, the train's engine was derailed during the collision and the deceased elephant is shown in the Fig.1, yet none of the 500 passengers was hurt.

Fig.1 Death of Elephant due to Train Collision in Anuradhapura Railway Line

The other recent accident was reported in 18th September 2018. The locomotive was EMD G12 power set, which was made in 1956 by the general Motor Diesel Company (Canada). The accident was happened due to the high speed of the train in a hill area and the damaged locomotive is shown in the Fig.2 and the deceased elephant in Fig.3 respectively.

Fig.2 18-09-2018 Collision and the Derailed Locomotive

Fig.3 18-09-2018 Collision-deceased Elephant

2 Research Methodology

We have studied elephant-train collision incidents in North Central province, with contrasting scenarios of geographical land use and conflict, *Manampitiya*, which was developed and settled under the Mahaweli irrigation project and the main agricultural practice was irrigated agriculture, with two annual growing seasons. The area was a mosaic of settlements, agriculture, and small forest patches with ill-defined human and elephant use areas. Elephants ranged within the habitat mosaic year round, occupying remnant forest patches and raiding adjacent crops at night. In contrast, *Yala* was dominated by a large protected area complex, and the main agricultural methods are 'slash and burn' agriculture and rain fed paddy cultivation. Human and elephant use areas were well defined and segregated. The protected area provided elephants with a refuge and food during the rainy season, when the single annual crop was grown. During the dry season, elephants moved into slash and burn areas and utilized leftover crops and pioneer vegetation in fallow fields. The land use pattern and agricultural practices in *Yala* facilitated co-existence, whereas that in *Manampitiya* led to year round conflict. On the other hand, there were so many elephant-train collisions have recorded over the past years in this region and yet no proper actions have been taken to avoid this problem. The only existing practice is to buzzer the horn of the train at a distance to alert the arrival of the train, which is an obsolete and has become an absurd method to protect the elephants from being harmed. As stated above, to cater this problem, we have introduced a novel elephant alerting and protection mechanism which avoids the movements of elephants towards the railway track while a train is arriving.

The proposed system consisted of two parts i.e. the Train arrival detection and signal generating system, which is developed using a vibration sensor and a control unit (PIC16F876 microcontroller). In addition, this mechanism is powered by a solar powered charging system to provide an uninterrupted supply. The proposed collision alerting system's sub unites are depicted in Fig.4.

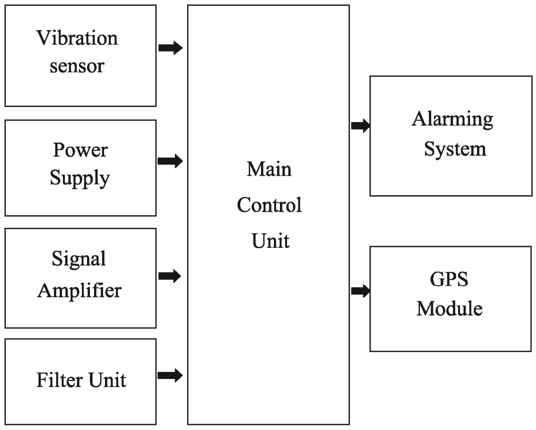

Fig.4 System Block Diagram

The Vibration Sensor measures the vibration induced by the train within the railway track. Here, the vibration sensor 801s module shown in Fig.5 is used to monitor the vibration along with the railway track. By means of the vibration signal, a buzzer (alarm) is generated to elephant's sensitive frequency to move the elephants away from the railway track.

This sensor module contains an LM393 amplifier, which acts as a comparator and a trimmer to adjust the sensitivity. The three major pins on this module are digital output, Power and analog output pins. The digital out produces a TTL signal that corresponds to the vibration of the sensor.

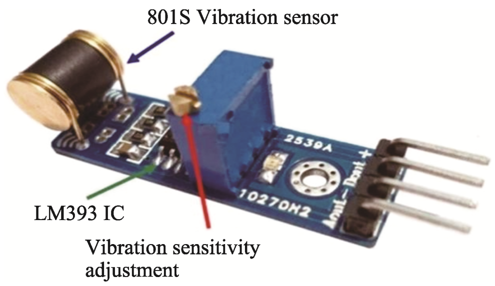

Fig.5 801s Vibration Sensor Module

2.1 Filter Unit

Due to the fact that the sensor node has to work on a very noisy environment, output of the transducer lies in few millivolts. Therefore, noise can be easily added to the signal and which definitely can cause undesired output. In order to filter out the noise in the captured signal, active low pass filter topology was used after the output signal.

Another important aspect is the stability of the filter unit, which totally depends on the quality of the passive elements. Cut-off frequency can be adjusted by varying the resistor and capacitor values. MCP601 a low noise operational amplifier with unity gain is used for filtration purposes. Note that one of the demarcating features of this filter unit is its anti-alliancing filtration capability, which directly helps to filter out the noise.

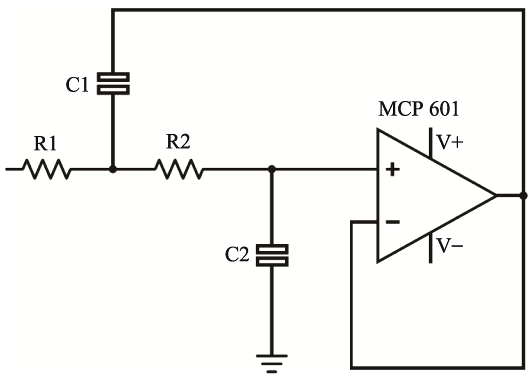

Fig.6 Active Low Pass Filter Topology

2.2 Data Collection

The data collection was carried out through a questionnaire survey to identify the elephant behavior patterns in the selected regions close to '*Habarana*' (*Mananpitiya*) and the technically detected GPS coordinates of the critical elephant-train locomotive collision points are tabulated in the following table 1.

Table 1 GPS Locations of Elephant Accidents (Source: Department of Wildlife Conservation)

Railway Station	Distance to the Collision Point (km)	GPS Coordinates of the Collision Point
Galoya	4.19	8.165261, 80.887576
Manampitiya	7.18	7.906672, 81.138488
Welikanda	2.83	7.955953, 81.273346
Habarana	8.65	8.103026, 80.809158
Polonnarauwa	8.60	7.910914, 81.100421

The mentioned collision locations and elephant crossing points were identified by considering the facts like details obtained from the relevant railway area road inspectors, from well experienced locomotive drivers who are frequently driving at these areas and from Civilians and farmers etc.

The following table 2 shows the approved speed limits for the locomotives in the elephant crossing points, which is further illustrated in Fig.7.

Table 2 Approved Speed Limits of the Locomotives in Elephant Crossing Points

Speed of the Locomotive (kmph)	Usual Speed (kmph)	Train Stop Distance (m) with Speed	
25-35	45-50	100m	35kmph
		800m	70kmph

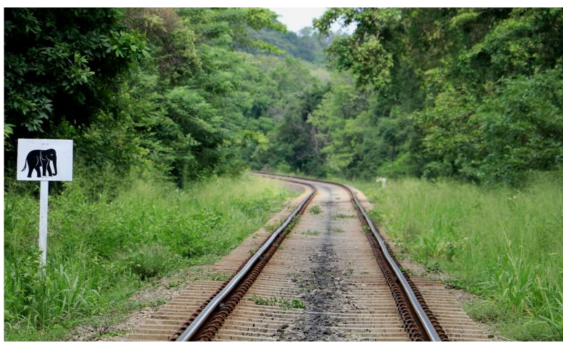

Fig.7 Elephant Crossing Point in Manampitiya

3 Circuit Design and Testing

As stated in section 2, a vibration sensor based circuit is designed by means of the Proteus® software package and its relevant PCB layout and the 3D view is illustrated in the Fig.8 and Fig.9 respectively.

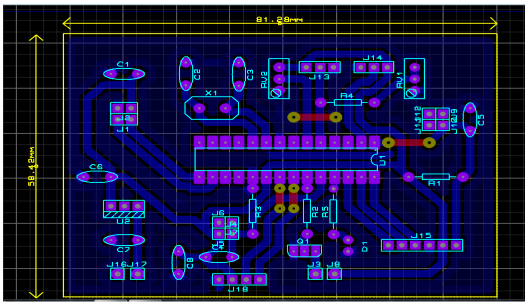

Fig.8 PCB Layout

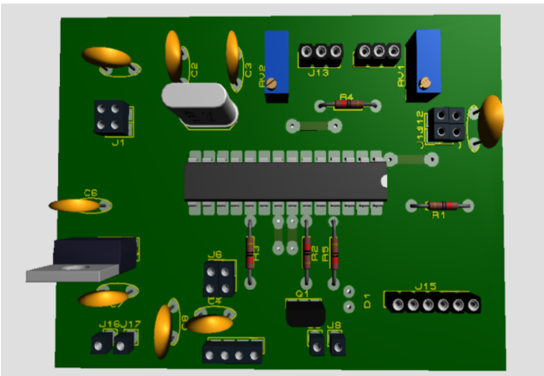

Fig.9 3D View of the Circuit

4 Measurements and Discussion

4.1 Vibration Sensor Range Measurements

In order to measure the vibration range of the locomotives, it is mandatory to select specific locations. Because while measuring the vibration patterns, the detected range could be varied from point to point due to several factors like, train speed, number of compartments of trains, number of passengers, types of sleepers of the railway track and Ballasts etc.

The testings were carried out within the railway stations from the *Polonnaruwa* to *Manampitiya*, where the exact location of the collision point was identified as 7.913562, 81.088902 in Google maps as shown in the Fig.10. The observed results in other GPS coordinates are also tabulated in the following table 3. It has been observed that the, 92.8s time is fair enough time interval for an elephant to safely move away from the track.

Table 3 GPS Coordinates of the Collision Points

GPS Coordinate	Vibration Distance (km)	Time (s)	Train Speed (kmph)
7.913562, 81.088902	1.38	92.8	50
7.910914, 81.100421	1.23	98.6	45
8.103026, 80.809158	1.28	95.3	48

Fig.10 A typical Collision Point in a Google Map

4.2 Prototype Implementation

The prototype implementation of the proposed design is shown in the Fig.11.

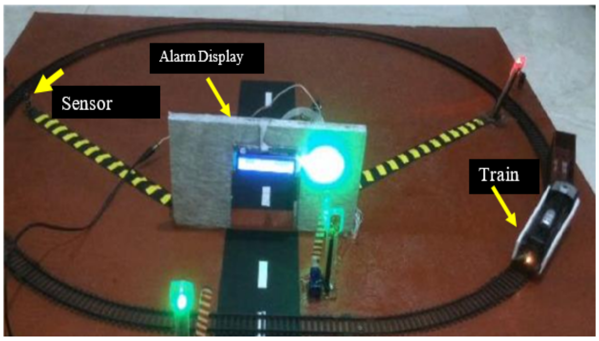

Fig.11 Prototype of the System

As stated earlier, the entire system is powered by means of a solar cell. When a locomotive is coming towards the sensor element and the locomotives vibration level reached to the sensor element's threshold level, a signal is transmitted to the main controller unit and then microcontroller sends that signal to the buzzer and infrasound alarming occurs. Apparently, sensor detects the vibration levels of the train from 1-1.5 km away from the collision point and the measured data are tabulated in the following table 4.

Table 4 Measured Noise Levels of the Locomotive (EMG D12 Power Set)

Date	Vibration Distance (km)	Time Detected (s)	Measured Equivalent Sound Level (dB)	Background Noise Level (dB)
15-12-2020	1.38	92.8	60	54
	1.34	93.6	60	55
	1.30	94.3	61	57
	1.28	95.3	59	55
	1.23	98.6	60	57
16-12-2020	1.38	92.8	60	58
	1.34	93.5	61	56
	1.30	94.1	60	57
	1.28	95.2	60	58
	1.23	98.5	59	57

5 Conclusions and Future Work

Conservation of elephants is considered as a major concern of conservation in elephant range countries. A variety of management strategies have been developed and are practiced at different scales for preventing and mitigating human elephant conflict. However, human elephant conflict remains pervasive as the majority of existing prevention strategies are driven by site specific factors that only offer short term solutions, while mitigation strategies frequently transfer conflict risk from one place to another. During the study of this research, we have proposed a novel scheme to detect the elephant train collisions in Sri Lanka. The proposed mechanism also highlights the importance of including anthropological and geographical knowledge to find sustainable solutions for this issue. As future works, Vibration sensor based train arrival detection system can be used for other applications such as to monitor unsafe railway gates in rural villages. Besides, the subject of vibration is highly used in industrial machinery, vehicle vibration monitoring industry and systems which deliver output based on the vibration. Therefore, several problems associated with this phenomenon can be used in further research aspects.

Finally, we suggest that just as wildlife needs are measured and modeled to improve conservation management planning, information about cultural values, norms, and decision making regarding the use of habitat to support local livelihoods. Above all, Government involvement is highly needed to implement any policy; otherwise the large sums of money spent researching this issue will have been in vain.

Acknowledgement

The authors wish to acknowledge Mr. Achintha Wimaladasa, Assistant supervisor of Department of Wildlife conservation Sri Lanka and Mr. Nilanka Nanayakkara, locomotive driver of Sri Lanka Railways for the assistance extended in preparing this paper.

References

[1] Department of Census and Statistics (1986) Census of Population and Housing 1981, General Report Department of Census and Statistics, Ministry of Plan Implementation Colombo, Sri Lanka.

[2] De Silva, M. and De Silva, P.K. (2007). Sri Lankan Elephant: Its Evolution, Ecology and Conservation. WHT Publications.1, 11-12.

[3] Ekanayake, S.K.K., Campos-Arceiz A., Rupasinghe, M., Pastorini, J. and Fernando, P. (2011). Patterns of crop raiding by Asian elephants in a human-dominated landscape in south-eastern Sri Lanka. Gajah. 34, 20-25.

[4] Fernando, P., Jayewardene, J., Prasad, T., Hendavitharana, W. and Pastorini, J. (2011). Current Status of Asian Elephants in Sri Lanka.Gajah. 35, 93-103. Fernando, P., Kumara, M.A., Williams, A.C.

[5] Wickramanayake, E., Aziz, T., & Sing, S.M. (2008). Review of human-elephant conflict mitigation measures practiced in South Asia. World Wide Fund for Nature.

[6] Jarungrattanapong, R. and Sajjanand, S. (2011). Analysis of policy options to convert human elephant conflict into human elephant harmony. Research Report No. 2011-RR14. Economy and Environment Program for Southeast Asia.

[7] Santiapillai, C., Wijeyamohan, S., Bandara, G., Athurupana, R., Dissanayake, N., and Read, B. (2010). An assessment of the human-elephant conflict in Sri Lanka. *Ceylon Journal of Science (Bio.Sci.).* Vol 39(1). 21-33.

[8] Thirgood, S., Woodroffe, R. and Rabinowitz, A. (2005). The impact of human-wildlife conflict on human lives and livelihoods in Woodroffe, R., Thirgood, S. and Rabinowitz, A. (eds). *People and Wildlife: Conflict or co-existence.* Cambridge University Press. The Edinburgh Building, Cambridge CB2 2RU, UK. 13-26.

[9] Department of Census and Statistics (2019) Department of Wild Life Conservation Sri Lanka. Available: http://www.dwc.gov.lk/.

[10] Sunday Observer (Sri Lanka): 'Trunk call to railways'. Available: http://www.sundayobserver.lk/2018/10/21/news-features/trunk-call-railways.

[11] "Daily Mirror (Sri Lanka): 2013-07-05 - TRAGEDY-Press Reader". Available: https://www.pressreader.com/sri-lanka/daily-mirror-sri-lanka/20130705/281921655634065.

[12] "Tragedies on railroad tracks Methods proposed to curb'-Daily Mirror". Available: http://www.dailymirror.lk/news-features/Tragedies-on-railroad-tracks-Methods-proposed-to-curb-jumbo-deaths-Authorities-still-at-discussion-s/131-156717.

Author Biographies

Nuwantha D. KULARATHNE, is a Graduate Diploma holder from The College of Engineering, The Institute of Engineers Sri Lanka (IESL-CE). His main research interests include mathematical modeling, signals and systems, wireless communication and IoT based research studies.

Email: nuwantha11@gmail.com

Sisaara PERERA, received his Bachelor's degree (B. Tech Honours in Engineering) from The Open university of Sri Lanka. He is currently a Lecturer attached to the Department of Electrical and Computer engineering at the same university. His main research interests include machine vision, image processing, robotics, nano-engineering and applications.

Email: msper@ou.ac.lk