IoT Enabled Elephant Detection System to Avert Mishaps in Railways

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Abstract
Elephant deaths in train accidents have become a serious issues for both the forest and railway authorities. The primary goal of this work is to provide a feasible solution to reduce elephant train accidents and safeguard elephant life. In this work, we developed a prototype to detect the presence of elephants in real time by using emerging approaches that makes use of the Machine learning (ML), Internet of Things (IoT) and Wireless Sensor Networks (WSN). The machine learning model is used to detect the presence of elephants in and around the railway track regions. Once the elephant is detected, the IoT system will track the location and number of elephants near the railway region by using camera. Further, the IoT device tries to emit honey bee and lion growl sound to deters away the elephant from rail track region. Also, it sends an alert message to the nearest railway station master and approaching train driver by using LoRa. The proposed IoT-enabled elephant detection system helps the railway officials to take proactive measures and to prevent elephant train collisions and protect both human lives and wildlife.

Keywords:
IoT, raspberry pi, Image Processing, Machine Learnig, LoRa, Human-Elephant conflict.

1. INTRODUCTION

Rapid increase in human population leads to huge demand on economic resources and their living environment. Human activities such as deforestation, urbanization, land-use changes, and infrastructure development affect every ecosystem on the earth and cause conflict between humans and wildlife. In that, Elephant Train Collision [1] (ETC) is a major issue across the world, especially in India there were 45 elephants killed on railway tracks and further, elephant deaths on railway tracks have nearly doubled from 10 to 19 during the period 2019 to 2021 [2]. The year-wise details of number of elephants killed in train accidents [3] is shown in Figure 1.

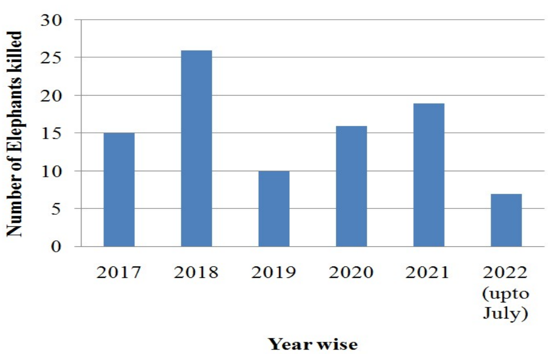

Fig.1. Elephant Train collsion on railway tracks around India from 2017 - 2022

Figure 2 shows a high speed train crushed and killed an elephant that was crossing the railway track line near Kanjikode in Palakkad district, Kerala in 2022 [4]. Not only elephants have been killed by train accidents; even other wild animals also killed by train accidents. The major elephant train collisions spotted by the railway officials at Tamilnadu state is the Ettimadai to Kanjikode railway track lines, which connect Kerala and Tamilnadu state. To resolve elephant-train collision issue, an IoT enabled elephant detection systems is a promising technology that has the potential to reduce the number of elephant train collisions in Indian railways.

Fig.2. Elephant-Train Collision at Kanjikode, Kerala [4]

Several strategies and techniques have been implemented by different parties with the objective of reducing the effects of Elephant Train Collision (ETC). The effective measures to address this issues are fencing along the railway tracks, reducing train speed near the elephant activity zones, train can use loud horns near elephant crossing zones or use innovative technologies such as drones or satellite monitoring, to track the elephant movement and predict potential collision zones more accurately.

The main objective of this work is to develop a prototype to detect the presence of elephants in real time by using emerging approaches that makes use of the Machine learning (ML), Internet of Things (IoT) and Wireless Sensor Networks (WSN). IoT-enabled elephant detection system that uses Internet of Things (IoT) technology to detect the presence of elephants in nearby railway track zones. The system typically consists of a network of sensors that are strategically placed near railway tracks where elephants are known to be frequent. The ML technique that predicts the presence of animal, type of animals and its movement. In our work, ML algorithm is trained to detect elephants. The proposed IoT-enabled elephant detection system provides a feasible solution to prevent these Elephant Train Collision (ETC) accidents and hereby saving our elephant lives.

Figure 3 shows the proposed framework to detect the elephant near railway track lines. The system consist of a cloud server, fog node, camera, loud speaker, camera and Raspberry Pi board. The proposed framework consist of three tiers. First tier contains camera module to capture pictures. The Raspberry Pi controls the camera to take pictures by around 360 degree with help of stepper motor. Second tier contains Fog node. It is responsible to process the received picture from tier 1 and report the presence of elephant to tier 1 and tier 3 for further process.

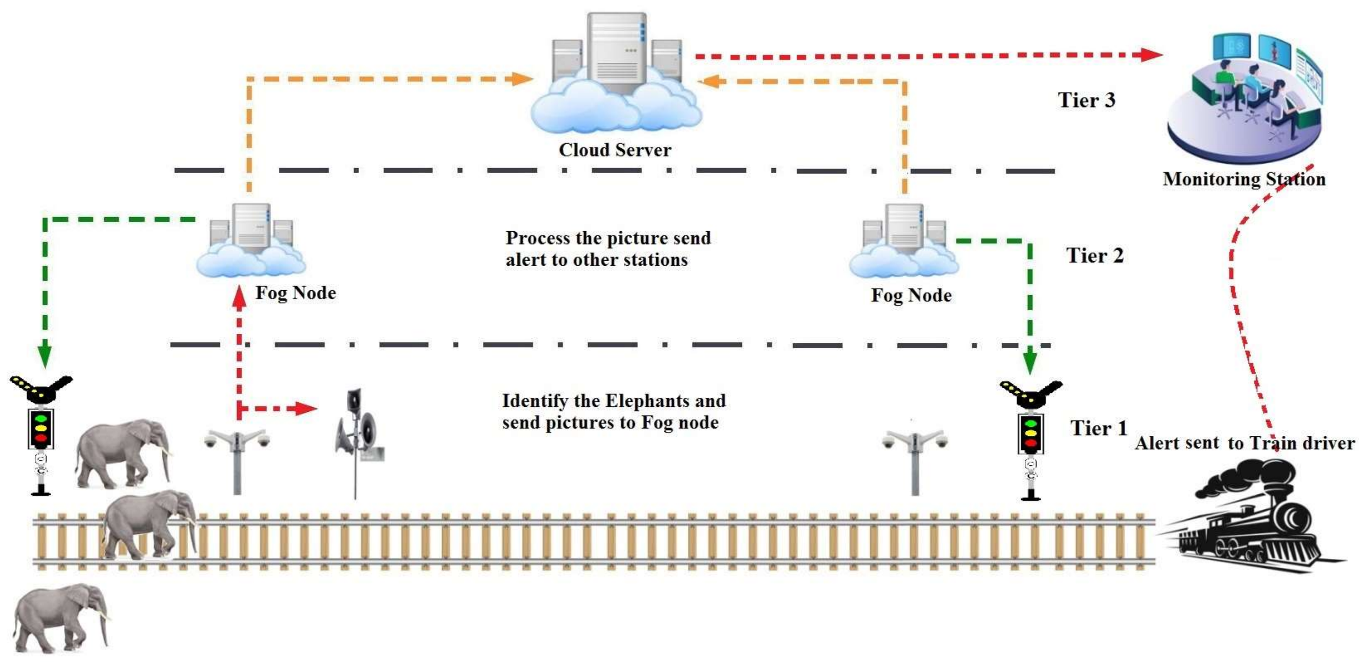

Fig.3. Workflow of Proposed Framework

Due to huge deployment cost and limited resources, we tested our proposed work by using elephant toys.

In rest of this paper, section 2, we discussed research work carried to overcome Elephant Train Collision. In section 3, we have described the components and methodology to develop IoT enabled elephant detection system are discussed. In section 4, the hardware implementation, dataset description and ML algorithm. The experimental results and its performance was elaborated in section 5. Finally, section 6 briefly summarizes our proposed work and outlines possible directions of future work.

2. RELATED LITERATURE

Elephant intrusion is a major problem causing collision of train and elephants, elephant death and injuries. The surveillance and monitoring of elephants in the railway track near forest area and villages is very difficult. To rectify this problem, researchers have used cameras and other kind of sensors to detect the elephants near railway track and villages. Mandal *et. al.* [5] proposed an unsupervised artificial neural network model using geophone sensors to detect elephants near the railway tracks which is supposed to activate bee sound or virtual cracker fire sound to deter away the elephant. Jagannathan *et. al.* [6] proposed elephant identification in the video frames by applying transfer learning approach to convolutional neural networks (CNN) such as SqueezeNet and VGG16 architectures. The author has compared the CNN architectures with conventional image processing techniques and custom created convolution neural network. VGG16 CNN architecture provided a higher accuracy of 94%. The authors [7] proposed a region-based convolution neural network. Pre-trained model such as SSD mobilenet v2, SSDLite mobilenet v2, SSD inception v2, Fast R-CNN inception v2, are used to build custom object detection model by transfer learning technique. SSDlite mobilenet v2 model produced the best results with accuracy of 85.4%.

In [8] Wireless Sensor Network (WSN) is used to detect the elephants and send signal to receiver which is connected to LoRa transmitter. SX1278 model of LoRa is used to build a peer-to-peer communication between WSN receiver end, elephant repelling system & base station. Base station resides in the threatened villages and it consists of alarm system to alert people. This alarm system activates when elephant detecting system detects elephants or when elephants break the fence and invade towards village which is identified through the laser protection system. Surabhi Gupta et. al. [9] proposed a deep vision-based model to identify the elephant using implanted video cameras. Four different models were proposed for the identification of elephants in image/video. One novel lightweight CNN based model is proposed. Three Transfer Learning (TL) models, i.e., ResNet50, MobileNet and Inception V3 have been experimented and tuned for elephant detection. Inception Net has performed best in binary classification. It achieved an accuracy of 99.91%. The model can be used for generating alarm on-site and in a train near the track for warning and hence saving elephant life. Girish et. al. [10] proposed an elephant detection and alert system using IoT in forest highways. YOLO (You just look once) algorithm is used for detection. IoT plays a major role along with Rasberry pi module to detect the animals and alert the vehicles. Sensors are used to detect the obstacle which activates pi camera configured by raspberry pi to capture live images or video and detect the movement of animals with help of image detection, then alert the people and vehicles in the forest highways.

In all the above proposed system, it either consists of detection part alone or communication part alone with some basic detection methods. Moreover, all the proposed system can work in places where internet is available, if suppose internet fails then information cannot be shared to alert the people. Various object detection algorithms like support vector machine, K-nearest neighbor, Region-based Convolution Neural Network and YOLO are proposed. Out of these algorithms, YOLOv5 architecture [11] performed well for detecting presence of elephants in forest environment. This architecture is also suitable for raspberry pi. The detected information is passed locally through LoRa network, so that even if internet is not available, the system can communicate the alert signal. Further the receiving node act as a gateway and passes information to internet and data is stored in cloud. This system helps to identify and tracking elephants. It is useful for forest authorities to reduce human- elephant conflicts.

3. METHODOLOGY

The proposed IoT enabled system detects the presence of elephants near and around railway track zone using sensors. The system also provides deterring methods to drive away elephants away from railway tracking zone. The block diagram of proposed system is shown in Figure 4. The system consists of a camera module connected to a raspberry pi board (end node) is used to take photos at regular intervals of time and it is sent to Fog node for further process. The camera module in the end node takes images and it is sent to fog node for further process. The camera module capture the pictures at an wide angle of 360 degree for that servo motor is attached to the camera module. The servo motor rotates the camera module at an angle 45 degree for every one picture captured by the camera device.

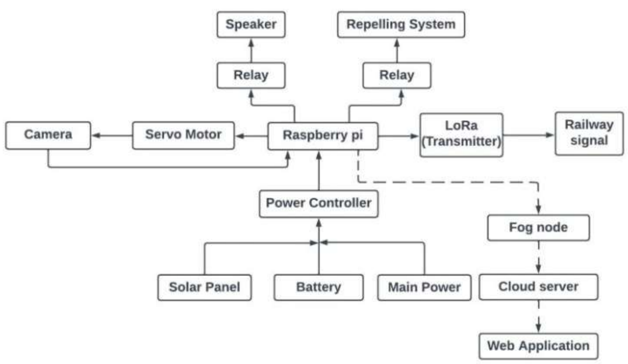

Fig.4. Block Diagram of IoT Enabled Elephant Detection

The machine learning model (YOLO) installed in Fog node is to processes the camera images for identifying the presence of elephants. If the elephant is detected by Fog node then, information about the elephant spotting and camera direction will be sent to end node. Based on the alert received from the fog node, the end node will turn the railway signal to red to avoid any mishaps using Lora communication. Also end node will triggers the speaker module to play the buzzing sound of swarm of honey bees and lion growl sound to drive away the elephant away from railway track zone. There by end node will trigger the camera to the elephant spotted location and monitor the elephant further. Based on the elephant movement the camera module will be turned to new elephant location by using servo motor.

The IoT enabled end node establishes a communication with another IoT enabled end node by using LoRa protocol. The end node is equipped with a separate LoRa module which acts as a transmitter and the coordinator node is equipped with a separate LoRa module which acts as a receiver. Data received at the coordinator node is updated to the cloud database through MQTT protocol. Coordinator node is configured as a client (publisher) which puts message to specified topic. Thingspeak dashboard is configured as client (subscriber) which listens to that topic and results are viewed through different widgets created. The cloud server will send the information to concerned railway officials.

4. IMPLEMENTATION

4.1. HARDWARE SETUP

The connection of Raspberry Pi board with other hardware components is shown in Figure 5. The Raspberry Pi board is connected to the laptop to monitor the elephant movements using HDMI cable. The Raspberry operating system (OS) is installed in the external memory of SD card. The internet connection is supplied to the board through an Ethernet port. Finally, the power supply (+5v) to the board is provided using USB charging cable or by external adaptor.

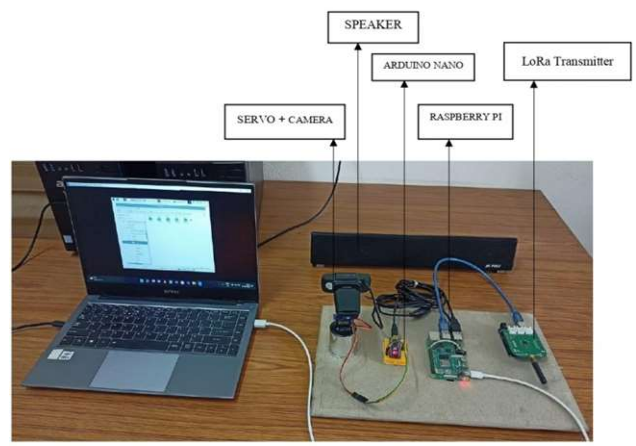

Fig.5. Proposed model for transmitter

Table.1. Compont Description

S.No	Component Name	Specification
1	Raspberry pi	Pi 4 Board
2	Arduino Nano	ATmega328P MCU
3	LoRa	SX1272 (860-1050 MHz) Transmission up to 16km range
4	Camera	Zebronics 5mp Webcam resolution of 1280×720
5	Servo motor	SG90 Micro Servo
6	Speaker	One unit

4.2. MACHINE LEARNING ALGORITHM

Convolutional Neural Network (CNN) is mainly used for image classification, object detection, and image recognition in real time. One popular CNN based object detection framework is You Only Look Once (YOLO). It uses a single neural network to process the entire given image, then separates it into parts and predicts bounding boxes. These bounding boxes are weighted by some expected probability. The YOLOv5 model works by first splitting the input image into AxA grid of cells and each cell in the grid predicts atleast 2 bounding boxes which involves x, y coordinate, width, height and confidence. Class prediction is done based on each cell. The Figure 6 shows elephant detection using YOLOv5 framework model. This study implements YOLO object detection using python OpenCV software. By using Yolov5 algorithm the elephant detection accuracy rate is found to be 98.6%.p

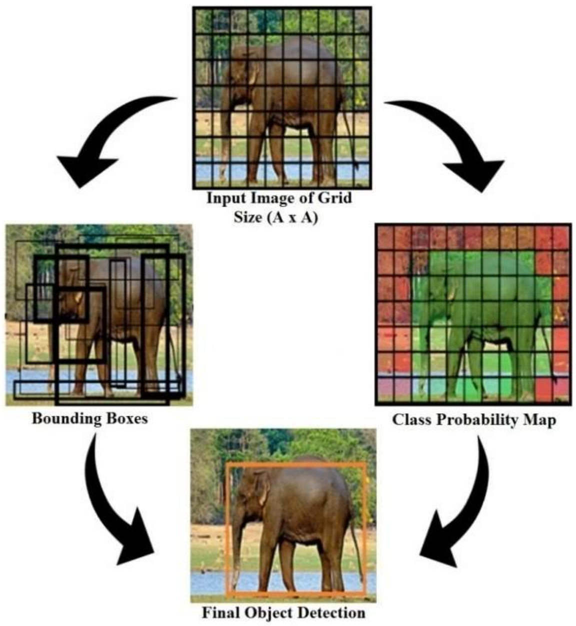

Fig.6. Elephant detection using YOLO framework

4.3. DATASET DESCRIPTION

The ML algorithm YOLO v5 is trained to detect the elephant from the dataset. Dataset is used for training and validating the elephant class. An open access elephant image dataset obtained from Open image v6 includes 377 elephant images which contains both images and text files of elephant class information. The elephant images includes real, toy, statue and label elephant images. In our research work, we pre-processed the images to improve raw images. All pre-processed images were labeled manually and resized to 214 x 214.

4.4. PROPOSED ELEPHANT IDENTIFICATION SYSTEM

The working of IoT enabled end node is to detect the presence of Elephant near the railway track zone is shown in Figure 7. The end node constantly checks if any elephant is present nearby and around the railway track zone by using camera. The servo motor rotates the camera module circularly at an angle of 45 degree to take images and it sent to Fog node with camera angle. The Fog node process the received images by using YOLOv5 machine learning (ML) algorithm. If the elephant is detected by ML algorithm then alert sent to raspberry pi node. The node will trigger the servo motor to stop rotating the camera further. Thereafter, the camera monitor the elephant at an angle where the elephant was detected earlier.

The raspberry pi board saves the elephant detected images and further it continuously monitors the elephant movements. Simultaneously, IoT enabled end node report the presence of elephant to the nearest station master, train driver and turn the railway signal to red by using LoRa protocol. The above information is in turn updated to a cloud database where the information can be viewed by anyone on internet. If the elephant found near and around railway track zone then the IoT end device tries to emit honey bee and lion growl sound to deters away the elephant from railway track zone.

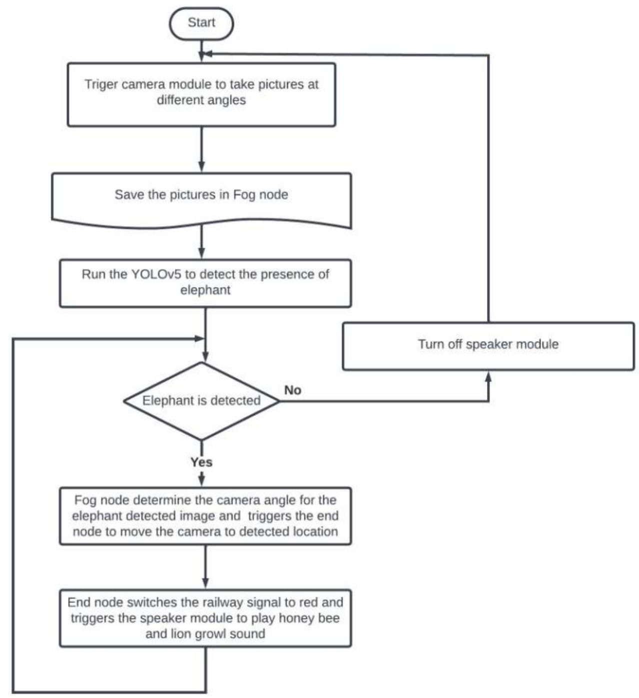

Fig.7. IoT enabled end node Elephant detection

4.5. THINGSPEAK CLOUD:

ThingSpeak is an analytics tool used to analyze, visualize and aggregate the live data streams. The ThinkSpeak cloud platform can send the data to other devices, use to monitor real time visualizations of data and to send alarms.

1. A demo account in Thingspeak is created by signing in through MATLAB account. Unique channel is assigned with “channel ID”, “Read keys” and “Write keys”. Write key is used to write data to cloud and read key is used toread data from cloud.
2. New fields (topic) are created in the channel by going to settings page. These are the spaces to which data is written or from which data will be read. The default method of reading and writing data is “HTTP”. But in order to save bandwidth and to prevent the channel to be idle for a long time “MQTT” protocol is used.
3. A new MQTT device is created by clicking into devices option on task bar. New user credentials like username,

client ID and password are created.

4. In the raspberry pi (coordinator node) side, “paho- mqtt” is installed through pip3 command. This is used for package installation in python. Basic example python code given in the package is used to change the new user credentials
5. Inside the main python code message topic is changed to the field name same as in Thingspeak dashboard (e.g., field= topic= “elephant presence”). Now raspberry pi is a client (publisher) and Thingpeak dashboard is another client (subscriber) while Thingspeak cloud being the broker.
6. In order to view the data meaningfully widgets are setup in dashboard. There are some basic widgets inbuilt. A custom widget using MATLAB code and maps is created to tell the location and status of each node distributed over a large area.

5. RESULTS AND DISCUSSION

IoT enabled elephant detection system is built using Rasperry pi hardware and the performance of the system is analyzed using various metrics

5.1. ANALYSING ELEPHANT DETECTION USING YOLO MODEL

Precision determines how many samples are correctly classified (True Positive) to the total number of images (True positive and False positive). Precision is expressed in Eq.(1)

$$Precision = \frac{TP}{TP+FP} \quad (1)$$

Recall is used to determine how many samples belonging to a positive class were classified as positive by the classifier. Recall is expressed in Eq.(2)

$$Recall = \frac{TP}{TP+FN} \quad (2)$$

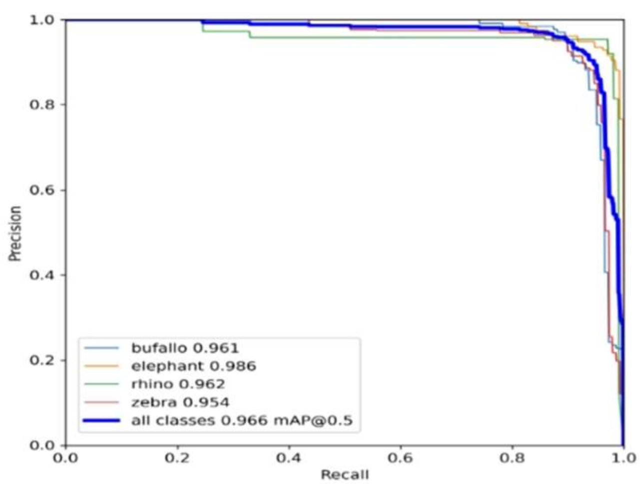

Fig.8. Precision – Recall curve

Figure 8 shows precision and recall curve for different animals. The precision recall curve shows the trade-off between precision and recall for different threshold. A high area under the curve represents both high recall and high precision, where high precision relates to a low false positive rate, and high recall relates to a low false negative rate. High scores for both show that the classifier is returning accurate results (high precision), as well as returning a majority of all positive results (high recall). This trained model has a large area under curve, hence this has high precision and high recall.

5.2. CASE STUDY

The servo motor is attached to the camera module to capture the pictures at an wide angle of 360 degree.. The servo motor rotates the camera at an angle 45 degree for every one picture captured by it. The pictures taken by the camera at different angle are shown in Figure 9. The captured images are sent to raspberry pi board for further process. The machine learning algorithm (ML) analyze the received images to detect the presence of elephant. If the elephant is detected by ML then, raspberry pi will trigger the servo motor to stop rotating the camera further. Thereafter, the camera monitor the elephant at an angle where the elephant was detected earlier.

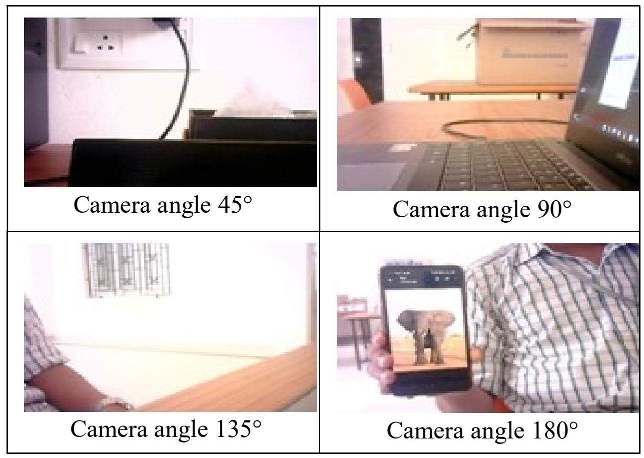

Fig.9. Images taken by camera at different angles

Two different cases were tried to test our IoT enabled elephant detection module.

Case 1 : Elephant is absent. The alert light in dashboard changes to dull red. The step function graph toggles to “0”.The location point in map changes to green. These are depicted in Figure 10(a).

Case 2 : Elephant is present. The alert light in dashboard changes to bright red. The step function graph toggles to “1”.The location point in map changes to red. These are depicted in Figure 10(b).

As soon as elephant is confirmed by the ML model, the raspberry pi at end node plays mp3 sound of buzzing honey bee swarm. This could save a lot of human lives from elephants as well as the endangered elephants from humans.

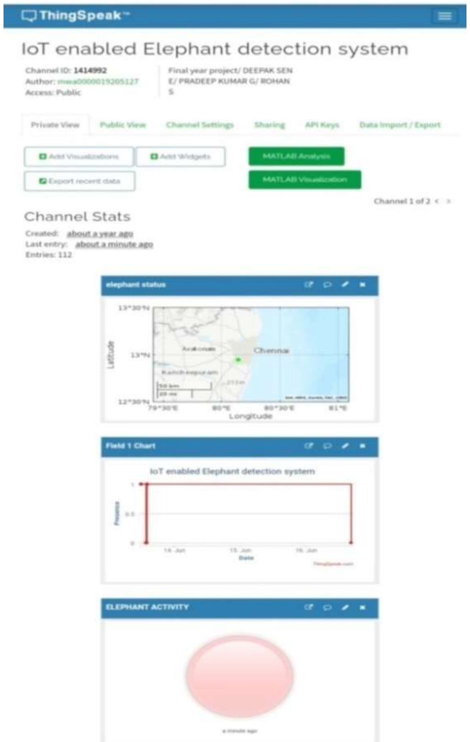

Fig.10(a): Dashboard When Elephant Is Not Detected

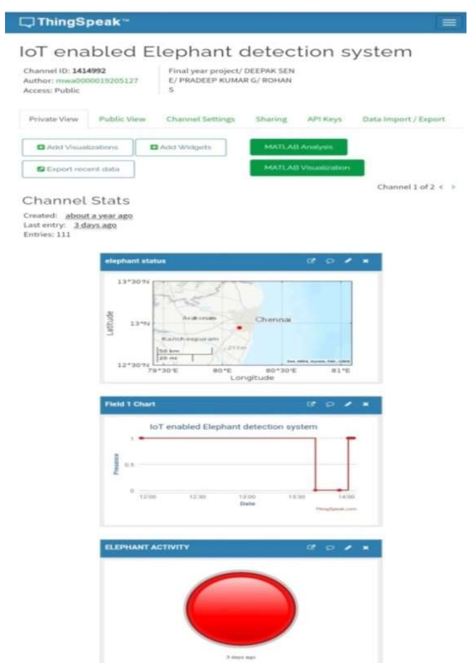

Fig. 10(b): Dashboard When Elephant Is Detected

6. CONCLUSION

In this research, we provided a feasible solution to reduce the problem of Elephant Train Collision (ETC) by using IoT enabled elephant detection system. The proposed surveillance mechanism monitors the elephant movement 24x7 and has the potential to decrease the elephant deaths across railway track regions. From the obtained results, we conclude that our model has elephant detection accuracy rate of 98.6%. Further, the machine learning model will be trained on night vision and thermal images so that the system could detect elephant during night time.

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