Autonomous Forest Surveillance & Safety System

Krishna Sai Varma U, Mohit P, Jithender Reddy J, Metilda Florence S
Department of Information Technology
S.R.M University
Chennai, India
krishnasaivarma@hotmail.com

Dr. Mohan S
College of Computer & Information Systems
Al Yamamah University
Kingdom of Saudi Arabia
s.mohan77@gmail.com

***Abstract*—Forest surveillance means monitoring the forest and preserving its wildlife and vegetation. It includes preventing forest fires, deforestation, monitoring endangered species, alerting in emergencies etc. The current day forest surveillance systems are implemented in many ways ranging from Closed-Circuit Television (CCTV) monitoring, camera traps, fire detectors, drones, and many more. All these methods are heteronomous or semi-automatic requiring a constant human attention and also consume a lot of resources making them inefficient and less reliable. Many of these tasks can be easily automated by machines and other technologies. The proposed project is a single autonomous surveillance system, based on object detection technology. The proposed system is capable of monitoring forest fires, intruders, wildlife etc, all at once and alerts the concerned officials immediately and precisely. The proposed system is implemented on a Raspberry Pi with a camera, fire sensors, and multiple other sensors. This system uses a hybrid object detection system which can be trained to detect specific animals, humans or tools. This helps in automating the monitoring of unwanted visitors, dangerous animals, forest fires, endangered species or restricted areas in the forest. The proposed system can not only store the video feed but can also sends the pictures to your email directly along with real-time video monitoring via the internet which allows the users to monitor from anywhere in the world. It also sends instant alerts to your phone via an SMS in emergencies. It is a cheap single module system which is easily expandable and comes with a controlling software which allows us to control the what animals to be detected and their alert levels and also gives us a primary analysis on various things like forest fires, animal population, trespassed areas etc by collecting data from various monitoring modules creating an information system of forest.**

Keywords*—Surveillance System; Hybrid Object Detection; Raspberry Pi; Forest Fires; Animal Detection

I. Objective

To reduce the manpower in a forest by implementing a fully automatic surveillance system using hybrid object detection and various machine learning technologies to monitor forest by detecting animals, capturing pictures & videos and alerting users in case of forest fires, rogue animals and others using email and message and collect data which can be used for Environmental information system.

II. Problem Statement

The existing forest surveillance systems cannot operate autonomously. They are either are heteronomous or semi-automatic requiring constant human attention, whose tasks can be easily automated by machines and other technologies thus increasing the likelihood of errors. They also consume a lot of resources and require high operation cost. These systems cannot identify specific targets and the alert mechanism is mostly done manually or semi-automatic making them unreliable.

III. Literature Review

The present-day forest surveillance is implemented in various manual ways like CCTV monitoring, camera traps and automatic ways like fire detecting sensors and drones, etc. but these are not completely autonomous [8]. most widely used methods include.

A. Close-Circuit Television(CCTV)

The Close-Circuit Television (CCTV) is a surveillance system where many cameras output to one live visual display, where a human monitors them. The problems encountered with this are that it needs a lot of space & cost to operate, it also produces low-resolution videos and mainly, the system's dependency on a human operator who detects some useful activities. It is defective and expensive to detect every event in the monitor buy human thus increasing the error rate.

B. Camera Traps

A camera trap is a setup with a camera that is activated remotely which is equipped with motion detection systems, like an Infrared sensor or proximity sensors. When a movement is detected by the sensors they will trigger the camera, capturing any footage in front of the camera. This method is used for decades for capturing wild animals when researchers are not present on the field. The problem with these is there are a lot of unnecessary pictures taken and this requires a human to elevate them. About 75% of these can be blank triggers or unrecognizable pictures and a human must sort through these images. In recent times we use image recognition software to sort these images [4][7] but this type of mechanism doesn't provide real-time alerts.

C. *Unmanned Aircraft Vehicle (UAV)*

A drone is a unmanned-aircraft vehicle (UAV) which is An aircraft without a pilot. They are controlled using a remote from the ground by a human. In recent times for forest surveillance, a Drone fitted with a camera is used to detect forest fires and its spread using video recognition software. However, these have a limited range of operation and are costly. They require a huge charge to fly and cannot be present always.

D. *Object Detection*

Object detection is a Computer technology that is used to identify different objects in digital images like humans, animals etc. There are many applications depending upon this Technology like robotics, security, face detection, medical to name a few. Object detection algorithms mainly used to extract features to recognize instances of an object. Detecting object like an animal in surveillance videos is a challenging task due to their different appearances and variety of poses they can adopt.

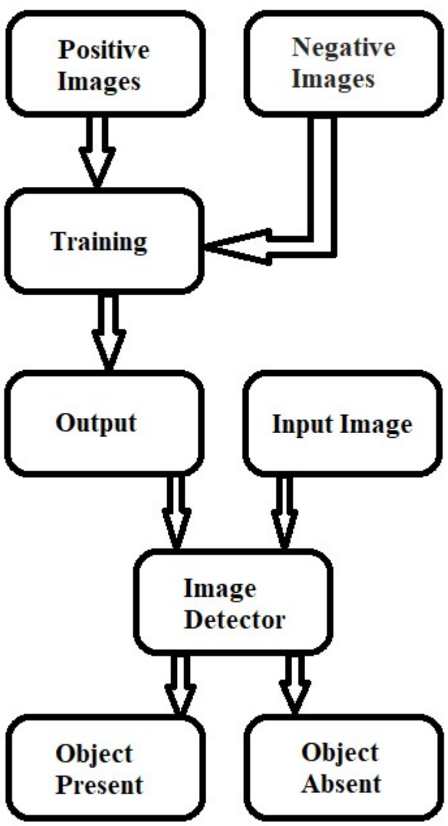

Fig. 1. Object detection process.

To extract these features, we first train the program to detect required objects and it gives us an XML file [3] of the objects required features. For this we give a huge set of positive images with the object is present and negative images with the object not present to the algorithm. The algorithm uses various detection techniques like haar features, neural networks etc, to find a set of usable features. To get these features the algorithm scans the images thousands of features and come out with a set of useful features in form of an XML file. Then we use these features to scan a digital image and identify if the object is present or not. We do it by scanning the image to identify if the output features are present or not. If they are present we take the images positive i.e object is present, or else we take it as a negative i.e object is absent. This is how an object is detected in an image.

E. *Problem Solution*

To solve these we need small. modular multi-purpose surveillance system which should run autonomously without human intervention and should detect and alert only for necessary subjects with high accuracy at low cost. It should be small and occupy less space and should have minimum operating cost and should alert uses precisely on topic. We proposed system is a smart surveillance system based on object detection which allows users to capture, monitor and store videos or photos using Raspberry Pi, camera, and multiple other sensors. The forest fire is identified using sensors like flame sensor and temperature sensor and human surveillance and animal surveillance is done using hybrid object detection system which can be trained to detect specific animals. It alerts users using email and text messages and users can select what to detect using simple program on a computer.

IV. IMPLEMENTATION OF PROPOSED SYSTEM

A. *Software*

1) Python: Python is a high-level, flexible, simple coding programming language. it uses an interpreter and widely used for general-purpose programming. This language can support structural and object-oriented programming, imperative, functional programming, and procedural styles. Python uses whitespace indentation to delimit code blocks which allows programs to be coded in fewer lines of code. It is very flexible, because of its ability to use modular components that were designed in other programming languages like c++, java etc. It has a large number of libraries like NumPy, SciPy, and Matplotlib etc with specialized libraries such as Biopython and Astropy.

2) OpenCV: OpenCV was created by Intel to accelerate commercial applications of computer vision with computational efficiency and a strong focus on real-time applications in mind. It's an open-source computer-vision which is free for commercial, public & academic use, and its libraries can greatly simplify computer-vision programming. OpenCV can take advantage of multi-core processing and has so many advanced capabilities like face detection, face tracking, face recognition, Kalman filtering, and a variety of artificial intelligence (AI) methods in plug and play form. OpenCV is a multi-platform framework which supports both Windows, Linux, IOS, Android and Mac OS X and has C++, C, Python and Java interfaces.

3) Haar Cascade Classifier: Haar Cascade Classifier uses Haar-like features for object detection. Haar-like features are digital image features used in object recognition. The detection algorithm is based upon an approach for human upright facial detection introduced by Viola and Jones. This algorithm designs a system by giving input as a huge number of positive pictures and negative pctures and train a classifier to detect the object. it consists of four main steps.

a) Haar Features: Haar features or digital features like shown in above images are used. Each feature is compared with image and a single value obtained by subtracting the sum of pixels under white rectangle from the sum of pixels under black rectangle.

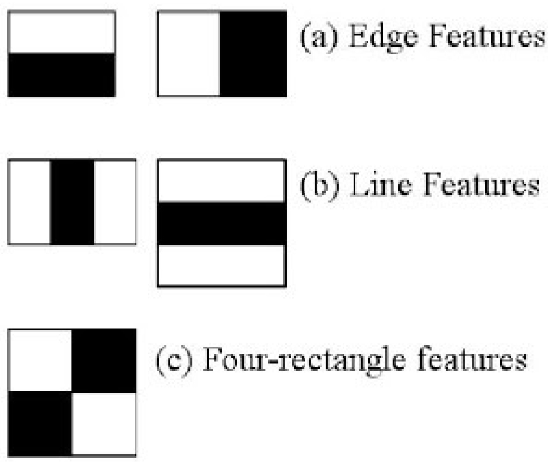

Fig. 2. Haar features for face detection.

b) Integral Image: An integral image is defined as two-dimensional looked up tables in the form of a matrix with the same size of the original image. This is calculated for all features on all images by using values of neighbouring features and finds the best threshold to find positives and negatives. We select the features with minimum error rate. Haar features are calculated all over the image which may have many features per image.

c) Adaboost: Summing up the entire image pixel and then subtracting them to get a single value is not efficient in real-time applications. This can be reduced by using Ada boost classifier. Ada boost reduces the redundant features. Here instead of summing up all the pixels, the integral image is used. Adaboost classifies relevant features and irrelevant features. After identifying relevant features and irrelevant features the Adaboost assigns a weight to all of them. It constructs a strong classifier by combining many Weak classifiers.

d) Cascading: This strong classifier is used to create a cascading sheet which consists of all the mathematical calculations required to detect the targeted animals from the given training dataset. This cascading sheet is in an XML format which is used by OpenCV to detect animals in real time.

4) K-nearest Neighbours Algorithm: The K-nearest neighbours (KNN) algorithm is a classifier under supervised learning of algorithms that is often used to classify complex data. Here we give a labelled training dataset consisting of a relationship between 2 points xx and yy. it learns a function h: X→Y, h: X→Y that predict yy using xx. This consist of two learning algorithms namely.

a) Non-parametric: It makes no assumptions about the function h, avoiding the dangers of modeling the underlying distribution of the data.

b) Instance-based: The algorithm doesn't learn any model. Instead, it chooses to memorize the training instances for the prediction phase.

$$dist((x, y), (a, b)) = \sqrt{(x - a)^2 + (y - b)^2} \quad (1)$$

This algorithm uses the Euclidean distance formula (1) to calculate the nearest neighbour around our target and boils down to forming a majority vote between the K most similar instances to a given "unseen" observation. The K value should be larger to classify the object more effectively.

B. Hardware

1) Raspberry Pi: The Raspberry Pi's are small single-board computers developed by the Raspberry Pi Foundation. The Raspberry Pi 3 has no Peripherals but comes with a Broadcom BCM2837 4× ARM Cortex-A53 1.2GHz processor with 4 usb ports, HDMI, SD card slot, 3.5mm audio jack, CSI, DSI, 40 GPIO pins, ethernet, built in wifi and Bluetooth with Linux as the main os but supports many platforms. It offers excellent hardware control compared to the conventional computers and is small and comparatively cheap. It helps to make a small compact tool which is perfectly suited for lightweight usage.

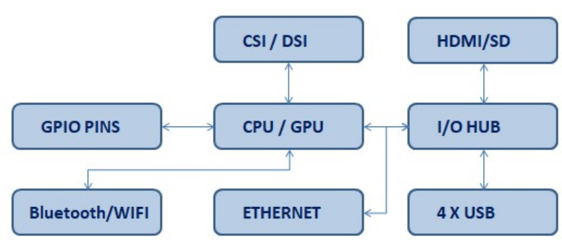

Fig. 3. Raspberry Pi block diagram

2) Camera: A camera is a photo sensor with an interface of either CSI or USB. It continuously captures images and sends it digitally in form of a video stream. A USB camera module is used for the project as It provides a way of using multiple types of high-resolution cameras without quality loss for continues streaming.

3) Passive Infrared Sensor: A passive infrared sensor (PIR sensor) is an electronic light sensor that is mostly used in PIR-based motion detectors which measure infrared (IR) light with rang up to 10 meters. It has an IR bulb which emits IR light and radiating light from objects in its field of view is detected by the sensor and gives a high voltage representing a movement.

4) Flame Sensor & Temperature Sensor: The temperature sensor detects temperature and gives output voltage according to it. We use LM35 series are precision integrated-circuit temperature devices which have an advantage over linear temperature sensors as output voltage linearly-proportional to the Centigrade temperature si it does not require any external calibration. it has an accuracy of ±¼°C and −55°C to 150°C temperature range. Flame Sensor is used to detect fire source using the light in range 760nm - 1100nm wavelength. It is based on the NPN silicon phototransistor sensor which has high speed and high sensitivity.

V. MODULES

A. Camera Module

The camera module consists of the camera and PIR sensor[2]. when the infrared beam produced by the PIR is disrupted movement is detected and triggers the camera sensor which streams the images in real time to Raspberry Pi, then video stream it is then analyzed by the Raspberry Pi using Object detection module and the object is identified and notified as per system rule.

B. Fire Detection Module

The fire detection module consists of the flame & temperature sensor. When a fire breaks out the flame sensor detects the light of flame in a specific range and outputs a high voltage. This is verified by the temperature sensor and when both are high we send an emergency alert.

C. Object Detection Module

This is a software module whose only purpose is to detect various animals from the camera feed. when the camera sends the feed it scans every frame with a fast haar cascade. when a specified animal is detected it sends those frames to the KNN classifier [6] which further detects the specific breed and type of animal. if it finds a match it takes a picture of the frame and sends it to the mail and message using notification module.

D. Notification Module

This surveillance system can mail the pictures using SMTP protocol to your email or cloud directly along with real-time video monitoring which allows the users to monitor from anywhere in the world. It can not only detect specified things but can also send instant alerts to your phone via a GSM module even in remote areas depending on the level of alert the notification possesses.

E. Controller Module

It is a Windows based software written in python which is used to control the Raspberry Pi. This software allows us to select specific animals that you want to detect from the list of available animals and their alert level using a server-client mechanism to exchange data between the controller and RPI allowing us to control the module remotely. Along with this it also gives us a live feed of the monitoring system and it also collects various data from motoring system like number of animals, species found, fire alerts, location etc and shows a basic analysis of population, probability of fire, biodiversity, density graph etc.

VI. RESULT AND DISCUSSION

We have trained only few animal data sets for the first trial. We have implemented the system in IIT Chennai for 5 days using 3 monitoring models at different locations in a single locality. In this trial, we mostly detected the deer in campus along with other humans, animals like dogs and monkeys. We have got positive hit results with an accuracy up to 78%. It gave the precise alert in the exact time and an email was sent to our ID along the with the picture and alert SMS was received at the same time. The primary analysis of the data shown us an estimated population of deer in the locality at the various time of the day in those three locations and the frequently used path of these animals was found by comparing data of all 5 days.

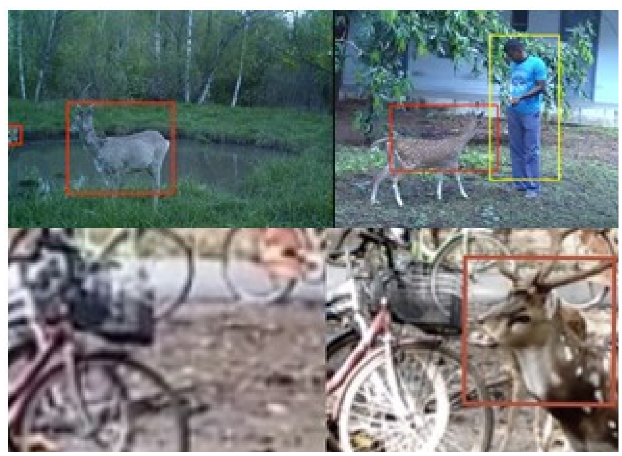

Fig. 4. Animals detected by our system

The challenge was changings in the light conditions which were affecting the RPI module programs making them useless at night. This can be rectified by using a night vision camera or other sensors. The KNN algorithm is reliable but slow when compared with the other algorithms thus making running animals pictures blurry. This can be rectified with RAM increase. a single animal can be detected multiple times but that was solved with multiple PIR sensors and a little logic change.

References

[1] A Study on Video Surveillance System for Object Detection and Tracking [online]https://www.researchgate.net/publication/299978232 A_Study_on_Video_Surveillance_System_for_Object_Detection_and_Tracking [accessed December 2017].

[2] Michael Janzen, Kaitlyn Visser, Darcy Visscher, Ian MacLeod, Dragomir Vujnovic, Ksenija Vujnovic. "Semi-automated camera trap image processing for the detection of ungulate fence crossing events", Environmental Monitoring and Assessment, 2017.

[3] Seo, "OpenCV haartraining (Rapid Object Detection With A Cascade of Boosted Classifiers Based on Haar-like Features)," [Online] http://note.sonots.com/SciSoftware/haartraining.html [Accessed December 2017].

[4] Mohammed Sadegh, Norouzzadeh Anh Nguyen Margaret Kosmala Ali Swanson Craig Packer and Jeff Clune - Automatically identifying wild animals in camera-trap images with deep learning(arXiv:1703.05830v4 [cs.CV] 5 Apr (2017).

[5] Goehner, K., Desell, T., Eckroad, R., Mohsenian, L., Burr, P., Caswell, N., Andes, A., & Ellis-Felege, S.. A comparison of background subtraction algorithms for detecting avian nesting events in uncontrolled outdoor video. In 2015 IEEE 11th international conference on e-science (e-Science) (pp. 187–195). IEEE. (2015).

[6] Swinnen, K.R., Reijniers, J., Breno, M., & Leirs, H.. A novel method to reduce time investment when processing videos from camera trap studies. PloS one, 9, e98,881. (2014).

[7] Yu, X., Wang, J., Kays, R., Jansen, P.A., Wang, T., & Huang, T. Automated identification of animal species in camera trap images. EURASIP Journal on Image and Video Processing, 2013, 52–53. (2013).

[8] Chamasemani, F.F, Affendey, L.L.: Systematic Review and Classification on Video Surveillance Systems. I.J. Information Technology and Computer Science, Vol. 07, 87-102. (2013).

[9] Paul. M*, Shah, M. E., Chakraborty, S.: Human detection in surveillance videos and its applications - a review. EURASIP Journal on Advances in Signal Processing, 176.(2013).

[10] Athanesious, J.J., Suresh, P.: Systematic Survey on Object Tracking Methods in Video. International Journal of Advanced Research in Computer Engineering & Technology,Vol.1,No.8, 42-247.(2012).

[11] Teddy, Ko.: A Survey on Behavior Analysis in Video Surveillance Applications, Video Surveillance, Prof.Weiyao Lin (Ed.), ISBN: 978-953-307-436-8,[Online] http://www.intechopen.com/books/videosurveillance/a-survey-on-behavior-analysis-in-video-surveillance-applications.(2011).

[12] T. Bouwmans, F. E. Baf and B. Vachon, "Background Modeling using Mixture of Gaussians for Foreground Detection -A Survey," Bentham Science Publishers, (2008) [Online]. https://hal.archives-ouvertes.fr/file/index/docid/338206/filename/RPCS_2008.pdf.(2008)