Road Safety from Animal Collisions

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***Abstract* - As the number of road accidents increases day by day, it becomes crucial to establish mechanisms to ensure safety. One of the leading causes of these accidents is the occurrence of animals on roads, causing drivers to get distracted and colliding with them or another vehicle in an attempt to save them. These collisions might prove to be fatal for the animal as well as humans. While it is not easy to predict the behaviour of animals and their sudden appearances on road, we can stir them away from it on detection. To prevent this, we introduce a device made using Raspberry Pi, which will be installed in the vehicles itself, designed to address this issue. It has been observed that animals tend to react differently to certain sounds and frequencies. This project makes use of such sounds and frequencies to instil a sense of fear, alertness or danger in the animal, driving them away from roads. The integration of artificial intelligence leads to successful detection of animals and frequency generation without the need for human intervention. In addition, we also propose roadside alarming signs that indicate the presence of animal in the vicinity, and a frequency generating devices at intersections or areas where there are high animal occurrences that will produce homing frequency to deter the animals from the road.**

Index Terms – Object Detection, Frequency generation, Artificial Intelligence, Raspberry Pi

INTRODUCTION

India's high mortality rate can be attributed to the surge in road accidents occurring every day. With over 168,000 deaths observed in 2022 alone, it has become a situation of high concern. A report by The Times of India suggests the occurrence of an accident every 3 minutes [1] highlighting the essence of this issue. These statistics showcase the alarming need of strong initiatives to eliminate the surging number of on road accidents and ensure safety on roads, especially in India.

One of the leading causes of these accidents is identified to be the collision of stray animals with moving traffic. The presence of animals on roads in India is a more prevalent sight than seeing planes in the sky. This causes mayhem and chaos on roads, leading to a disturbing view for people crossing. Such animals wander aimlessly due to lack of habitat and end up on roads causing a significant threat to people. There are times when the animals seem to be appearing out of nowhere, causing panic amongst drivers and leading to them losing control over the wheel and not being able to react in time for them to avoid the collision. The animals move with extreme uncertainty, further exacerbating the problem and hence it becomes an unavoidable cause of concern.

It was recorded that these collisions account for about 58% of accidents, making them the second biggest reason for road accidents in India [2]. This statistic reveals the weight of the dilemma drawing attention to its impact on both human and animal lives. This probabilistic statistic confirms that the existing systems of safety mechanisms are insufficient and incapable to eliminate the problem. This calls for a multifaceted idea that takes into account various factors such as controlling stray animal populations, better and improved road structure, and the use of advanced technologies to be able to address this issue better.

These collisions may prove to be fatal for the driver as well as the animal. The outcomes of such an encounter can be devastating, leaving harsh physical as well as emotional impacts on those involved. The prevention of such collisions is challenging, owing to factors such as high speed of vehicles, sudden appearance of the animal in front of the vehicle, negligence by the driver, etc. Therefore, it is crucial to create systems that minimise injuries or fatalities in addition to little to no economic losses.

Artificial Intelligence is increasingly integrated across various fields to enhance automation and efficient problem solving. It leverages data to find patterns and provide enhanced prediction capabilities. One such application of artificial intelligence is road safety. Through this project, we create a device that utilises the power of computer vision to eliminate the issue of animal collisions on roads. Upon detection of the said animal, the system generates alerting frequencies for the animals that stumble upon roads, thus ensuring the safety of both drivers and animals without the need of human intervention.

We also propose alarming signals and screens on roads that are embedded with animal detection capabilities. Upon detecting animals, the boards signal the oncoming vehicles of the presence of animals on the road. This gives the drivers enough time to make a decision and prevent collisions. At areas where there is high presence of animals, a homing frequency generator can be installed that will produce directed frequencies to deter the animals from the road.

BACKGROUND

I. Object Detection Using YOLO

Github link: https://github.com/DivyamAgg24/SaveTheStray

Dating back to 2016 when the first YOLO model called YOLOv1 was released, we have come a long way to YOLOv9. YOLOv1 used a single neural network and thus struggled on detection and bounding box generation on small objects or objects that were clustered. Advancements through the years has led to methods like batch normalisation in YOLOv2, use of Feature Pyramid Networks in YOLOv3, CSPDarkNet53 as a backbone network for YOLOv4, and further optimisations and improvements in architecture in the future models. The latest model in the series, YOLOv9, uses Generalised Efficient Layer Aggregation Network (GELAN) which provides the model with better computational efficiency, improved performance on smaller models. Another feature called Programmable Gradient Information (PGI) helps in smooth gradient flow and reduces the information bottleneck. Overall, this model boasts superior performance as compared to its previous counterparts.

II. Frequency

It is defined as the number of vibrations in the air in which the sound is propagating. It is measured in Hertz (Hz). Different living beings have the ability to perceive different levels of frequency. The range that a living creature can hear is known as audible frequency range. For humans, this range is between 20-20000 Hz. For other creatures like animals, it varies greatly.

TABLE I

SPECIES-FREQUENCY TABLE

Species	**Approximate Range (Hz)**
human	64-23,000
dog	67-45,000
cat	45-64,000
cow	23-35,000
chicken	125-2,000
horse	55-33,500
sheep	100-30,000
rabbit	360-42,000
rat	200-76,000

RELATED WORKS

Notable contributions have been made in the field of computer vision over the past years. Early object detection models included Viola-Jones' face detection using Haar-like features (2001)[3] and Dalal and Triggs' HOG features for pedestrian detection (2005)[4]. However, these models heavily relied on handcrafted features and had restricted capabilities. The shift from custom made features to deep-learning techniques proved to be groundbreaking. Models like R-CNN (2014)[5], Fast R-CNN (2015)[6], and Faster R-CNN (2015)[7] introduced end-to-end learning frameworks for object detection, granting automatic feature extraction and spatial localization. They further led to the birth of models like YOLO(You Only Look Once)[8] and SSD(Single Shot Multibox Detector)[9] which equipped us with real-time object detection.

There have been several studies that make use of object detection for identifying animals and wildlife. In the paper by Gabriel et al.[10], yolo models are trained on BRA-dataset to develop animal detection systems for highways. Uddagiri et al.[11] made use of a normalisation based attention module with yolov7 called NAM-YOLOv7, to detect dead animals on road to avoid offensive odours and potential widespread diseases. Sibusiso et al.[12] introduced a WildARE-YOLO model which is built on top of YOLOv5, with the aim of protection of endangered species and successful wildlife population monitoring.

Sharma et al. (2016)[16] created an alert system aimed at preventing animal-vehicle collisions. The method used a simple computer vision approach to detect animals ahead of time. The system considers the distance of the detected animal and alerts the driver accordingly. The speed of the vehicle is a critical component, as the system is designed to work efficiently only upto speed of 35 km/hr. Beyond this, the warning would be rendered useless as the driver would not be able to stop the vehicle in time to prevent a collision.

Incidents or experiences of an animal in the early stages of life also play an impact in their reaction to sounds and frequencies. If an animal associates a sound with a traumatic event, then that sound may become a source of fear and anxiety. Therefore, different animals react to sounds differently. While some sounds may provoke obvious or dangerous reactions others may leave the animals unfazed.

A study conducted by Katrina et al. [18] aimed at examining the ability of drivers to avoid animal collisions in the dark. The important findings from the conducted tests highlighted the importance of high-beam headlight usage, safe speed driving, and trying to avoid driving at night if possible

Several studies have proved the varying response of animals within a wide range of frequencies. Dr. Emma[13] stated the response of dogs to common household sounds changes as the nature of the sound changes. It was observed that dogs respond with intense fear to high frequency sounds as opposed to low-frequency sounds. A study was conducted by Mr Kumbhojkar[14] to observe the effect of sound intensity of safari vehicles, on behaviour and response of some mammals and birds. It was concluded that animals react to the vehicle sounds in three ways: a) initial vigilance, b) careful observation, and c) flee upon sensing danger

Maysoon et al.[15], developed a dog and animal repellent device called ASPECTEK, which made use of ultrasonic frequencies. The efficiency of the device was tested by using it on various groups of dogs. It was observed that the device repelled animals from the areas of wave centres. Regardless of their effect on animals, the use of ultrasound frequencies is unharming to humans as well as the animals' health.

Not so long ago, Volkswagen developed a device called RooBadge [17] that caters to the issue of kangaroo collisions on Australian roads. It achieves this by emitting audio deterrents using directional speakers. These speakers emit sound in a direction far ahead of the vehicle where it's most effective. Animal and rodent repelling devices harness ultrasonic frequencies to ward them off as per convenience.

FIGURE I

DOG REPELLENT DEVICE

METHODOLOGY

I. Software Used

- **Object Detection:** It is a computer vision technique that is used to identify and locate objects with an image or a video. It consists of two main tasks: object classification- that is, identifying the type of object and object localization which involves finding out the location of the object in the image. Real-time object detection processes frames from a video stream or sequence for detection and recognition. It has its applications in surveillance, robots, automatic vehicles, etc. This project uses a deep-learning based model called YOLOv9(You Only Look Once) which specialises in object detection. It is built on top of the YOLOv4-tiny architecture, and is lightweight and efficient. It was designed for the purpose of using it in embedded systems or mobile devices, where the computational resources are restricted. It is known for its high accuracy and improved speed as compared to its predecessors. The YOLOv9 is trained on the COCO (Common Objects in Context) dataset, which is a large-scale, public dataset, richly annotated collection of over 200,000 images featuring more than 80 object categories and 1.5 million object instances. It includes annotations for object detection, segmentation, and image captioning, supporting tasks such as instance segmentation, keypoint detection, and image captioning.

- **Frequency** Generation: The frequency generation task is achieved by making use of an AD9833 module programmed with spidev library. A code is written to initialise the registers of the AD9833 and setup the SPI. The detection from the model triggers a function in the code that produces specific frequency depending on the detected object. In case it is a human, then no frequency is produced, and if it is an animal, an appropriate frequency is generated which will drive the animal away.

- **Python Libraries Used:**

Github link: https://github.com/DivyamAgg24/SaveTheStray

TABLE II
LIST OF PYTHON LIBRARIES USED

Package	Version	Functionality
numpy	>=1.18.5	Used for for numerical computing
opencv-python	>=4.1.1	Used for computer vision and image processing, allowing real-time image and video capture, analysis, and manipulation
picamera2		It provides an interface for controlling and capturing images and video from the Raspberry Pi camera module, offering functionalities such as image capture, video recording, and configuration of camera settings
torch	>=1.7.0	Used for deep learning and machine learning, providing tools for tensor computation, automatic differentiation, and building neural networks
torchvision	>=0.8.1	torchvision is a Python package that provides access to popular datasets, model architectures , and image transformation utilities for computer vision tasks
albumentations	>=1.0.3	Used for advanced image augmentation
pycocotools	>=2.0	Provides tools for working with the COCO dataset
spidev		Provides an interface for interacting with SPI (Serial Peripheral Interface) devices on Linux-based systems, allowing communication with devices like sensors, ADCs, DACs, and other peripherals

II. Hardware Used

- **Raspberry Pi:** Raspberry Pi 4 is a single-board computer used for a wide range of applications like, product development, experimentation, education, etc. It features a quad-core ARM Cortex-A72 CPU, up to 8GB of RAM, dual micro-HDMI ports supporting 4K video output, USB 3.0 ports, and gigabit Ethernet. It can run on several operating systems like Raspberry Pi OS, Ubuntu, LibreELEC, Windows 10 IOT Core, etc. For a Raspberry Pi to work, it needs to be flashed with an OS initially. The OS is flashed on an SD card which is then used to boot the Pi. Tools like Raspberry Pi Imager or Win32 Disk Imager can be used for this task. Integration with a camera module makes it suitable for object detection tasks. The following image represents the pins of Raspberry Pi 4 and the pins enclosed in the boxes indicate the pins connected to the AD9833

- **AD9833 Frequency Generator:** It is a low-power, programmable waveform generator. It is based on direct digital synthesis (DDS) technology, which ensures a precise frequency output and stability. The frequency is produced as an electrical signal. The frequency can be a sine wave, a triangular wave or a square wave. Having a serial-interface, it is easier to control it via microcontrollers or single-board computers like the Raspberry Pi. It can produce frequency up to 12.5MHZ and works on a power supply from 2.3V to 5.5V. It can be easily programmed to output variable frequencies via the spidev library.

- **Camera:** The MSI Camera Module is a versatile, high-resolution camera designed for embedded and industrial applications. It supports interfaces like USB or MIPI CSI-2 and features customizable optics, including interchangeable lenses and infrared support for low-light detection. With robust build quality, it suits outdoor use and integrates seamlessly with platforms like Raspberry Pi. Ideal for tasks like animal tracking, its compatibility with OpenCV and MSI's SDK ensures efficient image processing and real-time control.

- **Speaker:** The speaker used operates at 4 ohm and 3W. It is used to convert the electrical signal produced by the AD9833 to sound. The AD9833 in itself has no components to produce sound, thus it is necessary to make use of a speaker.

- **Sensors:** Motion detection and heat-detection sensors to precisely narrow down the location of the animals

- **Servo Controlled Speaker:** A **servo-controlled speaker** is a setup where a speaker is mounted on a servo motor, allowing it to rotate and emit sound in specific directions. The servo motor, controlled by a microcontroller (like Raspberry Pi or Arduino), adjusts the speaker's position based on input signals, such as the location of a detected object or animal. This mechanism is ideal for applications requiring directional sound, as it can target specific areas or moving objects efficiently

WORKING

I. Vehicle Integrated Device

The camera module attached to the Raspberry Pi 4 enables real-time video capture of the environment it's put in. The module usually contains a high resolution camera compatible with the device, capturing a clear view of the input. The frames serve as input data to the object detection model fed in the raspberry pi module.

In the following step, the frames from the input are processed by pre-trained machine learning models. These models typically utilise deep neural network architectures such as convolutional neural networks (CNNs) or Vision Transformers, which are designed specifically to recognise patterns in the input and predict its contents. Each frame of the video is analysed separately, leaving no room for objects to go undetected.

Upon recognising the object in the frame and classifying it into a specific class, the model starts its output sequence. Initially the frequency associated with the animal detected is obtained. It then transmits a signal, alerting the AD9833 to generate the specified frequency. AD9833 is the tool that is being used to generate the required frequencies to deter animals from their paths, allowing them to be navigated to a safer place, away from the roads.

The Raspberry Pi 4 can be integrated with the AD9833 using the General purpose Input/Output (GPIO) pins belonging to the raspberry pi. These pins allow the raspberry pi to communicate with the AD9833 and other such components. Through these pins, the raspberry pi signals to run a script in the AD9833 that produces the targeted frequency corresponding to the animal.

Once the signal is received by the AD9833, it executes the algorithm to execute the corresponding frequency, which is predefined in its script. Varied species react differently to a wide range of frequencies, hence the script is tailored to produce a frequency within a particular range for each of the animals that commonly make their way to the roads.

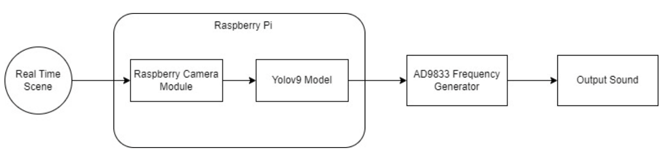

FIGURE II

BLOCK DIAGRAM OF THE WORKING OF THE MODEL

II. Road Signs

The system uses a Raspberry Pi module with a camera module to detect animals within a predefined radius around the road sign. YOLO or Vision Transformer or other models process real-time video input from the camera to identify and classify animals. Additionally, sensors like LiDAR can be used to accurately gauge the distance of the animal.

After the detection and distance estimation, the signals can be created using flashing LEDs attached to the road sign. LCD or LED panels can also be integrated with the road sign to provide icon warning or written warning like “Animal Ahead”, to the drivers.

In areas where animal occurrences are high, servo controlled speakers can be installed which will direct the frequencies at the animal to guide them in the desired direction.

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