Project Phase-II Report On

TranquiScan - Wildlife Sedation with Image Precision

Submitted in partial fulfillment of the requirements for the award of the degree of

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in

Computer Science and Engineering

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CERTIFICATE

This is to certify that the project report entitled ***"TranquiScan - Wildlife Sedation with Image Precision"*** *is a bonafide record of the work done by* ***Kevin Suresh (U2003118)****,* ***Joel Johnson (U2003104)****,* ***Henick Thadevous Peter (U2003094)*** *and* ***George Thomas Maruthathu (U2003086)****, submitted to the Rajagiri School of Engineering & Technology (RSET) (Autonomous) in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (B. Tech.) in Computer Science and Engineering during the academic year 2023-2024.*

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Abstract

The TranquiScan project is designed to mitigate human-wildlife conflict by offering a sophisticated wildlife management system. TranquiScan uses high-end technologies to detect animals in real-time. Different modules are used by the project to identify animals, watch them manually, release darts for sedation, and maintain a logged database of ungulates. This will ensure a productive and efficient system to manage wildlife.

It works on Raspberry Pi enabling Edge Computing, and enables real-time processing in outdoor environments which resolves the power consumption and connectivity issues. With the help of a high-resolution camera and an efficient processing system, TranquiScan's sentry mechanism is able to detect and locate ungulates quickly.

Compared to previous works, TranquiScan has the feature of being versatile and can be adapted in different situations. This project is beneficial for private and federal security agencies. The TranquiScan system is a new way to address safety. It protects the environment and contributes to broader environmental goals making it pioneering in conservational efforts.

Contents

List of Abbreviations

WSAN - Wireless Sensor and Actuator Networks

YOLOv3 - You Only Look Once version 2

RCU - Remote Control Unit

IoT - Internet of Things

LiPo - Lithium Polymer

GCP - Google Cloud Platform

GPU - Graphics Processing Unit

TPU - Tensor Processing Unit

CNN - Convolutional Neural Network

DCL - Deformable Convolutional Layers

AP - Average Precision

FLOPS - Floating point operations per second

CPU - Central Processing Unit

ML - Machine Learning

mAP - Mean Average Precision

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Chapter 1

Introduction

In this introductory chapter, the focus is on addressing the escalating challenges arising from human-wildlife conflicts. The TranquiScan project emerges as a new effort to solve these problems, combining modern technologies with wildlife care and protection work. This part explains the past problems and outlines what this project aims to achieve and why it's essential. The significance of TranquiScan in society and the industry is highlighted, showing its potential to revolutionize animal care practices and foster collaboration between conservation efforts and technology industries. Subsequent sections delve into the setup of the TranquiScan project, key research papers influencing its development, and the technical requirements.

1.1 Background

In the present-day world, due to an increase in human-animal conflicts, coexisting with wildlife has grown more difficult. These conflicts lead to issues such as crop damage, livestock predation, property damage, and even human casualties. Additionally, the ongoing threat of poaching in wildlife sanctuaries poses a grave danger to endangered species.

In India, hungry tigers desperate for shrinking prey grounds go into villages. This has led to the death of farmers and people living in fear. In Sri Lanka, plantations hurt elephants' homes, leading them to destroy rice fields. These are just small parts of a bigger problem. This makes it harder to protect animals that need help the most and puts them in even more danger. The harmful effects of such occurrences on nature are also very big. It messes up delicate living systems, interfering with the normal food chains and speeding up loss of different types of life.

Avoiding human-wildlife conflict is not just a moral imperative, but a strategic necessity. Investing in non-lethal deterrents shields communities and preserves precious animal lives. This is precisely what the project aims to accomplish via its novel implementation.

1.2 Problem Definition

The project inculcates a means of mitigating these conflicts by safely sedating and relocating problematic animals but also contributes to conservation efforts.

1.3 Scope and Motivation

The project aims to deliver a comprehensive wildlife management system, that employs detection, tranquilization, and data processing technologies to mitigate human-wildlife conflicts, enhance remote, non-invasive monitoring. The accurate detection of wildlife will help in being able to adopt the right strategies in their rehabilitation. Tranquilization will enable forest authorities to handle the animals in the proper manner, without having to bring in a sense of fear that an animal that has not been sedated may encounter in a similar situation. Non-invasive monitoring will be much useful in keeping track of all species under observation and their current state of being.

The motivation behind the project arises from the ever increasing number of cases on human-wildlife conflicts. As humans takeover forestland in search of new agricultural and commercial pastures, animals are found helpless and are forced to stray onto areas with human populace, leading to tense situations and loss of peace and monetary means for humans. An effective monitoring solution can be devised with the help of the project, while also being able to ensure the safety of animals, and alerting the concerned authorities.

1.4 Objectives

- To detect and identify wildlife in real-time while considering environmental factors.
- To safely sedate and immobilize wildlife in close proximity to human-populated areas.

- To emit turbulent sound frequencies to shoo off certain species, a.k.a scarecrow mechanism.
- Generate a log of ungulates in the vicinity.

1.5 Challenges

- Turret Mechanism failure due to unfavorable environmental conditions
- Animal not within the optimal range of the turret.
- Difficulty in training the model to identify certain species.
- Inability of detection in challenging environments such as low light regions or harsh weather.

1.6 Assumptions

1. Power can be provided to every turret unit in a region.
2. Animal Patterns are not blemished.
3. Suitable environment conditions and availability of light.
4. Animal falls within the range of the turret.

1.7 Societal / Industrial Relevance

The TranquiScan project is important to society due to the innovative solution it provides for human-wildlife conflicts. As more natural grounds are occupied by city and townships, it's leading to an increased impasse between wildlife and inhabitants. This causes a mismatch into several domains like danger of human life, damage to family give away, etc In order to address these challenges before, TranquiScan introduces a efficient and human wildlife management system. The project uses modern technologies to detect animals in real-time.

TranquiScan is not just relevant socially, but also has a significant industrial impact through the use of frontier technology, the project aims to become a pioneer one in terms of wildlife management and conservation. Different industries can adapt technologies for the purpose of their own goals from security sectors. This project provides an efficient platform for wildlife management. Along with it, it also encourages organizations to work together with industries belonging to the tech world. TranquiScan became much more than just a wildlife monitoring system, it was able to extend its scope with the help of image recognition.

Additionally, the assets of TranquiScan are tailored to meet broader initiatives for environmental conservation. This project of removing problematic animals, and sedating them fulfills the goal of protecting endangered species, and conserving biodiversity. This means that this Project acts as a catalyst for further research and development in the conservation industry, and it includes stewardship of technology and innovation. In order to refine the existing systems and help humans and wildlife live in harmony, we need to collaborate with research institutions, wildlife sanctuaries, and technology companies.

1.8 Organization of the Report

The report is organised into 6 chapters, chapter 1 being the current chapter, and the remainder chapters having the following content.

In Chapter 2, we study five research papers that connect technology and farming. The first paper presents a way of making videos better for wireless sensor networks. It helps to improve picture quality in them. The second article suggests a system for keeping animals away using AI on the edge, this helps cut down losses in farming. The third article talks about ways to save energy on devices used for finding wild animals. The fourth paper talks about a Robot gun for security jobs that is very good at finding intruders but has some problems in tracking by itself. The fifth report talks about a system to find out animal types on little machines. It has an improved YOLOv2, which helps identify animals better and faster for small devices like phones or computers. A side-by-side look at Table 2.4 shows the good points and problems of each study.

In Chapter 3, it shows what kind of computer parts and programs are needed for the system to keep animals away. Hardware includes Raspberry Pi, 12 volt direct current motors, servo motors and pi camera. You need Python 3.9, TensorFlow Lite, OpenCV, FreeCAD and Firebase Real-time Database for software requirements. The list of tasks the project needs to do is written in numbers. It gives a clear explanation of what that project can do.

The fourth chapter starts with a complete view of the planned system. It also includes an architecture drawing. A Gantt chart shows the times and dates for work schedules. It helps to show all tasks planned in a project clearly.

In Chapter 5, we delve into the intricacies of implementing TranquiScan, a cutting-edge wildlife management system designed to mitigate human-wildlife conflicts and promote conservation efforts. From the selection of datasets to the deployment of algorithms and the integration of hardware components, each aspect of TranquiScan's implementation is meticulously detailed to provide a comprehensive understanding of its functioning and capabilities.

In Chapter 6, we review the outcomes and results of the TranquiScan project goals, which aim to solve the human-wildlife conflicts through the development of novel wildlife management technologies. The chapter is introduced by a comprehensively performed results summary that leads to a thorough description and analysis of the obtained results in relation to the purpose and scope of the project.

The results will cover multiple aspects of the project development, such as deployment of detection and tranquilization technologies, model performance evaluations and hardware integration.

1.9 Conclusion

The first chapter sets the ground for learning about why TranquiScan is so important. By outlining the goals, obstacles and importance for society, it becomes clear that TranquiScan is a leading technology in wildlife protection. The next parts will explore more about the research, technicalities and design choices that TranquiScan is planning. This will give a complete idea of how it hopes to change wildlife management for better environmental safety goals. It also shows how teamwork with technology in conservation efforts could help keep our world safe and protect its different environments better.

Chapter 2

Literature Survey

2.1 Video Surveillance Over Wireless Sensor and Actuator Networks Using Active Cameras

D. Wu, S. Ci, H. Luo, Y. Ye and H. Wang, ”Video Surveillance Over Wireless Sensor and Actuator Networks Using Active Cameras,” in IEEE Transactions on Automatic Control, vol. 56, no. 10, pp. 2467-2472, Oct. 2011, doi: 10.1109/TAC.2011.2164034.

This paper describes a new content aware video coding and transmission strategy which is especially suitable for wireless sensor networks. Its primary aim in enhancing the visual quality of surveillance videos. The proposed plan intentionally focuses on improving the quality of what can be seen in surveillance video, and especially emphasizes improvements to how target areas are presented. Using precise coding and transmission methods, the scheme shows a remarkable improvement in display image quality for that portion of the target compared to its received video without having used content-aware processing.

The paper points out that at present, the optimization of video encoding and transmission is carried out on a per-frame basis. However, more optimal results can be expected by extending this process to cover several buffered frames. But this approach has the trade-off of increased computational complexity. In this paper the author discusses some of the problems that may arise from such an extension and examines how computational performance can be balanced against improved video quality. This award brings opportunities for further exploration, in terms of how to best optimize video coding and transmission across multiple frames while also balancing computational efficiency with better visual results.

2.1.1 Proposed System Model

A comprehensive approach to video capture, coding, transmission and monitoring Under the proposed system model for wireless video surveillance. Firstly, cameras record videos that are coded before being transmitted through a wireless sensor network to the Remote Control Unit (RCU).

This RCU becomes a centralized nerve center with exponentially increased computational capabilities and access to key information on the surveillance target. Camera control is all decided at the RCU. Using a computer to perform an equally thorough analysis of the video it receives, that dictates pan and tilt speeds as well as such other vital variables. Particularly in camera control decision-making and target monitoring, the RCU takes on a very important role. Armed with superior computational power and possessing critical information about the surveillance target, RCU is a control center for developing efficacious camera position strategies. Through careful video analysis, the controller located in RCU calculates and sets values for important camera control parameters such as pan and tilt velocities.

In terms of practical implementation, the RCU relays these back to the camera motor. In addition, the RCU actively participates in transmission video rebuilding, which is a key element of target monitoring. The RCU collects and processes the received video data, thus achieving a continuous and accurate monitoring of its surveillance target.

Another important innovation in the system is that video frames are processed using a content-aware approach. Each frame is divided into individual target and background parts, the system coding and transmitting instead only those of it which are targets. This prioritization strategy improves data transmission and reconstruction efficiency at the RCU, thereby optimizing the surveillance process. Besides, in order to maintain accuracy and reduce computational complexity on the camera side at once, background-foreground separation techniques are used by the system.

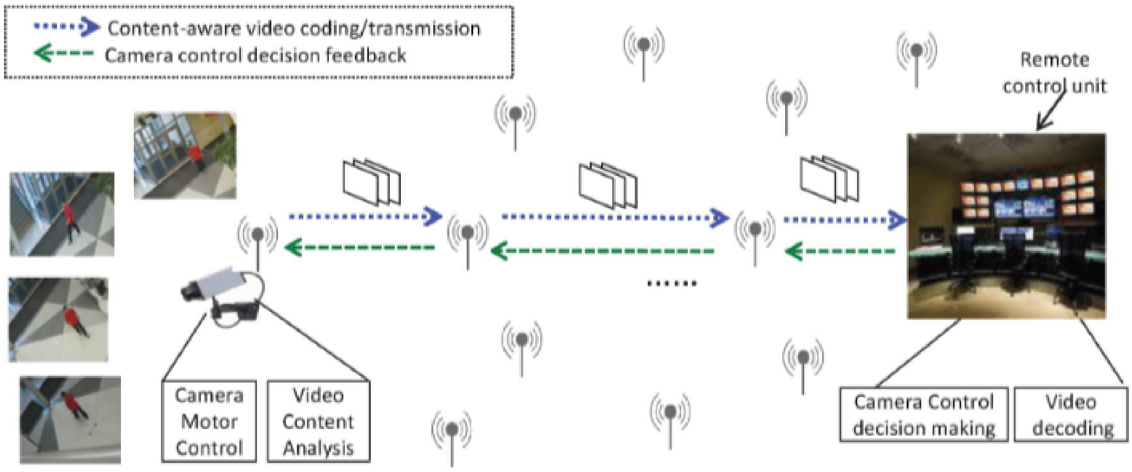


Figure 2.1: System model of the proposed framework for real-time video surveillance over WSANs with active cameras

2.1.2 Content Aware Video Coding and Transmission

A novel approach known as content-aware video coding undergoes testing on wireless video surveillance systems introduced in this research paper. This method greatly speeds up the processing of video data. The part comprising our intended target is coded and transmitted, while that composing background portion receives less attention. The video frames are evenly divided into groups of blocks. In particular, the target part is coded in Io Target packets. The background is comprised of Ib Background packet segments. The segmentation strategy is of course very important for making effective use of available resources and achieving a better overall performance out from wireless video surveillance systems.

(a) (b)

Figure 2.2: (a) Received video frame by using the proposed content-aware video coding and transmission. (b) Received video frame without using content-aware video coding and transmission.

The general goal of the content-aware strategy is to secure the best possible video quality without running afoul of delay constraints characteristic for most video surveillance applications. Toward this end, the delayed delivery of each packet is strictly regulated by maintaining a strict deadline for decoding frames. This is another important constraint, because it keeps the surveillance video smoothly flowing and with accurate camera control which are necessary for effective monitoring. In general, the proposed content-aware coding and transmission scheme is trying to raise the quality of images in what they hope will be seen as parts being monitored during actual surveillance. This would represent a significant development compared with conventional methods for encoding and sending video over networks.

2.1.3 Conclusions

The paper then outlines a co-design framework for video surveillance with active cameras, focusing on the aspects of video coding and transmission over wireless sensor or actuator networks. The framework suggests an autonomous method for camera control per received surveillance videos, and presents a video coding scheme that takes account of the content in order to achieve maximum quality under delay constraints. How video transmission delay and feedback of control decision affect camera-control decision making are examined.

2.2 Design, Development and Evaluation of an Intelligent Animal Repelling System for Crop Protection Based on Embedded Edge-AI

D. Adami, M. O. Ojo and S. Giordano, "Design, Development and Evaluation of an Intelligent Animal Repelling System for Crop Protection Based on Embedded Edge-AI," in IEEE Access, vol. 9, pp. 132125-132139, 2021, doi: 10.1109/ACCESS.2021.3114503.

An intelligent animal repelling system for crops developed through edge-AI is the focus of a wide ranging examination provided in this paper. Most of the paper is dedicated to developing a system which uses ultrasound and computer vision combined, in order to set up virtual fences for protecting crops from ungulate attacks. The authors reach their aim with the aid of IoT platforms such as Raspberry Pi and NVIDIA Jetson Nano, which they weigh on hardware costs versus performance against energy usage.

2.2.1 Intelligent Animal Repelling System Architecture

The animal repelling system architecture is an advanced solution that effectively prevents animals from entering certain areas. Fundamentally, it is a series of high-tech animal repelling devices. These belong to the ATSAMD21G18A 32-bit ARM Cortex M0 core family and include a series of basic circuits such as LoRa radio modules for connections, solar panels that provide self-sufficiency in power supply, LiPo batteries providing energy reserve capability (lithium polymer battery) rolled up inside the Among the most prominent characteristics of these tools, they can produce ultrasound signals-sending sound at a power level carrying as far away. The limits of the range can be adjusted to suit particular animal species that need dispelling.

The system's network infrastructure is equally firm, uniting IoT platforms like the Raspberry Pi with an optional neural compute stick and NVIDIA Jetson Nano. These edge computing devices are endowed with real-time object detection capabilities. Most of them use cutting-edge models such as YOLO and Tiny-YOLO, which can be trained to recognize ungulates, making the system capable of detecting animals in real time and driving them away automatically.

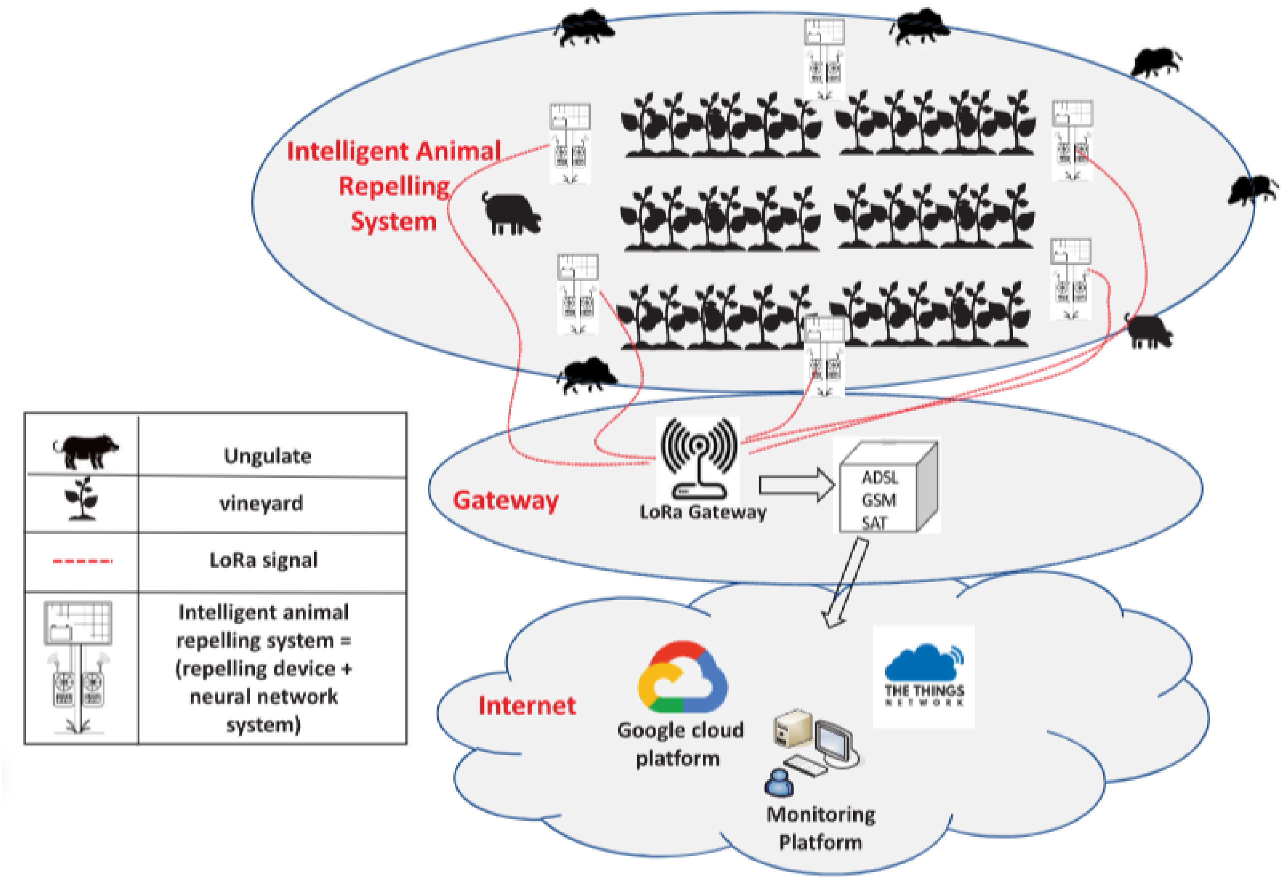


Figure 2.3: Intelligent Animal Repelling System Architecture

The system integrates these intelligent devices together with the ultrasound generator, so as to deploy animal detectors on power-constrained edge computing devices without compromising performance or real-time requirements. This architecture means that animal presence can be quickly detected, and the right ultrasonic signals emitted to scare them away. It is a very potent weapon for controlling interactions between animals in all kinds of settings.

2.2.2 Training Platform

Aware that their deep learning models required considerable computational effort to train, the authors of this project utilized Google Cloud Platform (GCP) for its specialities. In the GCP environment, they used a high-performance virtual machine configuration with 16 cores and 64GB of memory. Another important device in their training process was the single NVIDIA Tesla T4 GPU which adorned this sturdy virtual machine.

The Tesla T4 GPU has many advantages for machine learning tasks. With 16GB of GPU memory and equipped with NVIDIA Tensor Cores which speed up deep learning calculations, the model training process becomes faster and more effective. Also, it uses RTX hardware acceleration. Therefore ray operations are also performed quickly.

The T4 GPU is also particularly well-suited for accelerating inference or making predictions generated by deep learning models. Indeed, its ability to support low latency and high throughput makes it an indispensable tool in real-time applications and performance sensitive scenarios.

This means that the authors can train their model efficiently by utilizing this virtual machine on GCP, without having to buy a physical computer with built-in GPUs or TPUs. Besides this cutting down on training time, the fact that it had flexibility and scaleability of server added a major advantage offered by workspace in cloud-based computing to resource heavy tasks like deep learning model training.

2.2.3 Experimental Discussion

In the research paper, training process details for these two neural network models in animal repelling system (YOLOv3 and Tiny- YOLOv3) are covered within experimental results and discussion section.

The section talks about the different embedded platforms, like Raspberry Pi and NVIDIA Jetson Nano, for deploying trained models. The feasibility of (designing) an intelligent animal repelling system and its ability to satisfy the requirements for both real-time performance, as well as high precision is reported in qualitative results.

Object Detector	Platform	Mode	P[W]	FPS	Power Efficiency, FPS/W
YOLOv3	NVIDIA Jetson Nano	20W	17.32	4	0.231
YOLOv3	NVIDIA Jetson Nano	15W	12.94	3.2	0.247
YOLOv3	NVIDIA Jetson Nano	10W	8.5	3.2	0.376
YOLOv3	RPi 3B+	5W	-	-	-
YOLOv3	RPi 3B+ and NCS	5W	-	-	-
Tiny-YOLOv3	NVIDIA Jetson Nano	20W	16.7	14.8	0.832
Tiny-YOLOv3	NVIDIA Jetson Nano	15W	12.68	12.8	1.01
Tiny-YOLOv3	NVIDIA Jetson Nano	10W	8.3	10	1.205
Tiny-YOLOv3	RPi 3B+	5W	3.2	0.8	0.25
Tiny-YOLOv3	RPi 3B+ and NCS	5W	3.2	4	1.25

Table 2.1: Comparison between devices power consumption and performances with YOLOv3 and Tiny-YOLOv3

The section also includes a cost/performance analysis for each hardware/software platform, as well as measurements of average and peak CPU temperature.

Device	Cost($)	FPS	Cost/FPS
NVIDIA Jetson Nano	99	15	6.6
RPi 3B+ with Intel NCS	105	4	26.3
RPi 3B+	35	1	35

Table 2.2: Cost/performance analysis of the different embedded platforms.

Object Detector	Device	Fan	Peak Rating(C)	Average Rating(C)
YOLO v3	NVIDIA Jetson Nano	No	58 4	46
YOLO v3	NVIDIA Jetson Nano	Yes	38	30
Tiny-YOLO v3	NVIDIA Jetson Nano	No	51	38
Tiny-YOLO v3	NVIDIA Jetson Nano	Yes	30	24
Tiny-YOLO v3	RPi 3B+ & NCS	No	93	70
Tiny-YOLO v3	RPi 3B+ & NCS	Yes	60	35

Table 2.3: CPU temperature analysis of the different embedded platforms

The deployment methodology for the trained models on the selected embedded platforms is described, ensuring efficient and effective implementation of the animal detection system.

2.2.4 Conclusion

The research paper describes an intelligent animal repelling system for crop protection based on edge-AI. Using the combination of computer vision and ultrasound emission as a fence, this system protects crops from ungulates. It strikes an effective balance between performance, cost and energy efficiency using IoT platforms including Raspberry Pi and NVIDIA Jetson Nano. With the system's deployment and evaluation, including its ability to perform real-time object detection using custom trained models, it is evident how well suited this approach can be when meeting fast response times while keeping delicate ungulate identification. Combining edge computing and ultrasound emission is a new avenue to reduce production losses, helping farmers and agronomists in decision-making and crop management.

2.3 Energy Reduction Methods for Wild Animal Detection Devices

R. Sato, H. Saito, Y. Tomioka and Y. Kohira, "Energy Reduction Methods for Wild Animal Detection Devices," in IEEE Access, vol. 10, pp. 24149-24161, 2022, doi: 10.1109/ACCESS.2022.3155242.

The paper describes new energy saving techniques for wild animal detection devices. Particularly with wildlife conservation and monitoring in mind, it puts forward ideas on how further to improve efficiency. In order to compare the effectiveness of the approaches proposed in this paper, a baseline device is constructed by modifying an existing detection instrument. This baseline device uses a very lightweight CNN model; before carrying out tests, a pre-trained model is loaded onto the Raspberry Pi. The overall objective of this research is to help develop lower-power wild animal detection devices, which will make critical applications in wildlife conservation more environmentally friendly and cost effective.

2.3.1 System Architecture

The device used to detect wild animals in the paper is based on Raspberry Pi 3 Model B. Deep learning approaches are employed for animal detection. Consisting of sensors, cameras and a Raspberry Pi, it's responsible for image processing and classification. This camera trap image is sent to the edge device (Raspberry Pi) for deep learning inference. Moreover, the device saves power by making use of a lightweight CNN model for inference. The energy saving methods proposed include adjusting sensitivity for the motion sensor, attaching a hat, using frame difference method to detect motions and functional separation on device. By using OpenCV to implement the frame difference method and calculating between moving objects, wild animal movement can be detected. The device also channels information about detected wild animals to the cloud, so that it can be sent back out via mobile devices.

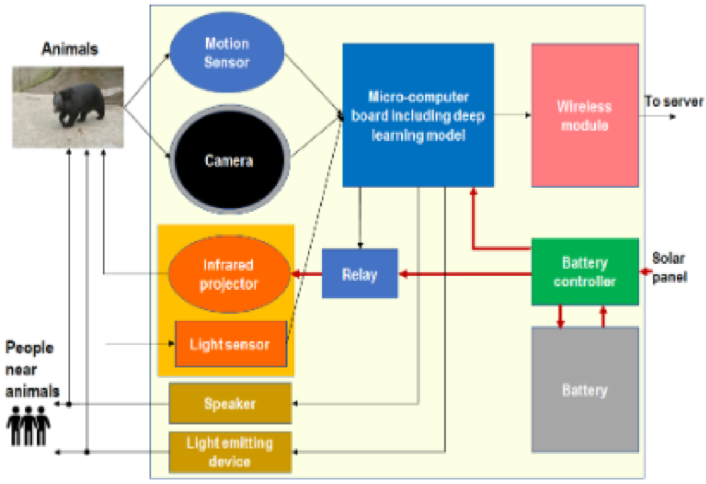


Figure 2.4: Structure of proposed detection device

2.3.2 Methods Used

Sensitivity Adjustment for the Motion Sensor: This method reduces the number of images taken by the camera by adjusting the sensitivity of the motion sensor.

Attachment of a Hat: The attachment of a hat reduces the number of sensing by the motion sensor, further reducing energy consumption.

Motion Detection by Frame Difference Method: The frame difference method is used to detect motion in the captured images. By reducing the number of inferences made by deep learning, this method helps in reducing energy consumption.

Separation of Functions on the Device: This method involves separating functions on the device to reduce power consumption during both operation time and idle time. By optimizing the device's functions, energy consumption is minimized.

2.3.3 Evaluation Results

An application to a wild animal detection device was used as the evaluation for the proposed energy reduction methods. Testing showed that fusing the different methods enabled a device's energy consumption to be reduced by more than half from its original level. The fall in sensings and inferences correspondingly corresponded to lower consumption of energy. Tweaking the threshold yielded even fewer inferences, showing how pivotal appropriate thresholds are determined by the device's location. Amalgamating such methods not only reduced the size of needed batteries and solar panels, but opened up areas for its effective deployment as well. Thus device costs were lowered. These indicate hope for reducing wild animal-caused accidents and crop damages. These experiments revealed the effectiveness of individual or combined application to reduce energy consumption in detection device.

2.4 Design and Implementation of Image Capture Sentry Gun Robot

D. Adami, M. O. Ojo and S. Giordano, "Design, Development and Evaluation of an Intelligent Animal Repelling System for Crop Protection Based on Embedded Edge-AI," in IEEE Access, vol. 9, pp. 132125-132139, 2021, doi: 10.1109/ACCESS.2021.3114503.

This paper represents a thorough discussion of the development and applications of an autonomous sentry bot, appropriately dubbed Sentry Gun. As the centrepiece of its design is a gun mounted on a stand which allows remote control from afar, it could be operated safely even out in no-man's land. The Sentry Gun, which was designed primarily for operation in red zones such as check posts or law enforcement agencies and borders uses a high-resolution camera with sophisticated software processing to scan the area specified by its field of view before detecting any movement there. In the case of patrol in autonomous mode, apart from reducing damage and casualties during its course, it also plays an important real role defending against illegal intrusions. It is priceless for security purposes; with defense applications as well.

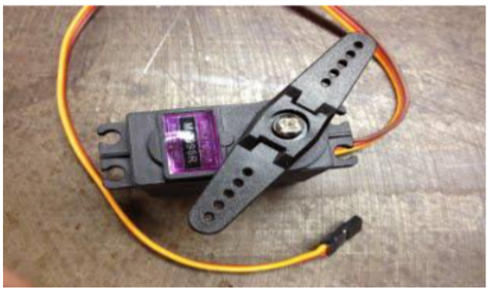
Figure 2.5: Sentry Gun Robot

Also found in the paper is how Sentry Gun operates, and among others specifications that it requires servos to control movement as well as firing (in user mode) and motors for operating compensating weights on guns. This design enables accurate control of angular positioning, velocity and acceleration. Operators can reign command over the robot from a laptop or CPU anywhere in the world with direct access to its signal line via WiFi modem. The interface also offers a Target selection scheme that allows operators to simply click on the desired target, quickly calculate its angles and then make precise shots. Also the paper discusses the technical considerations of sensing movement in autonomous mode, making use of background subtraction and frame differencing techniques to improve robots 'ability to pick up a potential intruder. Viewing the project as a whole, it is an attempt to build a thorough and practical system of sentry guns which has enormous implications for raising security levels.

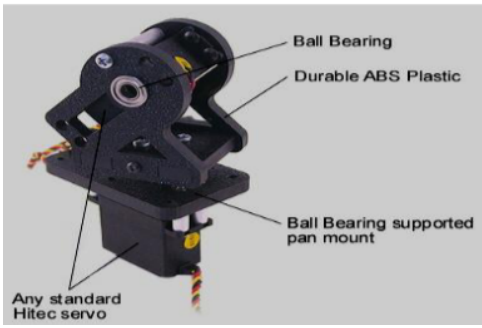
2.4.1 System Architecture

Designing and building the Sentry Gun robot People then constructed this machine based on a testing environment that they had previously placed together. The hardware parts used to design and develop it are crucial pieces for its functioning efficiency. The main processing unit in this project is naturally the Arduino Uno.

In order to get the highest degree of precision in control over robots movement there are servo motors built-in too. These motors, unlike the above two kinds in control of propeller power or directional controls for left and right wingflaps not only govern both vertical motion as well horizontal rotation of gun turret but also are used to determine trigger position. But despite its cheap price, what differentiates the Sentry Gun from most other toy guns is that it moves as a 2D plane displaced by servo motors. The latter are flexible and accurate when used properly but low precision utilization of their power and improved control technology would still negatively impact accuracy somewhat.



(a) Trigger Servo Motor



(b) Pan Servo Motor

Figure 2.6: Servo Motors Used

Complementing the servo motors are a JF39 Airsoft Gun, mounted on Justice's Sentry Gun robot stand. This airsoft gun, working in union with the robot's servo motors expands and adds to its capabilities further. Combined, these hardware components increase the overall performance and dependability of the Sentry Gun. All told this fits with embodying one important aspect for a functional and widely applicable security or defense artifact upon which further development can be based designwise.

2.4.2 Modes of Operation

The Sentry Gun robot has two different modes of operation, designed for various security situations. The robot's autonomous mode means that it remains stationary while its multiple sensors scan for potential targets. It locates a target, aims and fires at will in this case. In fact, this robot has been commonly used in high-security red alert areas where unauthorized access is strictly prohibited. It takes preemptive action on its own to shoot at whoever enters the surveillance zone (whether they are viewed as an enemy or ally) before it can be fired upon itself. It is at its best in life-or-death security applications, where a vigilant and swift response to threats can make all the difference.

On the other hand, in manual operation an operator can take direct command of his Sentry Gun from a safer vantage and more effective position with laptop as control panel. With a simple click on the desired target by its operator, the robot springs into action with automatic processes. After this, the Sentry Gun counts on its own and automatically determines the required angle. Aiming precisely at his target, it fires off an accurate shot. Manual mode allows the operator greater control, so that only targets of choice are hit-with fewer misses. Combining these two modes together, the Sentry Gun provides a flexible and reactive response for security or defense situations. It rectifies both autonomous vigilance with operator-directed accuracy of fire.

2.4.3 Conclusion

To sum up, the Image Capture Sentry Gun Robot which features an Arduino controller represents a semi-autonomous solution for security and defense needs. Using high-resolution cameras combined with refined software, the robot can accurately discern movement. In autonomous mode it is even capable of working within red zones and other high risk areas. The choice of servo motors to the robot's motion provides a high degree of precision control, explaining in part why it is so effective. Capable of operating in manual and autonomous modes, the Sentry Gun improves security measures at check posts or points along borders while deterring illegal intrusions and reducing casualties.

2.5 An Accurate and Fast Animal Species Detection System for Embedded Devices

M. Ibraheam, K. F. Li and F. Gebali, ”An Accurate and Fast Animal Species Detection System for Embedded Devices,” in IEEE Access, vol. 11, pp. 23462-23473, 2023, doi: 10.1109/ACCESS.2023.3252499

The paper ”An Accurate and Fast Animal Species Detection System for Embedded Devices” introduces an animal species detection system designed for embedded devices to address wildlife encounters in remote regions and highways. The proposed system, a modified version of YOLOv2, demonstrates a 5.0% accuracy improvement and a 12.0% increase in speed compared to the original model. It incorporates features like multi-level merging and removing specific convolutional layers to enhance feature extraction and reduce computational complexity. The model is evaluated against YOLOv2, YOLOv3, and YOLOv4, making it suitable for deployment on resource-constrained embedded devices.

2.5.1 System Architecture

The proposed animal species detection system is based on a modified version of the YOLOv2 model, designed for deployment on embedded devices. It utilizes convolutional neural networks (CNNs) and deformable convolutional layers (DCLs) to improve detection accuracy and speed. The system employs multi-level features merging by adding a pass-through layer to enhance feature extraction ability and accuracy. It also removes repeated 3x3 convolutional layers in the seventh block of the YOLOv2 architecture to reduce computational complexity and increase detection speed without sacrificing accuracy.

The system was trained and tested using Python 3.7 under the PyCharm development environment, and implemented on a system with a Core i7-10750H Processor, NVIDIA GeForce RTX 2070, 32 GB RAM, and Windows 10 Professional x64 operating system. For deployment, an RP4B with a 1.5GHz 64-bit quad-core CPU, 128 GB storage, and 8 GB RAM was used.The system's GPU was utilized to accelerate the training process by installing CUDA 10. The modified YOLOv2 model outperformed the original YOLOv2 by 5.0% in accuracy and 12.0% in speed, making it more suitable for deployment on embedded devices compared to YOLOv3 and YOLOv4.

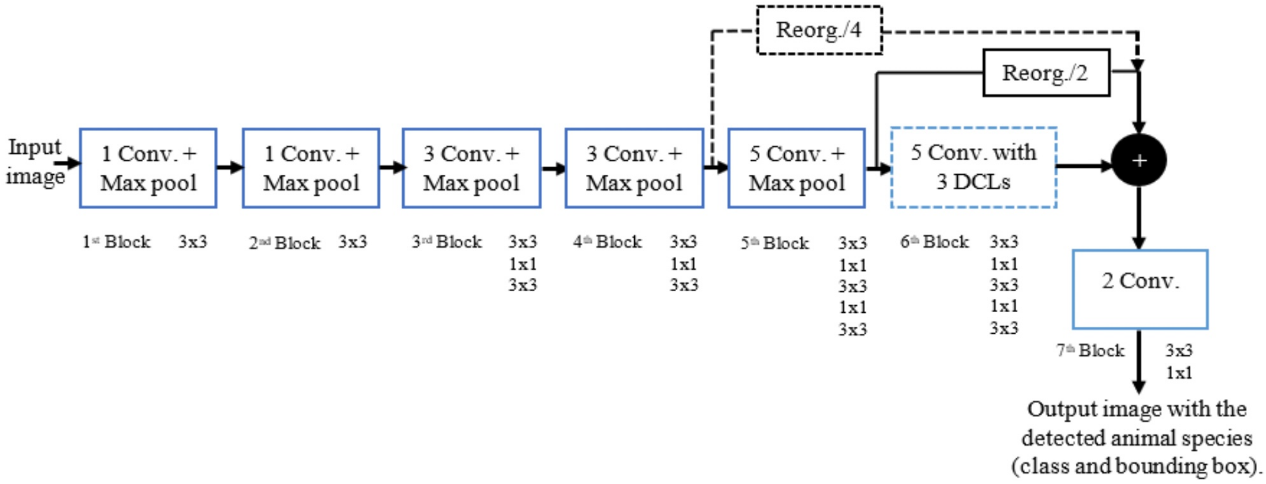


Figure 2.7: Architecture of the proposed YOLOv2 animal species detector.

2.6 Summary and Gaps Identified

In the literature review, we look at five research articles. The first paper talks about a new video coding method for wireless sensor networks. It's designed to improve the quality of watching things through cameras in these systems. The second paper is very important. It talks about a system to keep animals away by using edge-AI inside, offering cost and performance study with results from experiments. The third article is about ways to save energy in devices used for finding wild animals. The fourth paper talks about a robot guard gun for safety and protection jobs. The fifth paper suggests a quick and precise system for identifying animal species on small machines, with an updated YOLOv2 model making it more accurate than the first. In these, the second document is very important because of its effect on devices that have limited resources.

Table 2.4: Advantages and Disadvantages of papers in review

Paper Name	**Advantages**	**Disadvantages**
An Accurate and Fast Animal Species Detection System for Embedded Devices	Modified YOLOv2 delivers 5.0% better accuracy and 12.0faster detection for efficient real-time animal species identification. Optimized for embedded devices, the model's reduced complexity and removed convolutional layers make it ideal for resource-constrained platforms like Raspberry Pi 4 Model B.	Focused on animal species detection, the model's applicability might be constrained to this specific task, limiting versatility. Potential need for sorted datasets may pose a preprocessing challenge, particularly if the dataset lacks organization.
Design, Development and Evaluation of an Intelligent Animal Repelling System for Crop Protection Based on Embedded Edge-AI	Reduces production losses by protecting crops from ungulate attacks. Utilizes edge computing for real-time response and improved system performance.	Energy supply constraints in rural environments may challenge continuous operation Network connectivity limitations in rural areas can affect data transmission and real-time updates, potentially impacting system effectiveness.

Paper Name	Advantages	Disadvantages
Energy Reduction Methods for Wild Animal Detection Devices	Energy reduction methods, like motion sensor sensitivity adjustment and attaching a hat, decrease camera images and motion sensor sensings. Frame difference method, implemented with OpenCV, lowers inferences by focusing on moving object regions, reducing overall energy consumption.	Fewer sensings and inferences may decrease wild animal detection accuracy due to reduced data points. Proposed energy reduction methods are context-specific for wild animal detection devices and may not apply universally.
Video Surveillance Over Wireless Sensor and Actuator Networks Using Active Cameras	Improves visual quality in the target part of surveillance videos compared to traditional transmission methods. Optimizes video encoding and transmission on a frame-by-frame basis, enhancing efficiency and video quality.	Limits consideration of long-term dependencies by optimizing one frame at a time, potentially leading to sub-optimal video quality. Computational complexity increases, especially when optimizing over multiple buffered frames, posing challenges in resource-constrained environments.
Design and Implementation of Image Capture Sentry Gun Robot	Sentry Gun excels in accurately detecting and locating intruders, enhancing its reliability as a security measure. Capable of autonomous operation, the robot minimizes the need for human intervention, proving effective in red zones and high-risk areas.	In autonomous mode, the Sentry Gun's tracking capability is constrained, exhibiting sensitivity to system calibration and successfully tracking only 1 to 2 objects at human walking speed.

Chapter 3

Requirements

3.1 Hardware and Software Requirements

3.1.1 Hardware Requirements

- Raspberry Pi
- 5V DC Motors
- Arduino Uno
- MG90 Servo Motors
- Pi Camera
- L298N H Bridge
- 9V Batteries

3.1.2 Software Requirements

- Python 3.9
- TensorFlow Lite
- OpenCV
- FreeCAD
- Firebase Real-time Database

Chapter 4

System Architecture

This chapter describes the system architecture in a general way, highlighting its modularity and interconnections. The main principle of TranquiScan is that it performs object detection in real time, marking animals and possible threats. This is followed by the turret system guided through continuous feedback to lead on accurate targeting. Identified animals are immobilized with a tranquilizer dart, recording key details to be analyzed and notifying authorities. Furthermore, manual override of the turret allows for remote adjustments of turrets orientation at critical moments. To understand more about the detailed implementation let us delve further.

4.1 System Overview

The TranquiScan wildlife management system includes a number of interrelated modules aimed at solving the problems related to human-wildlife conflicts. The Animal Identification module is part of an EfficientDet0 model being used to perform real-time object detection on resource limited devices such as the Raspberry Pi. This module records frames from an embedded camera, performs image processing and illustrates identified animals and poachers with bounding boxes indicating their respective positions. This lays the groundwork for more informed decision-making in subsequent stages.

The Turret Tracking module uses two MG90 servos to make dynamic adjustments of aim on a motorized turret so as the target image in view sight remains at its center. This module works through a continuous feedback loop to readjusts the turret according to dynamic changes in the environment as they happen. Once an animal is tracked correctly, the Dart Release module kicks in. It chooses an appropriate tranquilizing dart from a revolving magazine and fires it at the targeted animal with DC Motors. This not only paralyzes the animal but logs an event, which captures time, and then will then alert appropriate authorities.

Additionally, the Turret Manual Override module allows users to remotely adjust the turret's orientation, offering flexibility during critical moments. This manual control feature, integrated with the overall automated system, empowers users to make real-time adjustments, ensuring a comprehensive and responsive approach to wildlife management and conflict resolution.

4.2 Architectural Design

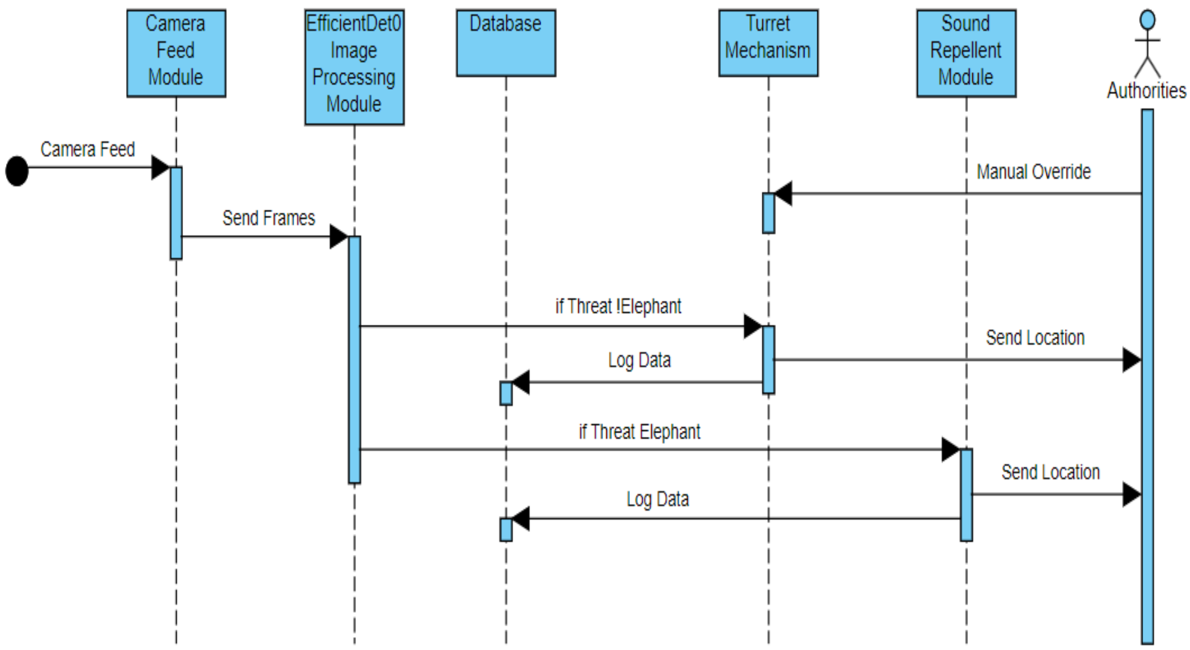


Figure 4.1: Sequence diagram indicating Tranquilization Mechanism

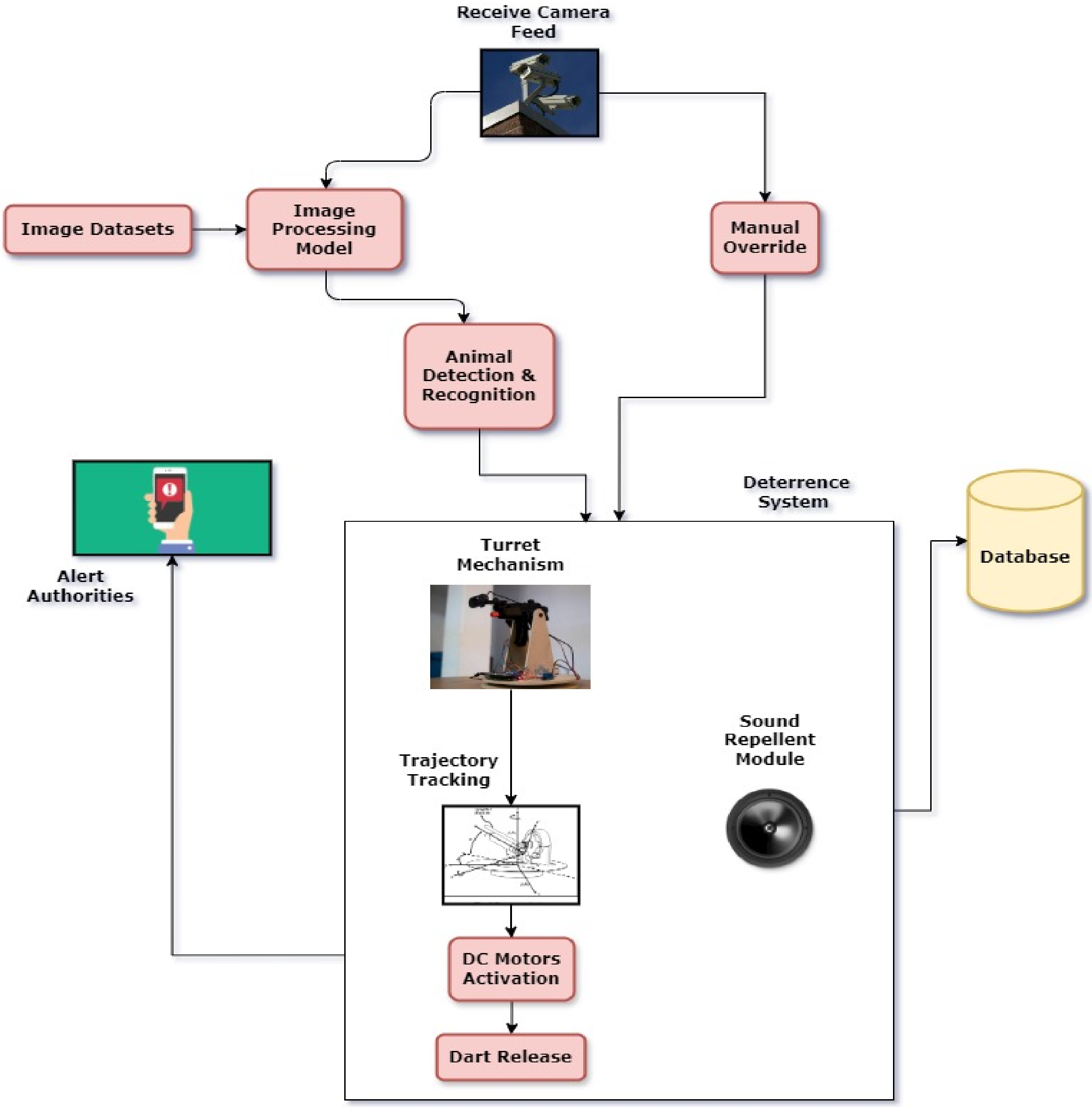


Figure 4.2: Architectural Diagram

4.3 Module Division

The proposed system can be sub-divided into five main modules:

- Animal Identification
- Turret Tracking
- Dart Release
- Sound Repellent System

- Turret Manual Override

4.3.1 Animal Identification

We will be utilizing a EfficientDet0 model, specifically designed for efficient performance on resource-constrained devices such as the Raspberry Pi. In this comprehensive system, a camera continuously captures video footage of the surrounding environment, converting it into individual frames. These frames are subsequently input into the EfficientDet0 model, facilitating object detection. The EfficientDet0 model meticulously processes each frame, adept at identifying and classifying various objects, including animals and potential poachers within the scene. Upon detection, these entities are highlighted with bounding boxes, offering a visual representation of their precise location within the frame. Moreover, the system goes beyond mere detection by providing additional insights. It not only marks the presence of animals and poachers but also identifies the species of the detected animal. This added layer of information enhances the system's capabilities, making it a valuable tool for wildlife monitoring and conservation efforts.

4.3.2 Turret Tracking

Using various onboard servos, the turret's aim is adjusted to seamlessly track the target animal. One servo controls the horizontal movement (pan motion) of the camera, allowing it to sweep across the scene, while another servo manages the vertical movement (tilt motion), adjusting the camera's angle. The primary objective is to align the turret so that it is centered on the detected animal within the camera's field of view. This alignment is achieved by coinciding the center of the camera's field of view with the center of the bounding box around the animal. The system operates through a feedback loop, creating a continuous refinement of its position based on real-time input. As the camera captures the scene and the target animal's position is detected, the servos receive feedback signals, prompting adjustments to ensure the turret remains precisely centered on the animal. This dynamic process allows the system to adapt to the target's movements, providing a responsive and accurate tracking mechanism.

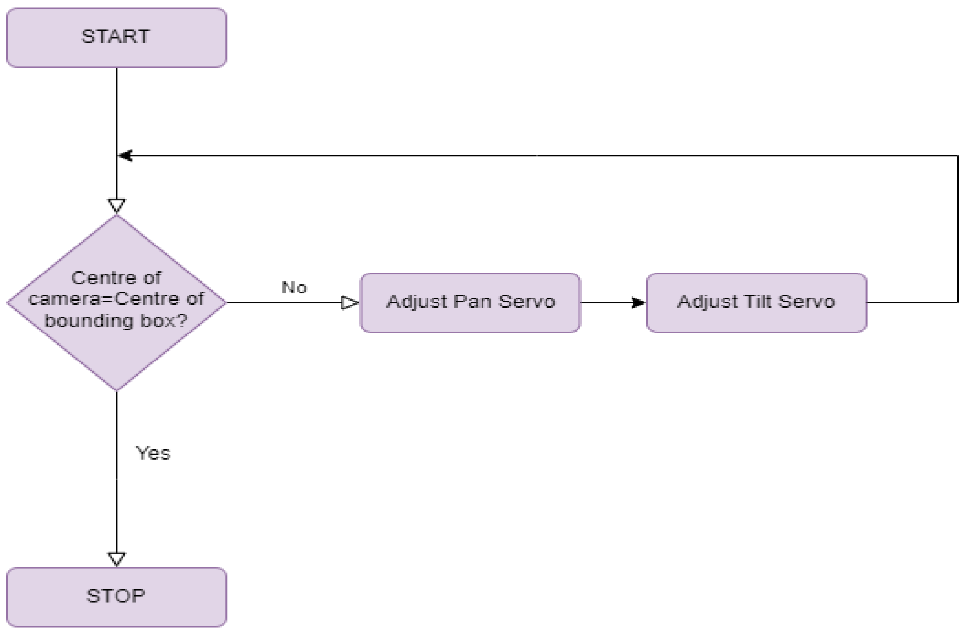


Figure 4.3: Turret Tracking Flow Diagram

4.3.3 Dart Release

Once the animal has been identified, the system drops a dart into the chamber. The dart is then propelled using two DC Motors. The system also incorporates a logging mechanism. When the dart is fired, the system captures and records essential information, including the timestamp. This documentation serves not only as a record of the event but also as a crucial tool for authorities. In the event of dart deployment, the system automatically triggers an alert to notify relevant authorities, which allows a fast and informed response to the situation.

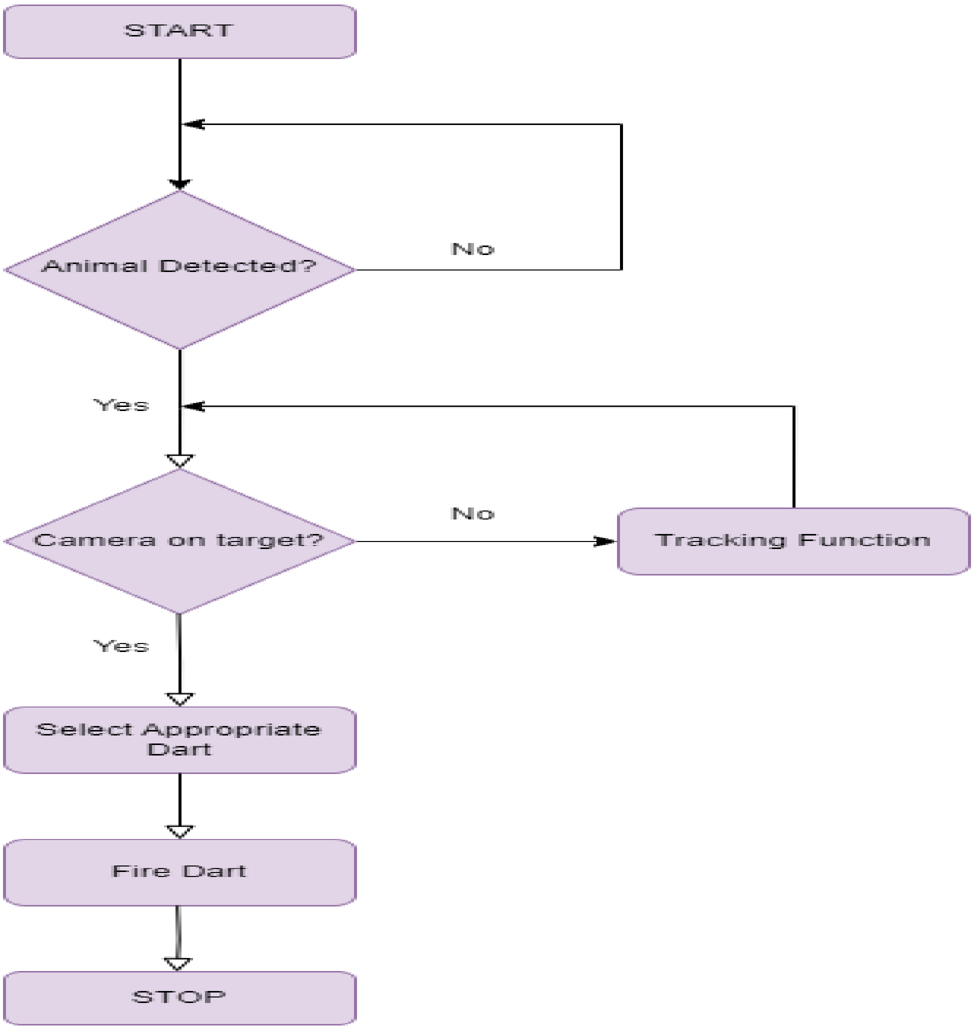


Figure 4.4: Dart Release Flow Diagram

4.3.4 Sound Repellent System

In situations where the large ungulates such as elephants are found, there may be some challenges of a speedy tranquilization. To overcome such risks, the TranquiScan system installs the sound repellent feature. The system makes a sound mimicking bees with the intention to scare elephants away by making them run away from the area.

This approach harnesses elephants' inherent behaviors, and provides an effective solution without a direct encounter. The system which uses the sound as a non-invasive repellent boosts safety for both wildlife and human populations, which in turns contributes to effective human-wildlife conflict mitigation measures.

4.3.5 Turret Manual Override

The motorized turret system offers users the capability to remotely adjust the orientation of the turret. Through a user interface, users can interact with the turret, modifying its angle or direction to survey the area or initiate actions such as firing a dart. One notable aspect is the real-time manual control feature, providing users with the ability to make adjustments during crucial moments. This capability enhances the system's versatility, making it adaptable to various scenarios where precise control over the turret's orientation is essential. Whether it's for surveillance purposes or responding to specific events, users can take command of the turret system to meet their unique requirements.

4.4 Work Breakdown and Responsibilities

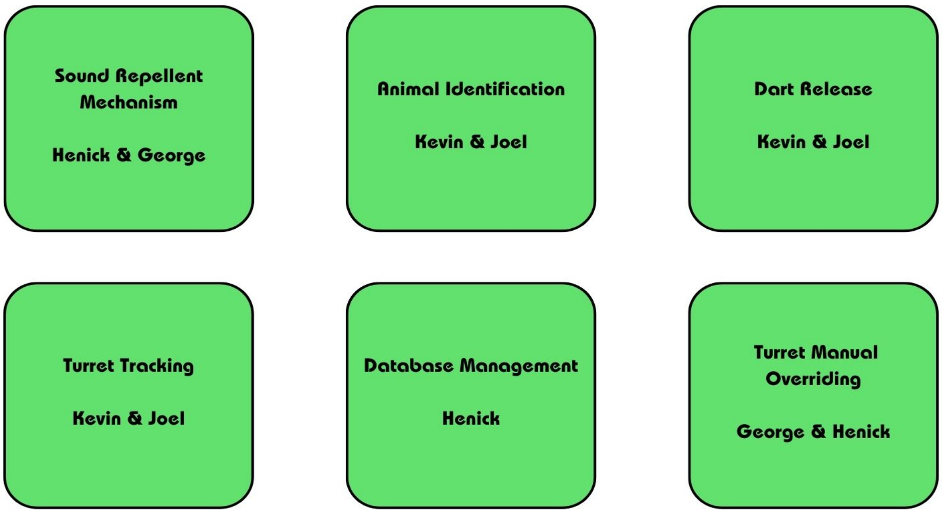


Figure 4.5: Work Distribution

4.5 Work Schedule - Gantt Chart

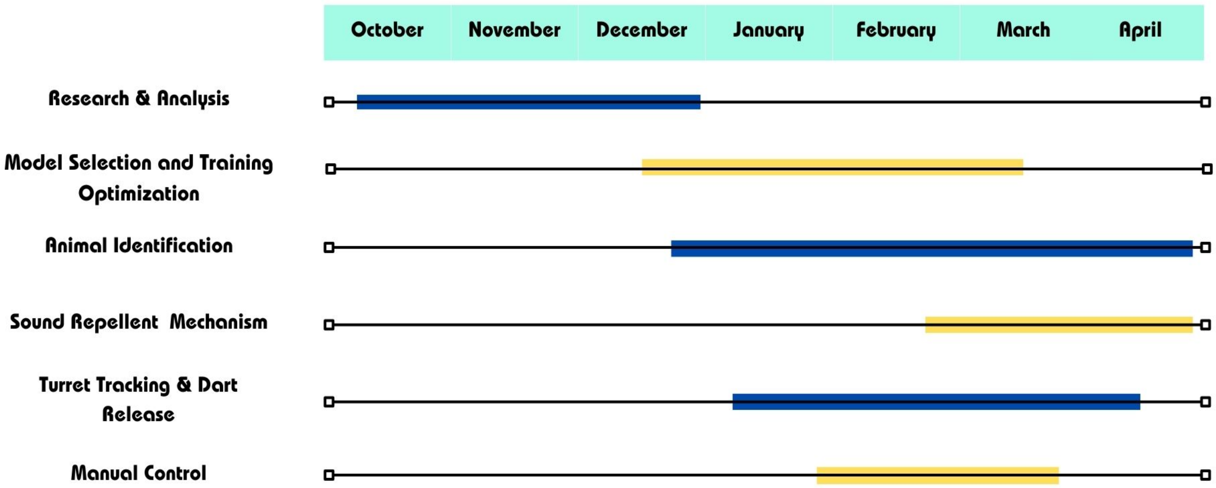


Figure 4.6: Timeline of each module

4.6 Conclusion

The fourth chapter investigates the complexity of the proposed system, providing a comprehensive view into its architecture, design and modular organization. The diagram provides a high-level overview of the architectural design.A sequence diagram is used to elaborate on the architecture, focusing particularly on events during tranquilization and poacher detection. The modular division section outlines the system into five main modules, which defines the purpose and function of each. This chapter ends with an extensive analysis of the workload distribution among team members and a Gantt chart indicating the module development timeline.

Chapter 5

System Implementation

In this chapter, we delve into the intricacies of implementing TranquiScan, a cutting-edge wildlife management system designed to mitigate human-wildlife conflicts and promote conservation efforts. From the selection of datasets to the deployment of algorithms and the integration of hardware components, each aspect of TranquiScan's implementation is meticulously detailed to provide a comprehensive understanding of its functioning and capabilities.

5.1 Datasets Identified

The datasets for the TranquiScan project were obtained from Google Open Images V7 that served as the source of a huge and varied set of images for training and testing purposes. Specifically, four classes were utilized: elephant, leopard, tiger, and the wild boar. These classes represent a major attention to big animals which are mostly in the direct contact with people and in conservation programs. Google Open Images dataset possesses many benefits, such as its large size, rich variety of species, and labelled annotations, which enable more rigorous model training and assessment. Furthermore, the dataset accessibility brings along reproducibility and comparability with other studies, which are the signs of being transparent and reliable in the project's findings.

One of the ways TranquiScan leverages the Google Open Images V7 dataset is that it has access to multitude of annotated images varying from different species and their habitats. This enables the development of models that are accurate and validated for specific species and that can pick out target animals with a high precision. The use of classes across different kinds of animals like elephants, leopards, tigers, and wild boar implies that the models trained have the ability to handle a range of wildlife encounters effectively. Besides, the presence of annotated labels reduce the project's workflow and it becomes more efficient because it helps in the preparation of datasets, as well as the model evaluation. Finally, Google Open Images V7 dataset is the key factor that helps TranquiScan wildlife management system to perform at the highest level and increases its reliability, which leads to the problem solving of human-wildlife conflicts and conservation.

5.2 The EfficientDet0 Algorithm

The EfficientDet0 model is an advanced deep learning architecture widely employed for fast and precise object identification. It relies on a lightweight yet powwerful CNN backbone, inspired by EfficientNet structures, which efficiently extracts hierarchical features from images, enabling the model to discern intricate patterns, particularly in animal identification tasks. By leveraging a scalable object identification platform, EfficientDet0 achieves a fine balance between model efficiency and detection accuracy, making it suitable for resource-constrained environments.

A key factor contributing to EfficientDet0's success is feature fusion, which integrates details from multiple levels of abstraction by blending low-level and high-level features. This fusion process enables the model to robustly detect animals across various scales, orientations, and environmental conditions without compromising computational efficiency, crucial for precise animal recognition.

During training, EfficientDet0 learns from annotated animal images through supervised learning, iteratively optimizing model parameters through gradient descent. Data augmentation techniques, such as rotations and brightness adjustments, enhance the model's generalization and robustness, simulating diverse environmental conditions and improving performance on unseen data.

In inference, the trained EfficientDet0 model identifies animals in new images, employing algorithms like non-maximum suppression (NMS) to filter out redundant detections and outputting bounding boxes around classified species. This ensures high reliability in the model's predictions by retaining only the most confident and accurate detections.

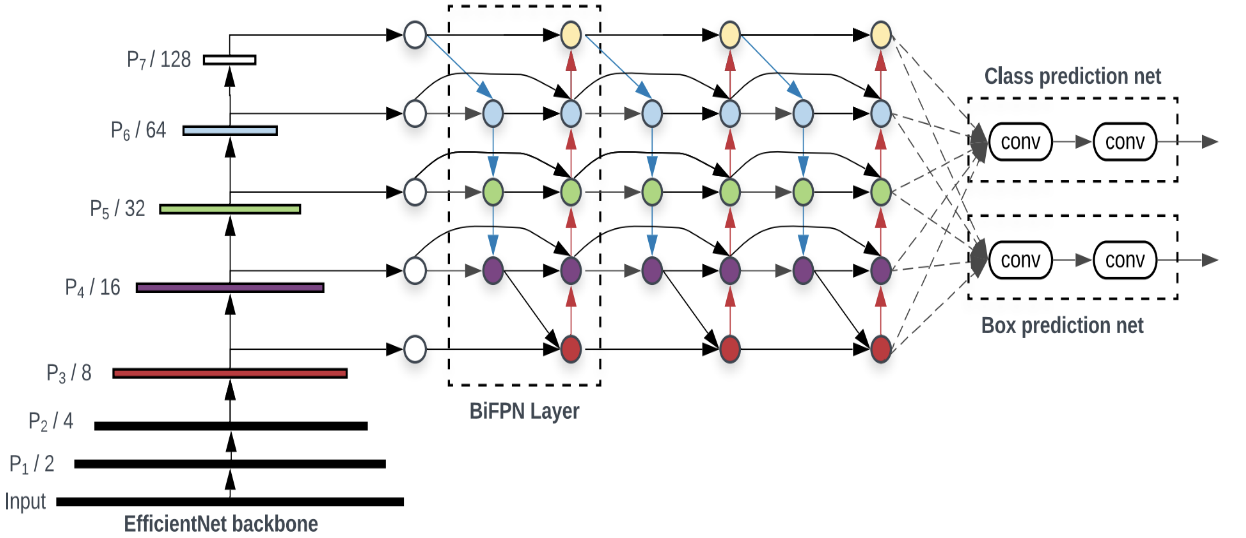


Figure 3: **EfficientDet architecture** – It employs EfficientNet [36] as the backbone network, BiFPN as the feature network, and shared class/box prediction network. Both BiFPN layers and class/box net layers are repeated multiple times based on different resource constraints as shown in Table 1.

Figure 5.1: EfficientDet0 Structure

5.3 Database Design

The object detection system uses a Firebase Realtime Database for storing information about detected animals. It is a cloud-hosted NoSQL database that enables storing and synchronizing data between your users in real-time. The database schema consists of a single table which stores information about detected animals.

Each entry in this table represents a detection event and contains the following fields:
Breed: Represents the type of animal detected.
Timestamp: Indicates the date and time when the detection occurred.

If an animal of a particular breed is detected again within a period of 20 seconds it is not logged onto the database. If the threshold has crossed and the same animal is present in the frame , its information is stored.

Reasons for Choosing Firebase Real-time Database:

- Scalability: Firebase is managed by Google, offering automatic scaling to handle a large number of concurrent connections and massive amounts of data. As our system may encounter varying loads based on detection events, scalability is essential.

- Ease of Use: Firebase offers simple and intuitive APIs for web and mobile platforms, making it easy to integrate with our Python-based object detection system. This simplicity reduces development time and effort.

- Cross-Platform Support: Firebase supports multiple platforms, including web, Android, iOS, and Unity. This flexibility allows us to extend our system to various devices and platforms seamlessly.

- Authentication and Security: Firebase provides built-in authentication and security rules to control access to the database. This ensures that only authorized users can read and write data, maintaining data integrity and privacy.

5.4 Description of Implementation Strategies

5.4.1 Implementation of Image Processing Model

The TranquiScan system tracks objects by calculating the horizontal and vertical offsets of bounding boxes from the screen's center. These offsets are used to compute the angles required for adjusting the pan and tilt servos. The updated angle values are then sent to the GPIO pins connected to the servos, ensuring precise tracking of detected objects.

```
# Initialize the object detection model
base_options = core.BaseOptions(
    file_name=model, use_coral=enable_edgetpu, num_threads=num_threads)

# this line is to modify no.of objects detected and confidence score
detection_options = processor.DetectionOptions(
    max_results=1, score_threshold=0.65)

options = vision.ObjectDetectorOptions(
    base_options=base_options, detection_options=detection_options)
detector = vision.ObjectDetector.create_from_options(options)

# Continuously capture images from the camera and run inference
while cap.isOpened():
  success, image = cap.read()
  if not success:
    sys.exit(
        'ERROR: Unable to read from webcam. Please verify your webcam settings.'
    )
```

Figure 5.2: Code Segment showing initialisation and usage of model

5.4.2 Implementation of Turret Tracking

In each frame, once the object is detected, the centre of the bounding boxes are obtained. Then the horizontal offset and vertical offset of the bounding box from the centre of the screen is calculated.

Using these values, the angle to adjust the pan servo and the angle to adjust the tilt servo is calculated and the new angle values are sent to the GPIO pins where the servos are connected.

```
# Draw circle at the center of the screen
cv2.circle(image, (centre_x, centre_y), 5, (255, 0, 0), -1)

for detection in detections:
    #Calculate centre of the bounding box
    bounding_box = detection.bounding_box
    boxcentre_x = int(bounding_box.origin_x + (bounding_box.width / 2))
    boxcentre_y = int(bounding_box.origin_y + (bounding_box.height / 2))

    # Draw circle at the center of the bounding box
    cv2.circle(image, (boxcentre_x, boxcentre_y), 5, (0, 255, 0), -1)

    # Print bounding box centre and how much its offset from centre of screen
    print("Box X,Y:", boxcentre_x, boxcentre_y)
    print("Offset coordinates (x, y):", centre_x - boxcentre_x, ",", centre_y - boxcentre_y)
```

Figure 5.3: Code Segment showing computation of bounding box coordinates

5.4.3 Implementation of Dart Release

Once the object has been centred by the turret for a specified amount of time, the dart is ejected by using a servo motor and propelled by 2 DC motors. The angle of the servo is increased by 100 degrees to load the dart into the chamber and 'pyfirmata' module is used to communicate with the Arduino to activate the DC motors.

5.4.4 Implementation of Manual Override

In case of the animal not being recognised or the bounding boxes not being visualised, the user can activate the Manual Override of the Turret by pressing the M key. This then allows the user to adjust the pan angle and tilt angle of servo by using the arrow keys. The user can then fire the dart by pressing the space bar key. This mode can be deactivated by pressing the M key again.

5.4.5 Implementation of Sound Repellent

In situations where the large ungulates such as elephants are found, there may be some challenges of a speedy tranquilization. To overcome such risks, the TranquiScan system installs the sound repellent feature. The system makes a sound mimicking bees with the intention to scare elephants away by making them run away from the area.

This approach harnesses elephants' inherent behaviors, and provides an effective solution without a direct encounter. The system which uses the sound as a non-invasive repellent boosts safety for both wildlife and human populations, which in turns contributes to effective human-wildlife conflict mitigation measures.

5.5 Chapter Conclusion

In this chapter, we've explored the intricate implementation details of TranquiScan, a comprehensive wildlife management system. Using the Google Open Images V7 dataset, TranquiScan ensures rigorous model training and evaluation, focusing on key animal species vital in human-wildlife conflicts and conservation. The integration of the EfficientDet0 algorithm further enhances its capabilities, enabling fast and precise object identification critical for addressing wildlife-related challenges effectively. Moreover, the adoption of Firebase Real-time Database ensures TranquiScan's commitment to scalability, simplicity, and data security, facilitating seamless real-time data synchronization. Through the integration of these components, TranquiScan emerges as a potent tool in promoting coexistence between humans and wildlife while contributing significantly to conservation efforts, setting a precedent for future wildlife management systems.

Chapter 6

Results and Discussions

This chapter reviews the outcomes and results of the TranquiScan project goals, which aim to solve the human-wildlife conflicts through the development of novel wildlife management technologies. The chapter is introduced by a comprehensively performed results summary that leads to a thorough description and analysis of the obtained results in relation to the purpose and scope of the project.

The results will cover multiple aspects of the project development, such as deployment of detection and tranquilization technologies, model performance evaluations and hardware integration.

6.1 Overview

In this chapter, we provide an outline of the outcomes and results of the TranquiScan project, a novel wildlife management technology aimed at alleviating the human-wildlife conflict. The chapter starts with a brief overview of the results that is an introduction to an in-depth examination and discussion of these results within the objectives and scope of the project.

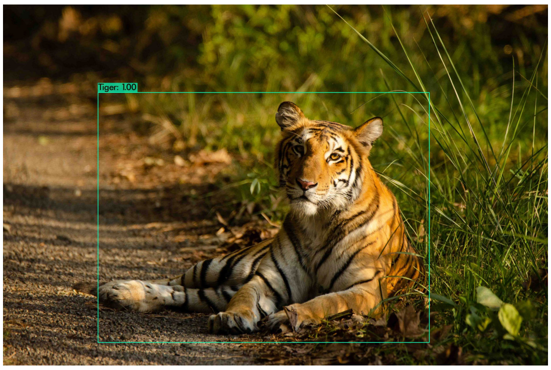
6.2 Testing

This section provides the test phase of the TranquiScan project which is shown the detection, tranquilization and hardware components operations. Sequential evaluation was carried out for checking the working and dependability of the technologies in the real-life situations where they were actually used. The actual testing of the TranquiScan system was to verify the fact that it was not only the best, but also the most effective in preventing conflicts between humans and wildlife.

6.2.1 Testing of Object Detection Model with still input images

This segment showcases the results achieved, where the detection and tranquilization accuracy are higher than the average. The final results are aimed at proving the reliability and efficiency of the TranquiScan system in real situations.

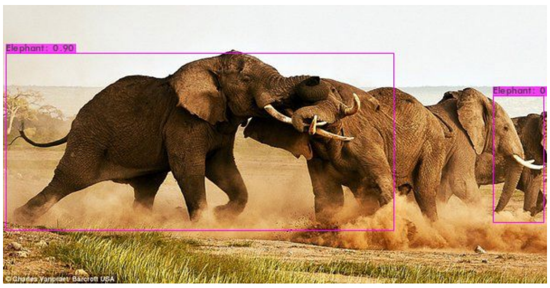
(a) An Image from the Elephant Class



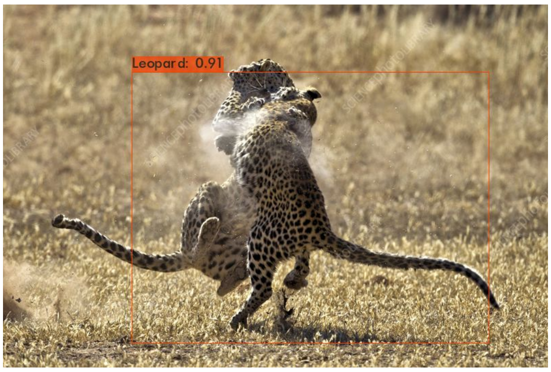
(b) An Image from the Tiger Class

Figure 6.1: Results where high level of accuracy is depicted

Here, results show problems with the presence of multiple ungulates within the frame and also their conflicts with each other which leads to lower accuracy levels. On the other hand, it is noted that with more training and refinement, these complexities can be tackled and accuracy levels can be increased, resulting in a system with better performance.



(a) Elephants in Conflict

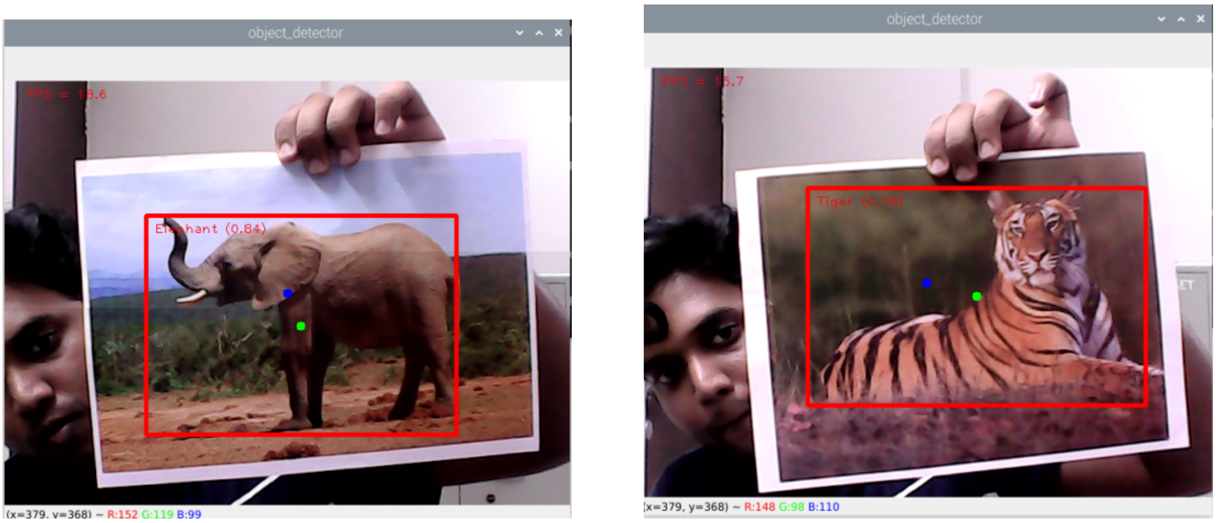


(b) Leopards in Conflict

Figure 6.2: Results where lower levels of accuracy is depicted

6.2.2 Testing of Object Detection Model with video feed

For the purpose of evaluating the performance of the object detection model in real-time conditions, the testing was performed using a live video feed. With practical constraints not allowing direct testing with the animals, pictures depicting different groups of animals were shown to the camera as a proxy for testing.



(a) An Image from the Elephant Class

(b) An Image from the Tiger Class

Figure 6.3: Video feed Detection

In the course of testing, the TranquiScan system processed the video sensor data in real time and identified and marked the animal species within the frames. All the classes of animals have been correctly identified and annotated by the model, with an accuracy of 75% and above, which reveals the model's competence in recognizing different kinds of wildlife species.

While no live animals were involved in the testing phase, the model was put through situations similar to the real world, making it possible to accurately check the model's performance. The system's capability to find and classify animals was meticulously validated using image proxies which showed its performance and reliability in wildlife management applications.

6.2.3 Testing of Firebase Database

The following subsection depicts the testing process of the Firebase database incorporation within the TranquiScan system. The findings demonstrate the efficiency with which the Firebase database is able to gather and organize detection data, thereby aiding in effective tracking and evaluation of each animal event. Several images of various ungulates were set in front of the feed which they were detected and the class name and the detection time were recorded in the Database.

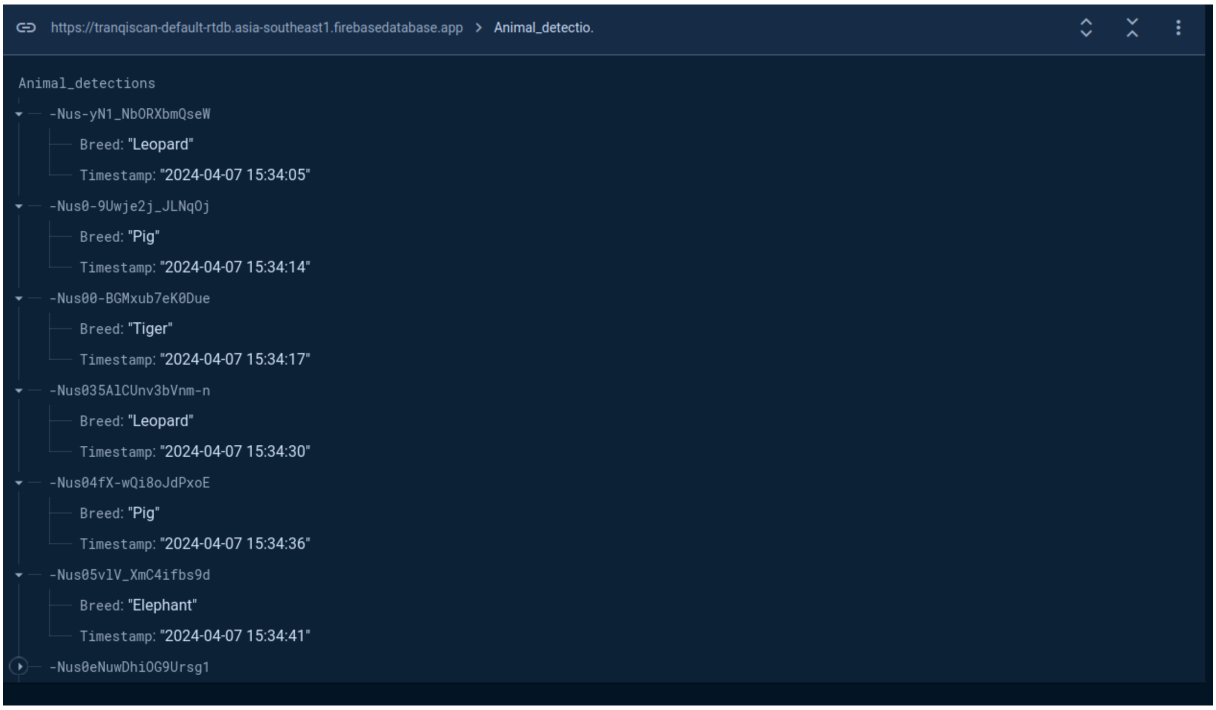


Figure 6.4: Database Entries for each of the classes

6.3 Quantitative Results

In this section, we provide a quantitative analysis of the various EfficientDet models performance on the basis of the Average Precision (AP), FLOPS, and latency of both CPU and GPU configurations. The goal is to pick up a suitable EfficientDet model for eventual integration into the TranquiScan system, with an emphasis on its performance in resource-limited environments like the Raspberry Pi.

The quantitative analysis carried out here provides the basis of the EfficientDet model's performance attributes that will be discussed in this paper. We are planning to achieve

Table 6.1: Comparison between different EfficientDet Models

Model	tet-dev AP	tet-dev AP_{50}	tet-dev AP_{75}	val AP	Params	Ratio	FLOPs	Ratio	Latency GPU$_{ms}$	Latency CPU$_{s}$
EfficientDet-D0 (512)	**33.8**	**52.2**	**35.8**	**33.5**	**3.9M**	**1x**	**2.5B**	**1x**	**16**	**0.32**
YOLOv3 [31]	33.0	57.9	34.4	-	-	-	71B	28x	$51^{\dagger}$	-
EfficientDet-D1 (640)	**39.6**	**58.6**	**42.3**	**39.1**	**6.6M**	**1x**	**6.1B**	**1x**	**20**	**0.74**
RetinaNet-R50 (640) [21]	37.0	-	-	-	34M	6.7x	97B	16x	27	2.8
RetinaNet-R101 (640)[21]	37.9	-	-	-	53M	8.0x	127B	21x	34	3.6
EfficientDet-D2 (768)	**43.0**	**62.3**	**46.2**	**42.5**	**8.1M**	**1x**	**11B**	**1x**	**24**	**1.2**
RetinaNet-R50 (1024) [21]	40.1	-	-	-	34M	4.3x	248B	23x	51	7.5
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EfficientDet-D4 (1024)	**49.4**	**69.0**	**53.4**	**49.0**	**21M**	**1x**	**55B**	**1x**	**74**	**4.8**
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EfficientDet-D7 (1536)	**52.2**	**71.4**	**56.3**	**51.8**	**52M**	**1x**	**325B**	**1x**	**262**	**24**

this by making comparisons of AP scores, FLOPS, and latency metrics across different model configurations and understand the best model for the real-time wildlife detection and management application.

The conclusion can be summarized by saying that EfficientDet0 was found to be the most suitable model for deployment within the TranquiScan system. With its low latency, FLOPS count and precision level, the Tiny-ML model is a good fit for edge applications that can run on the Raspberry Pi platform. The appropriate selection of EfficientDet0 guarantees the best efficiency and resource utilization thus ensuring the TranquiScan system works better in the conflict by human wildlife conflicts.

6.4 Graphical Analysis

This section provides a visual exploration and analysis of key performance metrics within the TranquiScan project. Through graphical representations, we aim to elucidate important insights into the effectiveness and efficiency of various components and models utilized in the system.

6.4.1 Equivalent Model Comparisions and why EfficientDet0?

EfficientDet is now a popular choice as the state of the art among image detection models, as it is both accurate and fast when compared to other image detection models. Before EfficientDet became a norm for image detection, YOLOv3 had been the model of choice.

EfficientDet is demonstrated on the COCO detection dataset to have the highest performance among similar models in comparison to model size. COCO consists of 80 object categories that cover a vast vision semantics and it is regarded as the standard for image detection tasks. The goal is to see if the model can make COCO simple, then it will be able to transfer to other image detection tasks, the only requirement being the sufficient training data for that particular new task.

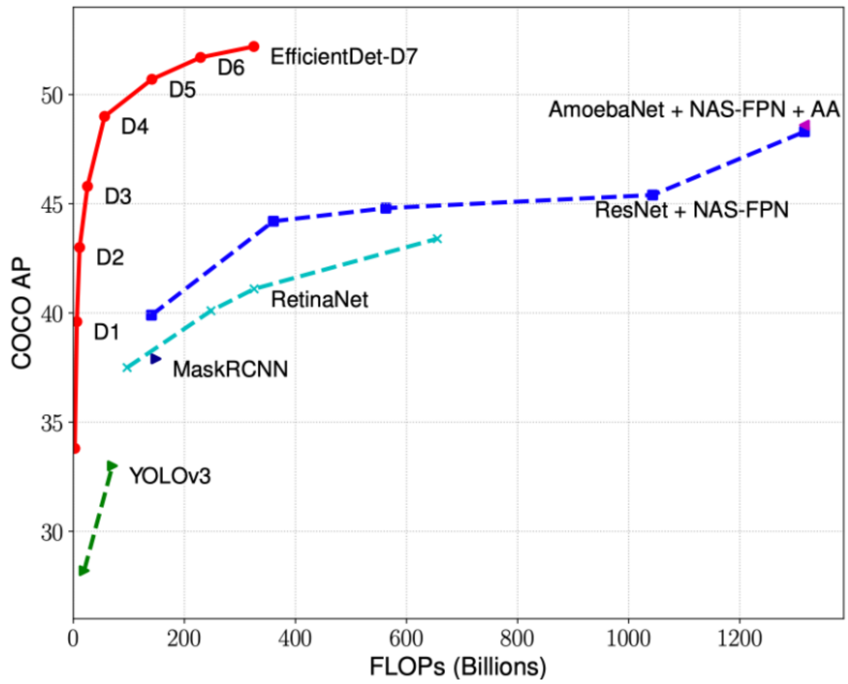

Figure 6.5: EfficientDet's Performance

Choosing an EfficientDet model involves a trade-off between accuracy and performance, which depends on the use case. For example, if the model needs to be deployed on an edge device, then a small variant should be used. Similarly, if the goal is to use the model for real-time video analysis, a smaller variant would be preferred because it provides higher frames per second (FPS). On the other hand, larger variants are suitable for those tasks that tolerate longer inference time, e.g. one-time analysis of static images, as they show better results in terms of accuracy.

6.4.2 mAP and Loss

Here, we evaluate a metric called mean Average Precision (mAP) and loss functions over the training time of the TranquiScan system. While the mAP metric serves as an indicator of the model's effectiveness in detecting and labeling objects, the loss metric reveals the training's stability and its tendency towards convergence and optimization.

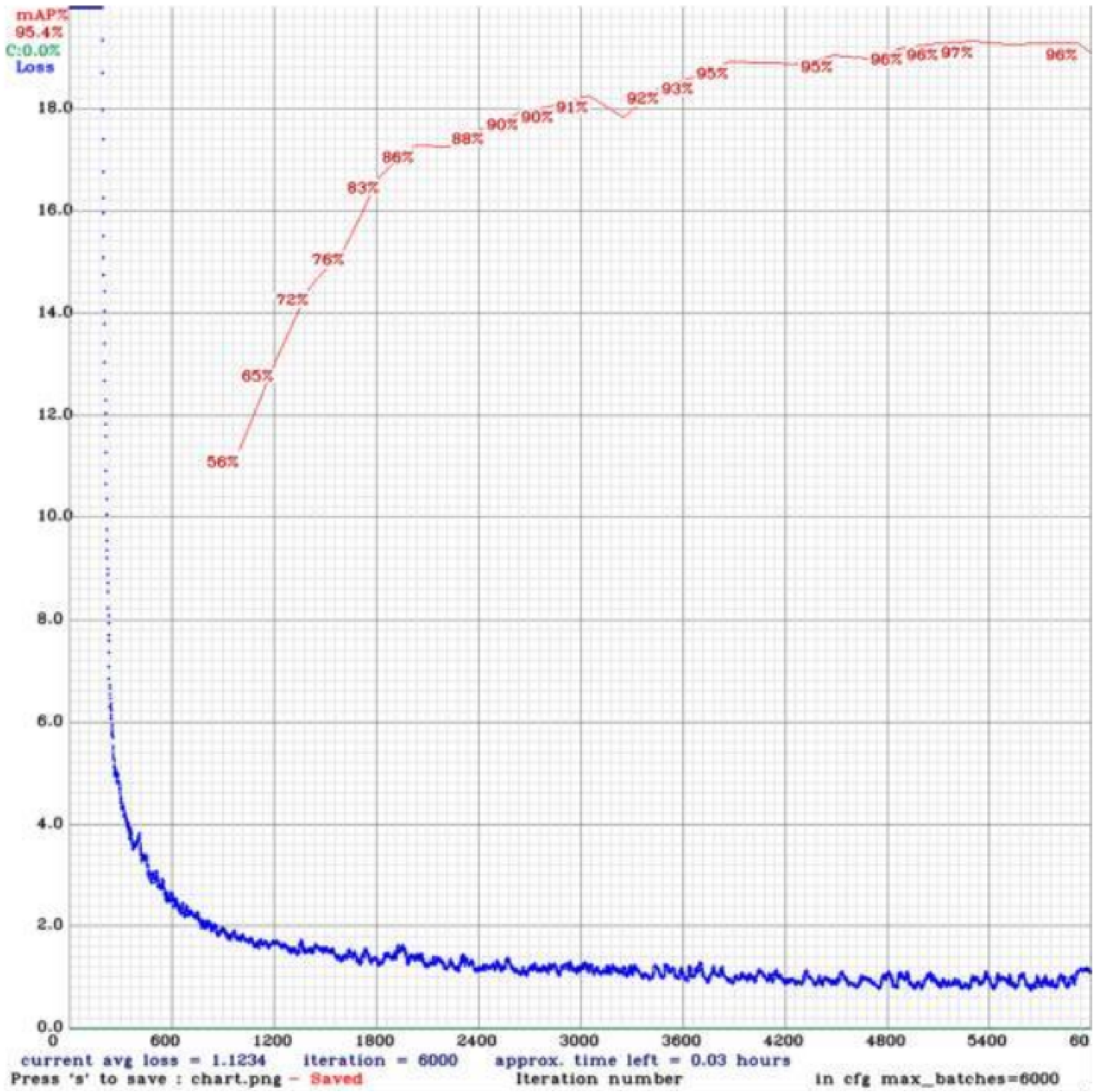

Figure 6.6: Graph representing mAP and Loss over time during the training process

In this graph one can see how the mAP and loss values are changing during the course of the training epochs. With these patterns in focus, we get deeper understanding about the models learning path and its convergence performance. This data is important for the adjustments to be made in the training process to achieve better results.

6.5 Chapter Conclusion

In summary, the results and discussions demonstrated in this chapter therefore demonstrate the great achievements achieved through the TranquiScan project in resolving human-wildlife conflicts. The leveraging of cutting-edge technologies, for example, object detection models and Firebase database integration, has proven to produce successful results for the improvement of wildlife management and conservation endeavors. However, the barriers still persist, notably when managing populations of multiple ungulates and human conflicts within the frames. Nevertheless, the results open up the way to more research and development in the wildlife management field. Tranquiscan project is the essential tool for achieving sustainable cohabitation of humans and nature on one hand, and preserving biosphere and local communities on the other hand.

Chapter 7

Conclusions & Future Scope

The TranquiScan project stands as a groundbreaking initiative in addressing the escalating challenges of human-wildlife conflicts. By seamlessly integrating cutting-edge technologies like real-time wildlife detection, tranquilization, and image recognition, TranquiScan not only safeguards human lives and property but also contributes significantly to environmental conservation efforts. Its adaptability in diverse scenarios, remote monitoring capabilities, and the synergy between technology and wildlife management make it a holistic solution for mitigating conflicts and preserving biodiversity.

Looking ahead, the TranquiScan project can continue to make further developments and extensions in future. In subsequent versions, increasing the accuracy of image recognition algorithms for better animal detection could be enhanced together with adoption of advanced sensors that will enable getting more precise environmental data and researching how AI-based decision making processes might help optimize wildlife management strategies. Furthermore, the incorporation of evolving technologies such as drone surveillance and machine learning algorithms can potentially improve TranquiScan's overall functions and enhance its solutions for human-wildlife conflict resolution. Perhaps the cooperation of research establishments and conservation societies could result in a worldwide applicable solution to wildlife management; one that ensures a sustainable form of symbiotic living between mankind and nature.

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Appendix A: Presentation

TranquiScan - Wildlife Sedation with Image Precision

Kevin Suresh (45) (U2003118)
Joel Johnson (32) (U2003104)
Henick Thadevous Peter (21) (U2003094)
George Thomas Maruthathu (12) (U2003086)

RSET
Guide: Mr. Harikrishnan M,
Asst. Professor,
Dept. of CSE

April 28, 2024

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Problem Definition

In the present-day world, due to an increase in human-animal conflicts, coexisting with wildlife has grown more difficult.
These conflicts lead to issues such as crop damage, livestock predation, property damage, and even human casualties.

Project Objective

Develop a comprehensive wildlife management system, that employs detection, tranquilization, and data processing technologies to mitigate human-wildlife conflicts, and enhance remote, non-invasive monitoring in protected sanctuaries.

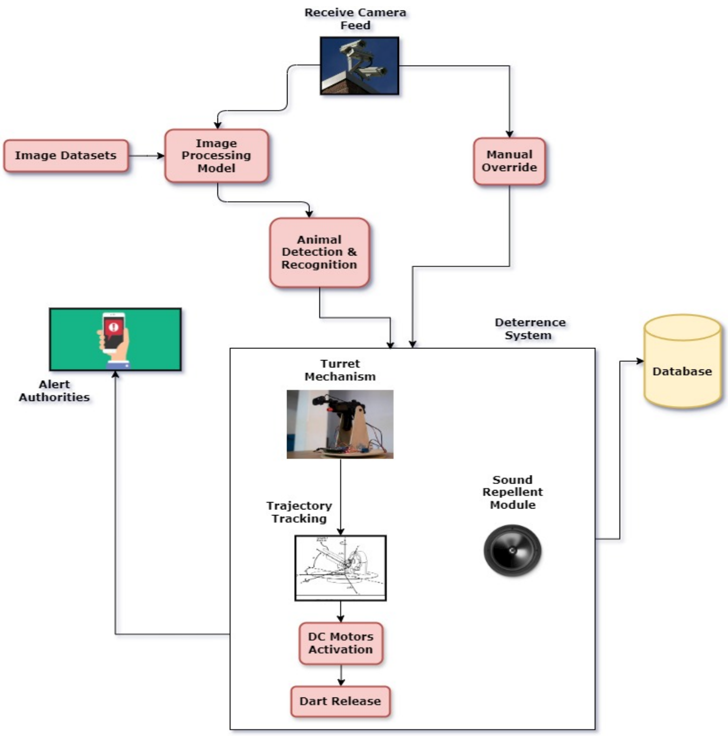
Novelty Of Idea and Scope Of Implementation

- TranquiScan innovatively addresses human-wildlife conflicts with **real-time animal detection** and precision dart release.
- The project employs a **EfficientDet0** model for on-the-fly animal identification, optimized for resource-constrained devices like the Raspberry Pi.
- Modules include **turret tracking** with a feedback loop, dart release with motorized propelling, sound deterrence for large ungulates, and manual turret override for user flexibility.

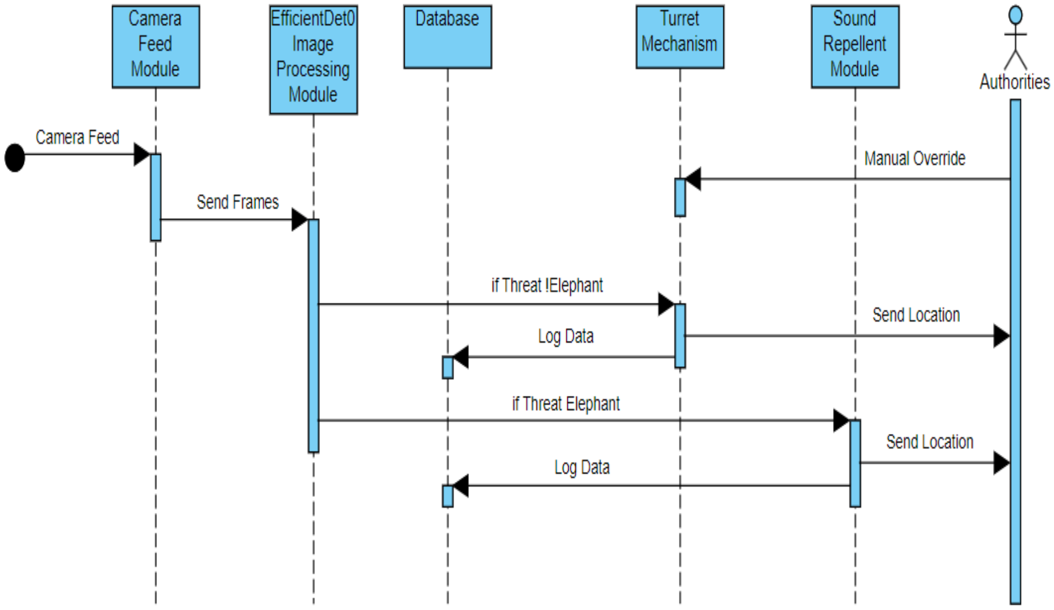
Proposed Method

- Detect and identify wildlife in real-time while considering environmental factors.
- Safely sedate and immobilize wildlife in close proximity to human-populated areas.
- Using Sound Deterrence for larger ungulates.
- Logging Priority Events
- Manual Override for delicate situations

Architecture Diagram



Sequence Diagram



Modules

- Animal Identification
- Turret Tracking
- Dart Release
- Sound Repellent System
- Turret Manual Overriding

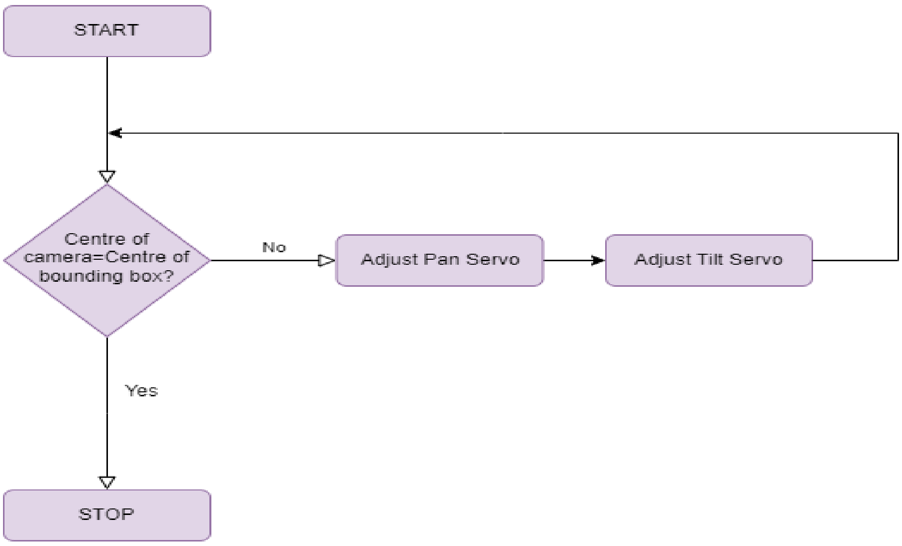
Animal Identification

- We will be using a EfficientDet0 model, which is optimized for resource-constrained devices like the Raspberry Pi.
- The camera continuously captures frames of the environment, which are fed into the EfficientDet0 model for object detection.
- The EfficientDet0 model processes each frame, identifying and classifying objects, which are the animals in our case.
- Detected animals are marked with bounding boxes, providing a visual representation of their location within the frame.

Turret Tracking

- Using various onboard servos, the turret's aim is adjusted such that it tracks the target animal.
- The aim is adjusted in a way that the turret is centered on the centre of the bounding box of the detected animal in the camera's field of view.
- The system operates through a feedback loop, continuously refining its position based on real-time input in each frame.

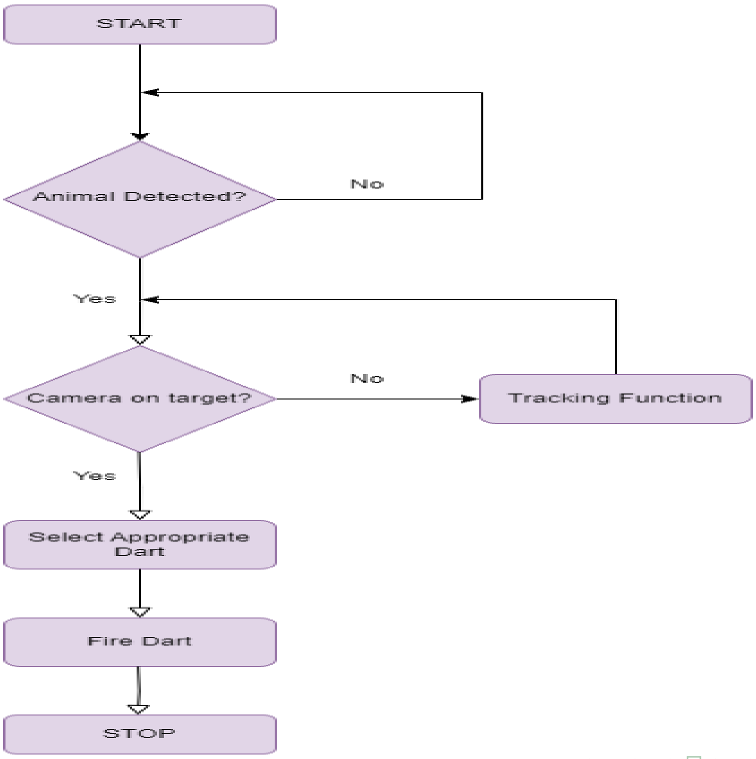
Turret Tracking



Dart Release

- Once the animal has been identified, the dart is loaded into the chamber using a Servo Motor.
- The dart will then be propelled by 2 DC Motors, which activates by sending the active signal to the Arduino.
- The system will log the time and current view of camera when the dart is fired and will alert the authorities.

Dart Release



Sound Repellent System

- In situations where the large ungulates such as elephants are found, there may be some challenges of a speedy tranquilization.
- The system makes a sound mimicking bees with the intention to scare elephants away by making them run away from the area.
- This approach harnesses elephants' inherent behaviors, and provides an effective solution without a direct encounter.

Turret Manual Override

- The motorized turret system allows users to adjust the turret's orientation remotely.
- This can be implemented by constantly listening to keyboard for the input to convert it to manual mode. Users can interact with the turret's movement by adjusting its angle or direction, surveying the area or firing a dart through a user interface.
- The Raspberry Pi can then process these commands and move the turret system accordingly.
- This manual control feature provides flexibility for real-time adjustments, enabling users to take control over the turret during critical moments.

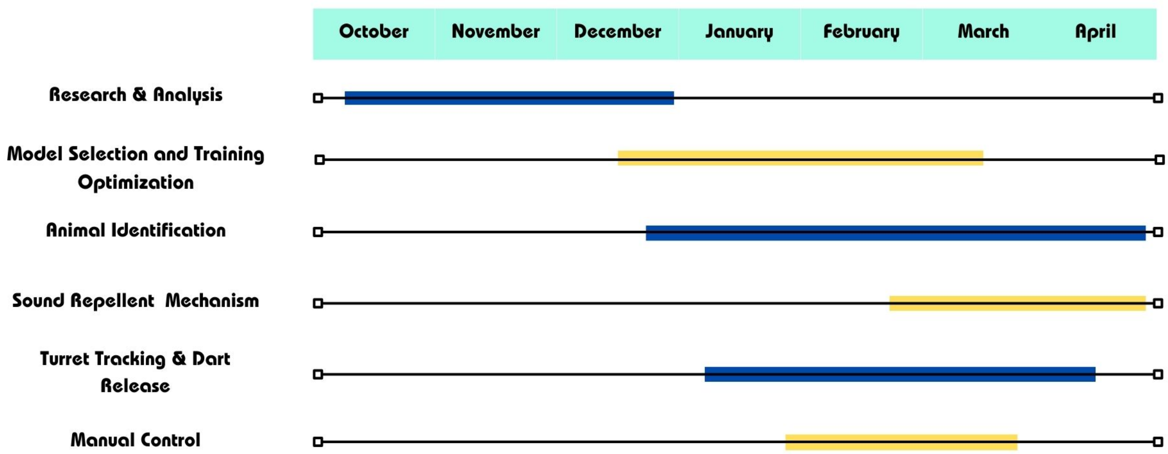
Software/Hardware Requirements

- Raspberry Pi 5
- 5V DC Motors
- Servo Motors
- Arduino
- L298D H Bridge
- NoIR Pi Camera
- FreeCAD
- Python 3.9
- TensorFlow Lite
- OpenCV
- Firebase Real-time Database

Budget

Component	Quantity	Estimated Cost
Raspberry Pi 5	1	Rs.8350
Raspberry Pi 5 Active Cooler	1	Rs.500
Raspberry Pi 5 Power Adapter	1	Rs.1000
DC Motor	2	Rs.200
Servo Motor	3	Rs.600
L298N	1	Rs.400
NoIR Pi Camera	1	Rs.1000
Total	14	13350-15100

Project Gantt Chart



Work done for 30% Evaluation

- Determining best model for object detection application
- Collection of Dataset Classes, Labelling and generation of intermediary training files
- Training and implementation of Object Detection Model
- Testing and Combating erroneous output

Work done for 60% Evaluation

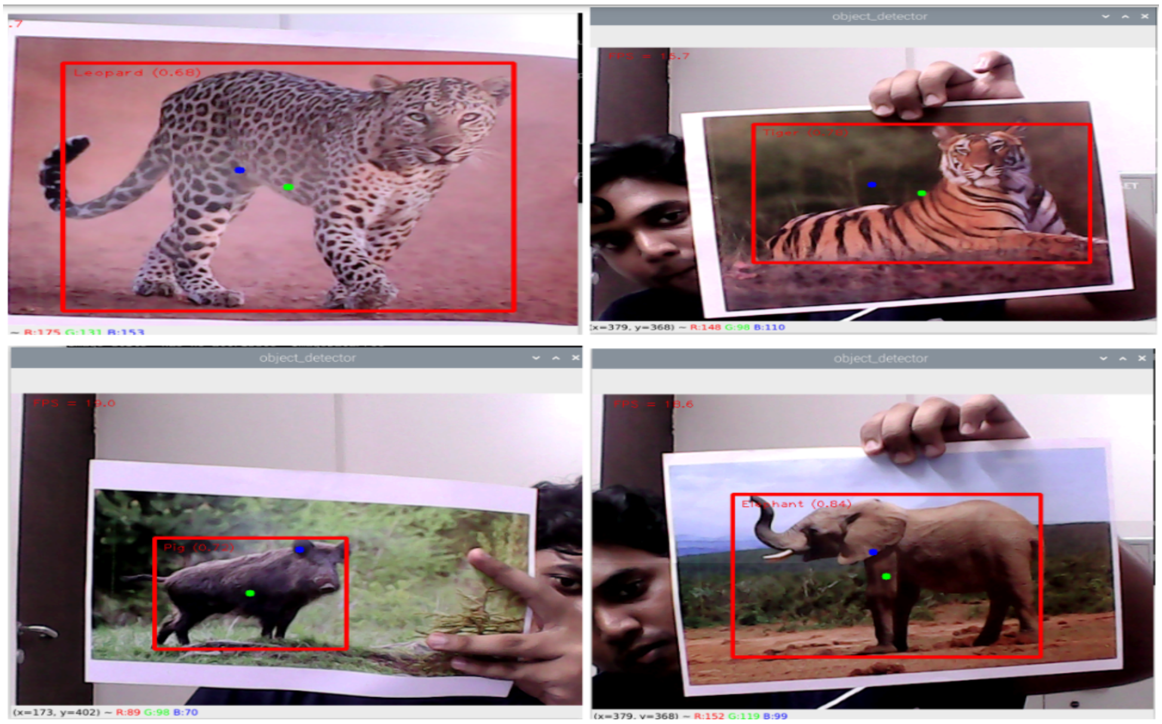
- Switched to EfficientDet model written on TensorFlow platform after further research to improve performance in edge devices
- Training and implementation of new model in Raspberry Pi Edge Computing Device
- Sound Emission implementation for repelling ungulate
- Motor movement to track object from video feed
- Designed 3D models of turret parts in Blender (.stl files)

Results - Still images fed into model

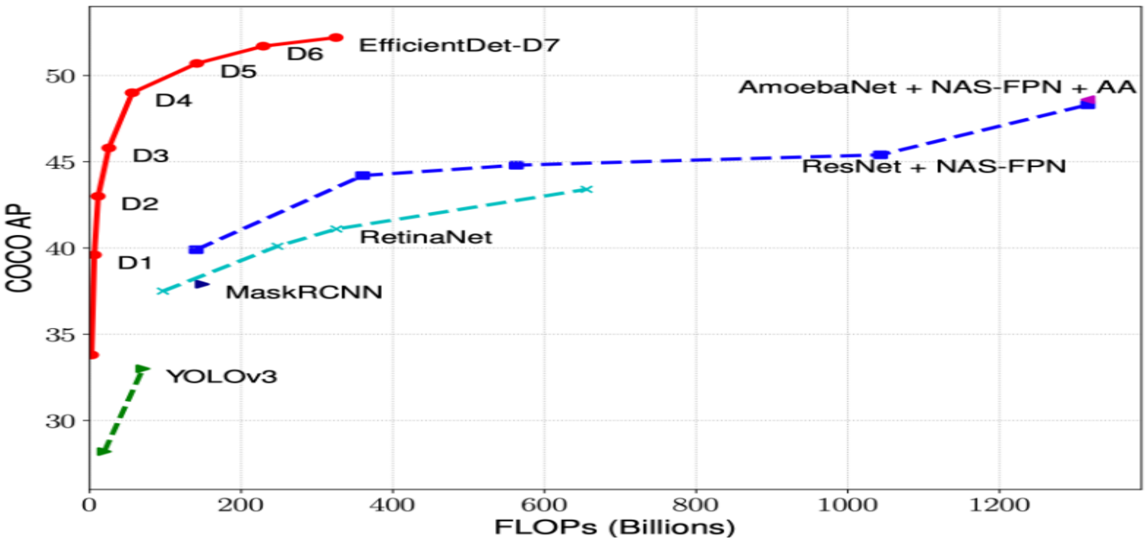
Results - Video feed fed into model

For the purpose of evaluating the performance of the object detection model in real-time conditions, the testing was performed using a live video feed. With practical constraints not allowing direct testing with the animals, pictures depicting different groups of animals were shown to the camera as a proxy for testing.

Results - Video feed fed into model



Graphical Analysis - Why EfficientDet ?



EfficientDet is demonstrated on the COCO detection dataset to have the highest performance among similar models in comparison to model size.

Graphical Analysis - Why EfficientDet ?

COCO consists of 80 object categories that cover a vast array of vision semantics and it is regarded as the standard for image detection tasks.
EfficientDet achieves the best performance in the fewest training epochs among object detection model architectures, making it a highly scalable architecture especially when operating with limited compute.

Graphical Analysis - mAP and Loss

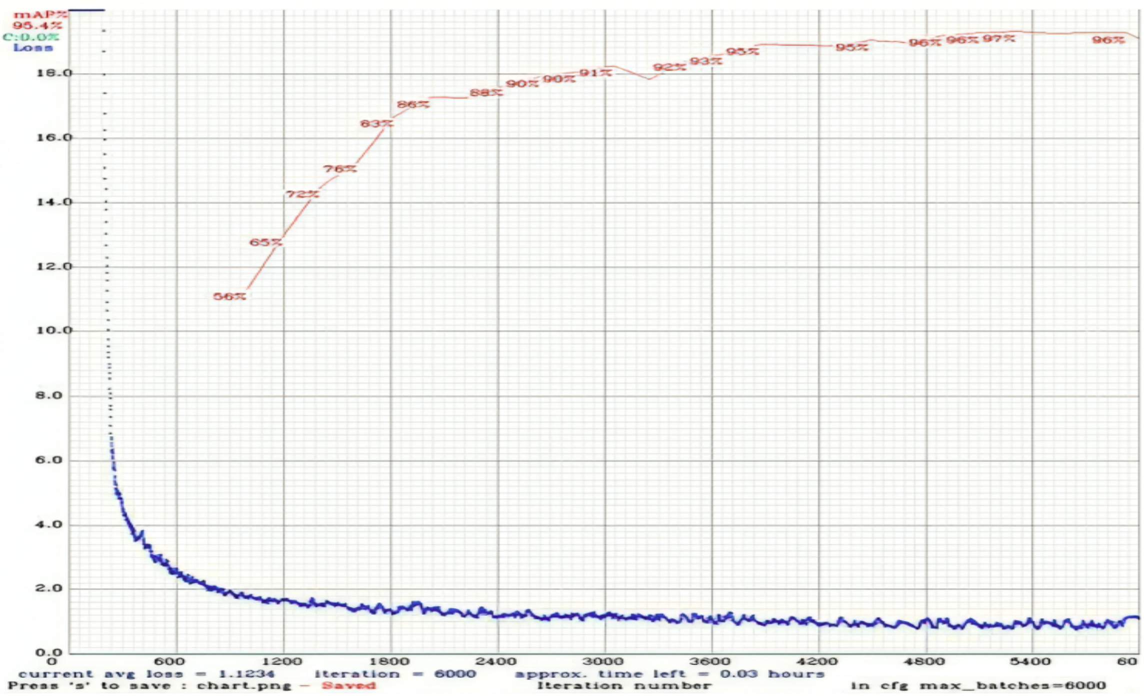


Fig: mAP and Loss over time during training

Graphical Analysis - mAP and Loss

While the mAP metric serves as an indicator of the model's effectiveness in detecting and labeling objects, the loss metric reveals the training's stability and its tendency towards convergence and optimization.
With the Mean Average Precision going as high as 95.4% and the loss as low as 1.124 and decreasing, we can see the training heading towards an acceptable level of accuracy and point of convergence.

Quantitative Analysis - Model Comparison

	tet-dev			val					Latency	
Model	AP	AP_{50}	AP_{75}	AP	Params	Ratio	FLOPs	Ratio	GPU_{ms}	CPU_{s}
EfficientDet-D0 (512)	**33.8**	**52.2**	**35.8**	**33.5**	**3.9M**	**1x**	**2.5B**	**1x**	**16**	**0.32**
YOLOv3 [31]	33.0	57.9	34.4	-	-	-	71B	28x	$51^{\dagger}$	-
EfficientDet-D1 (640)	**39.6**	**58.6**	**42.3**	**39.1**	**6.6M**	**1x**	**6.1B**	**1x**	**20**	**0.74**
RetinaNet-R50 (640) [21]	37.0	-	-	-	34M	6.7x	97B	16x	27	2.8
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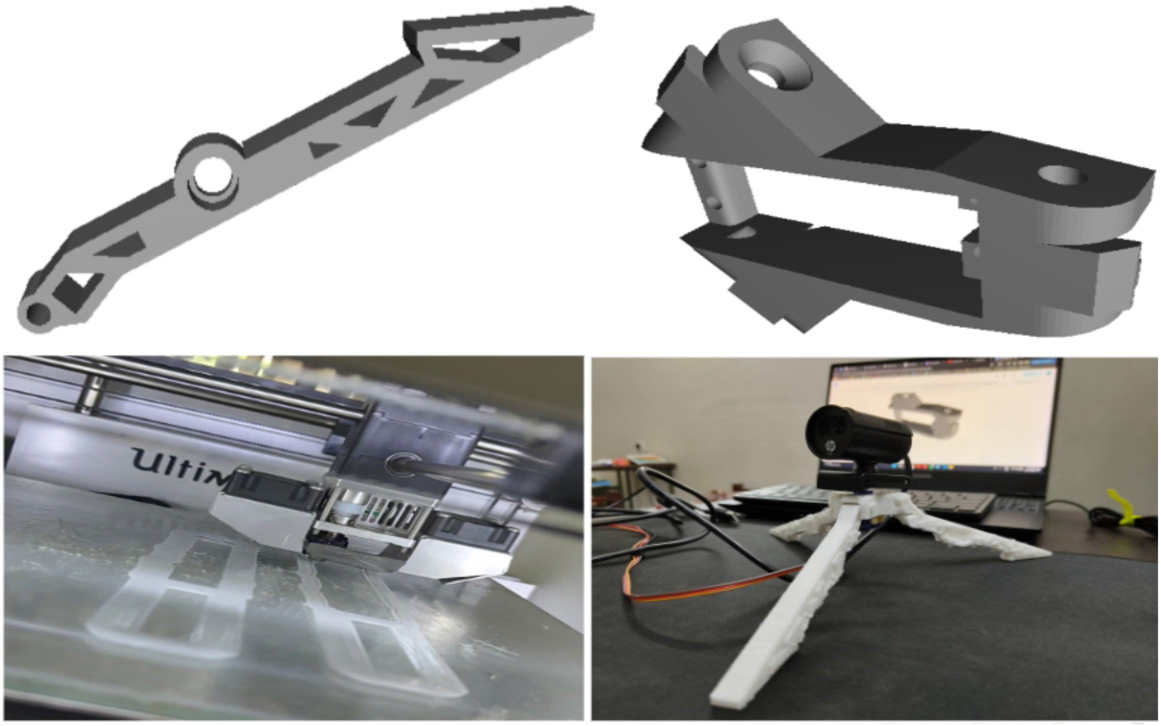
The Turret Mechanism



Database Entries - Firebase Realtime Database

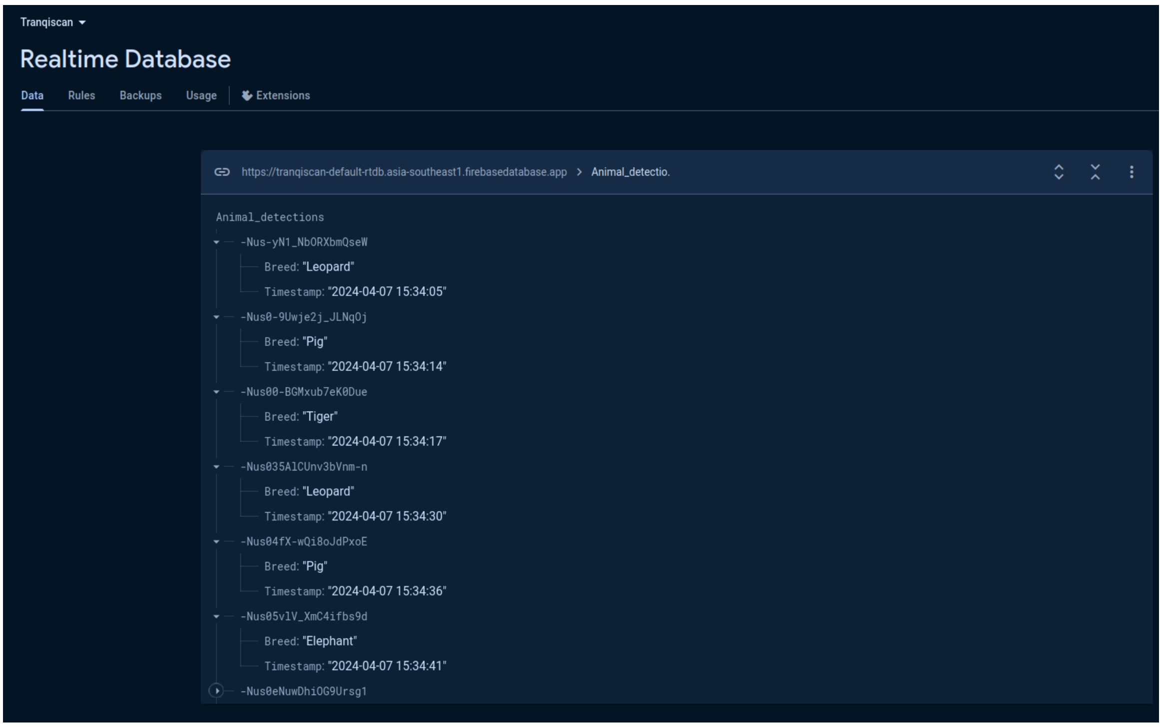


Fig: Entries of different ungulate classes and their timestamps

Database Entries - Firebase Realtime Database

The object detection system uses a Firebase Realtime Database for storing information about detected animals. It is a cloud-hosted NoSQL database that enables storing and synchronizing data between your users in real-time. The database schema consists of a single table which stores information about detected animals. Each entry in this table represents a detection event and contains the following fields:

- Breed: Represents the type of animal detected.
- Timestamp: Indicates the date and time when the detection occurred.

Future Scope

Embark on continued research and development in tranquilization methods and emphasize the impact of our model in giving the best possible solution. Address challenges such as improvement in image processing capabilities through ongoing research and advocate for continued funding to improve model capabilities.

Task Distribution

Sound Repellent Mechanism Henick & George	Animal Identification Kevin & Joel	Dart Release Kevin & Joel
Turret Tracking Kevin & Joel	Database Management Henick	Turret Manual Overriding George & Henick

Conclusion

The TranquiScan project represents a multifaceted approach to addressing human-wildlife conflicts and enhancing wildlife conservation efforts. By integrating advanced technologies and remote monitoring capabilities, this system aims to safeguard both human communities and wildlife populations while promoting coexistence.

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Appendix B: Vision, Mission, Programme Outcomes and Course Outcomes

Vision, Mission, Programme Outcomes and Course Outcomes

Institute Vision

To evolve into a premier technological institution, moulding eminent professionals with creative minds, innovative ideas and sound practical skill, and to shape a future where technology works for the enrichment of mankind.

Institute Mission

To impart state-of-the-art knowledge to individuals in various technological disciplines and to inculcate in them a high degree of social consciousness and human values, thereby enabling them to face the challenges of life with courage and conviction.

Department Vision

To become a centre of excellence in Computer Science and Engineering, moulding professionals catering to the research and professional needs of national and international organizations.

Department Mission

To inspire and nurture students, with up-to-date knowledge in Computer Science and Engineering, ethics, team spirit, leadership abilities, innovation and creativity to come out with solutions meeting societal needs.

Programme Outcomes (PO)

Engineering Graduates will be able to:

1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and Team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

10. Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Programme Specific Outcomes (PSO)

A graduate of the Computer Science and Engineering Program will demonstrate:

PSO1: Computer Science Specific Skills
The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas by understanding the core principles and concepts of computer science and thereby engage in national grand challenges.

PSO2: Programming and Software Development Skills
The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry.

PSO3: Professional Skills
The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur.

Course Outcomes (CO)

Course Outcome 1: Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: Apply).

Course Outcome 2: Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: Apply).

Course Outcome 3: Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks (Cognitive knowledge level: Apply).

Course Outcome 4: Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: Apply).

Course Outcome 5: Identify technology/research gaps and propose innovative/creative solutions (Cognitive knowledge level: Analyze).

Course Outcome 6: Organize and communicate technical and scientific findings effectively in written and oral forms (Cognitive knowledge level: Apply).

Appendix C: CO-PO-PSO Mapping

CO-PO AND CO-PSO MAPPING

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	2	2	2	1	2	2	2	1	1	1	1	2	3		
CO 2	2	2	2		1	3	3	1	1		1	1		2	
CO 3									3	2	2	1			3
CO 4					2			3	2	2	3	2			3
CO 5	2	3	3	1	2							1	3		
CO 6					2			2	2	3	1	1			3

3/2/1: high/medium/low

JUSTIFICATIONS FOR CO-PO MAPPING & CO-PSO MAPPING

MAPPING	LOW/MEDIUM/ HIGH	JUSTIFICATION
100003/ CS722U.1-PO 1	M	Knowledge in the area of technology for project development using various tools results in better modeling.
100003/ CS722U.1-PO 2	M	Knowledge acquired in the selected area of project development can be used to identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions.
100003/ CS722U.1-PO 3	M	Can use the acquired knowledge in designing solutions to complex problems.
100003/ CS722U.1-PO 4	M	Can use the acquired knowledge in designing solutions to complex problems.

100003/ CS722U.1-PO 5	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.1-PO 6	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.1-PO 7	M	Project development based on societal and environmental context solution identification is the need for sustainable development.
100003/ CS722U.1-PO 8	L	Project development should be based on professional ethics and responsibilities.
100003/ CS722U.1-PO 9	L	Project development using a systematic approach based on well defined principles will result in teamwork.
100003/ CS722U.1-PO 10	M	Project brings technological changes in society.
100003/ CS722U.1-PO 11	H	Acquiring knowledge for project development gathers skills in design, analysis, development and implementation of algorithms.
100003/ CS722U.1-PO 12	H	Knowledge for project development contributes engineering skills in computing & information gatherings.

100003/ CS722U.2-PO 1	H	Knowledge acquired for project development will also include systematic planning, developing, testing and implementation in computer science solutions in various domains.
100003/ CS722U.2-PO 2	H	Project design and development using a systematic approach brings knowledge in mathematics and engineering fundamentals.
100003/ CS722U.2-PO 3	H	Identifying, formulating and analyzing the project results in a systematic approach.
100003/ CS722U.2-PO 5	H	Systematic approach is the tip for solving complex problems in various domains.
100003/ CS722U.2-PO 6	H	Systematic approach in the technical and design aspects provide valid conclusions.
100003/ CS722U.2-PO 7	H	Systematic approach in the technical and design aspects demonstrate the knowledge of sustainable development.
100003/ CS722U.2-PO 8	M	Identification and justification of technical aspects of project development demonstrates the need for sustainable development.
100003/ CS722U.2-PO 9	H	Apply professional ethics and responsibilities in engineering practice of development.
100003/ CS722U.2-PO 11	H	Systematic approach also includes effective reporting and documentation which gives clear instructions.

100003/ CS722U.2-PO 12	M	Project development using a systematic approach based on well defined principles will result in better teamwork.
100003/ CS722U.3-PO 9	H	Project development as a team brings the ability to engage in independent and lifelong learning.
100003/ CS722U.3-PO 10	H	Identification, formulation and justification in technical aspects will be based on acquiring skills in design and development of algorithms.
100003/ CS722U.3-PO 11	H	Identification, formulation and justification in technical aspects provides the betterment of life in various domains.
100003/ CS722U.3-PO 12	H	Students are able to interpret, improve and redefine technical aspects with mathematics, science and engineering fundamentals for the solutions of complex problems.
100003/ CS722U.4-PO 5	H	Students are able to interpret, improve and redefine technical aspects with identification formulation and analysis of complex problems.
100003/ CS722U.4-PO 8	H	Students are able to interpret, improve and redefine technical aspects to meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
100003/ CS722U.4-PO 9	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis

		and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.4-PO 10	H	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools for better products.
100003/ CS722U.4-PO 11	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.4-PO 12	H	Students are able to interpret, improve and redefine technical aspects for demonstrating the knowledge of, and need for sustainable development.
100003/ CS722U.5-PO 1	H	Students are able to interpret, improve and redefine technical aspects, apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.5-PO 2	M	Students are able to interpret, improve and redefine technical aspects, communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
100003/ CS722U.5-PO 3	H	Students are able to interpret, improve and redefine technical aspects to demonstrate knowledge and understanding of the engineering and management principle in multidisciplinary environments.

100003/ CS722U.5-PO 4	H	Students are able to interpret, improve and redefine technical aspects, recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
100003/ CS722U.5-PO 5	M	Students are able to interpret, improve and redefine technical aspects in acquiring skills to design, analyze and develop algorithms and implement those using high-level programming languages.
100003/ CS722U.5-PO 12	M	Students are able to interpret, improve and redefine technical aspects and contribute their engineering skills in computing and information engineering domains like network design and administration, database design and knowledge engineering.
100003/ CS722U.6-PO 5	M	Students are able to interpret, improve and redefine technical aspects and develop strong skills in systematic planning, developing, testing, implementing and providing IT solutions for different domains which helps in the betterment of life.
100003/ CS722U.6-PO 8	H	Students will be able to associate with a team as an effective team player for the development of technical projects by applying the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
100003/ CS722U.6-PO 9	H	Students will be able to associate with a team as an effective team player to identify, formulate, review research literature, and analyze complex engineering problems

100003/ CS722U.6-PO 10	M	Students will be able to associate with a team as an effective team player for designing solutions to complex engineering problems and design system components.
100003/ CS722U.6-PO 11	M	Students will be able to associate with a team as an effective team player, use research-based knowledge and research methods including design of experiments, analysis and interpretation of data.
100003/ CS722U.6-PO 12	H	Students will be able to associate with a team as an effective team player, applying ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.1-PS O1	H	Students are able to develop Computer Science Specific Skills by modeling and solving problems.
100003/ CS722U.2-PS O2	M	Developing products, processes or technologies for sustainable and socially relevant applications can promote Programming and Software Development Skills.
100003/ CS722U.3-PS O3	H	Working in a team can result in the effective development of Professional Skills.
100003/ CS722U.4-PS O3	H	Planning and scheduling can result in the effective development of Professional Skills.
100003/ CS722U.5-PS O1	H	Students are able to develop Computer Science Specific Skills by creating innovative solutions to problems.
100003/ CS722U.6-PS O3	H	Organizing and communicating technical and scientific findings can help in the effective development of Professional Skills.