Enhancing Sustainable Coconut Crop Protection through Machine Learning-Driven Integrated Strategies

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Final Report

B.Sc. (Hons) Degree in Information Technology Specialized in Software Engineering

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Preliminary detection of presence of crop raiding macaque monkeys through audio analysis

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Declaration of the Candidate

I declare that this is our own work, and this proposal does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

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The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

Name of the supervisor: Mr. Vishan Jayasinghearachchi

Name of the co-supervisor: Mr. Samadhi Rathnayake

……. ……..

Signature of Supervisor: Date

(Mr. Vishan Jayasinghearachchi)

…… ……

Signature of Co-supervisor: Date

(Mr. Samadhi Rathnayake)

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ABSTRACT

Agricultural communities worldwide are facing many challenges. These challenges not only affect the livelihoods of individual farmers but also have profound impacts on the economic well-being and sustainability of entire communities. One of the most common issues of rural areas is the persistence of pests, which pose a formidable obstacle to successful crop cultivation and economic prosperity. In numerous rural villages, farmers are locked in a constant battle against pests that devastate their crops. These pests, ranging from insects to larger animals, not only devour the fruits of farmers' labor but also inflict significant damage on their crops and plants. Among these pests, macaque monkeys have emerged as a major concern in agricultural areas. They harm various crops, including fruits, vegetables, grains, and flowers, posing a continual threat to farmers.

The problems caused by pests are much more than just losing crops. Farmers suffer a lot financially as they try to defend their crops and way of life from these pesky invaders. Dealing with pests costs farmers a lot of money, not just from the crops they eat, but also from trying to control them and fixing up the damaged crops. And even when the pests are gone, the damage they leave behind, like lower crop yields and poorer quality produce, can keep hurting farmers' incomes and the stability of the economy.

In response to these critical challenges, researchers and agricultural experts have been striving to develop innovative solutions to mitigate the impact of pests on farming communities. One such effort focuses automated strategies on detecting the presence of the macaque monkeys and repel them. The research aims to help a village overcome its pest issues by using smart solutions for pest control. But it's not just about fixing the problem for now. The goal is to give farmers the knowledge and tools they need to handle pest challenges in the long run. This way, farming in the village can stay strong and sustainable for the future.

Keywords – Crop protection, Macaque monkey, Macaque Detection

1. INTRODUCTION

1.1 BACKGROUND STUDY

The coconut palm (Cocos nucifera) plays a vital role in the economies of many tropical regions, providing resources like coconut water, oil, and desiccated coconut that support various industries and international trade. However, sustaining coconut farming faces challenges, particularly from diseases and pests that harm crop quality and yield. Traditional pest control methods such as shooting, afraid monkeys are not good to reduce the harm. Hence, there's a growing need for innovative and eco-friendly approaches to protect coconut crops sustainably.

This research aims to integrate advanced machine-learning techniques with conventional agricultural practices to enhance pest and disease management in coconut farming. Using deep learning models, early detection of the presence of macaque monkeys and using repelling methods that do not harm the environment. That promises more effective control while minimizing environmental impact. Several pests pose significant threats to coconut palms, notably whiteflies, macaque monkeys, and coconut caterpillars, particularly in places like Sri Lanka. Combining agricultural expertise with technology is crucial to developing sustainable pest management strategies urgently.

This study proposes a pest control system leveraging cutting-edge technology. Central to our approach is the integration of sensors with a mobile application. This system proactively addresses damage from whiteflies and coconut caterpillars, emphasizing early detection, accurate identification, understanding pest behavior, and deterring macaque monkeys. For macaque detection, our system employs a network of strategically placed sensors equipped with image recognition technology to provide real-time information on their presence. This information is verified to reduce false alarms, and non-invasive sound techniques are used to deter macaques humanely. In addition, our system utilizes pattern prediction algorithms to detect early signs of pest presence by analyzing data. The mobile application notifies farmers promptly upon identification and offers tailored pest management solutions that prioritize sustainability and eco-friendliness.

1.2 LITERATURE REVIEW

Recent studies explored different animal classification strategies. Acoustic and visual methods are commonly employed for classification purposes. Vithakshana L. G. C, Samankula W. G.

D. M proposed an IoT-based animal classification system using a convolutional neural network. The hardware implementation was designed to collect the data. In the system, they got audio clips for 10 species. audio clips were preprocessed using the Mel-frequency Cepstral Coefficient (MFCC). A CNN architecture based on TensorFlow was used for the training process. 400 sound clips were used including 40 per each animal species. Audios are formatted using Audacity.

Che Yong Yeo, S. A. R. Al-Haddad, and C. K. Ng present an animal identification system leveraging voice pattern recognition. It integrates zero-cross-rate (ZCR), Mel-Frequency Cepstral Coefficients, and Dynamic Time Warping (DTW) algorithms. ZCR detects voice endpoints, filtering out silence, while MFCC extracts compact, less redundant voice features. DTW handles voice pattern classification, finding the optimal path between input and reference voices in the database. Results affirm the system's effectiveness, showcasing its ability to accurately identify animals by their distinct vocal patterns.

Authors of proposed a bird classifier system. They used bird audio recordings and bird species classification. They used the Mel-frequency cepstral coefficient (MFCC) and tested it through different algorithms, namely Naïve Bayes, J4.8, and Multilayer perceptron (MLP), to classify bird species. J4.8 has the highest accuracy (78.40%). K.H. Frommolt and K.H. Tauchert researched birds using the bioacoustics monitoring system. The study presents two convolutional neural network approaches for bird call detection in audio recordings.

1.3 RESEARCH GAP

The detection and management of pest species, particularly those with significant economic and ecological impacts, have been areas of active research within agricultural and environmental science disciplines. However, within this broad field, there exists a notable gap in the literature concerning the specific application of sound analysis for the detection of macaque monkeys, a species known to pose substantial challenges to agricultural systems and human-wildlife coexistence in many regions.

One of the primary gaps in previous research is the limited focus on macaque monkey detection using sound analysis. While studies have explored sound-based approaches for pest detection, including insects and birds, there is a scarcity of prior research specifically dedicated to macaque monkey detection through sound analysis. This gap highlights the novelty and uniqueness of the proposed approach, which aims to fill this void by leveraging sound analysis techniques to identify and track macaque monkey activity in agricultural settings. Furthermore, while previous research has separately investigated the use of IoT devices and deep learning algorithms for pest detection and management, there is a lack of integration between these technologies, particularly concerning macaque monkey detection. The integration of IoT devices, such as sound-recording sensors, with advanced deep learning algorithms represents a significant advancement in technological capabilities. By combining these technologies, the proposed research aims to enhance the accuracy and efficiency of macaque monkey detection and tracking, setting it apart from previous studies that may have focused on individual technological components. Another significant gap in the existing

literature pertains to the absence of real-time monitoring and catching the location using the implemented device, in previous studies on pest detection through sound analysis. While some research may have utilized sound analysis techniques for pest detection, the lack of real-time monitoring and location tracking limits the ability to monitor and respond to pest activity effectively.

1.4 RESEARCH PROBLEM

“Macaque monkeys can be presence any time in the day. How to detect the presence of macaque monkeys? “This is the main problem.

The traditional methods used to detect and repel macaques in agricultural settings rely heavily on manual observation and physical barriers. However, these approaches are labor-intensive, inefficient, and often fail to provide timely or accurate detection of macaque presence. So these facts causes significant problem for farmers, as macaques can appear on farmlands unpredictably, and it's impractical for farmers to monitor their fields constantly. Consequently, there's a pressing need to find more effective solutions for detecting and repelling macaques in real-time.

In response to this challenge, this study proposes an innovative solution that integrates sound analysis, IoT devices, and deep learning algorithms. This approach aims to address the shortcomings of traditional methods and provide farmers with a more efficient means of detecting and repelling macaques while minimizing labor and ecological impact.

2. OBJECTIVES

2.1 MAIN OBJECTIVE

The primary aim of this research is to design, develop, and implement an advanced system for detecting and repelling macaque monkeys in agricultural environments. This system will utilize cutting-edge technologies such as sound analysis, IoT devices, and deep learning algorithms to provide farmers with an efficient and effective solution for managing macaque incursions.

2.2 SPECIFIC OBJECTIVE

To design and implement IoT devices equipped with sound sensors for automated macaque detection:

The first specific objective is to design and implement IoT devices equipped with sound sensors specifically tailored for macaque detection. These devices will be strategically placed across agricultural fields to continuously monitor for macaque vocalizations, allowing for automated detection of their presence.

To develop deep learning algorithms for analyzing sound data and accurately identifying macaque vocalizations:

The second objective involves developing deep learning algorithms capable of analyzing sound data collected by the IoT devices. These algorithms will be trained to accurately identify macaque vocalizations amidst background noise, ensuring reliable detection of macaque activity.

Integration of GPS Functionality:

The third objective is to integrate GPS functionality into the IoT devices to enable getting the locations of each device and from that find the macaque monkey behaviours. This integration will provide farmers with valuable insights into the spatial dynamics of macaque populations, facilitating targeted intervention strategies.

To Predict the Future Macaque Behavior:

For predict the future behaviors of macaque monkeys for the specific farmland some environmental facts should be important. For that location, temperature, humidity are catched using the developed device.

To provide farmers with a user-friendly mobile application for accessing real-time macaque detection alerts and intervention recommendations:

Develop a user-friendly mobile application that interfaces with the IoT devices and provides farmers with real-time macaque detection alerts and intervention recommendations.

3. METHODOLOGY

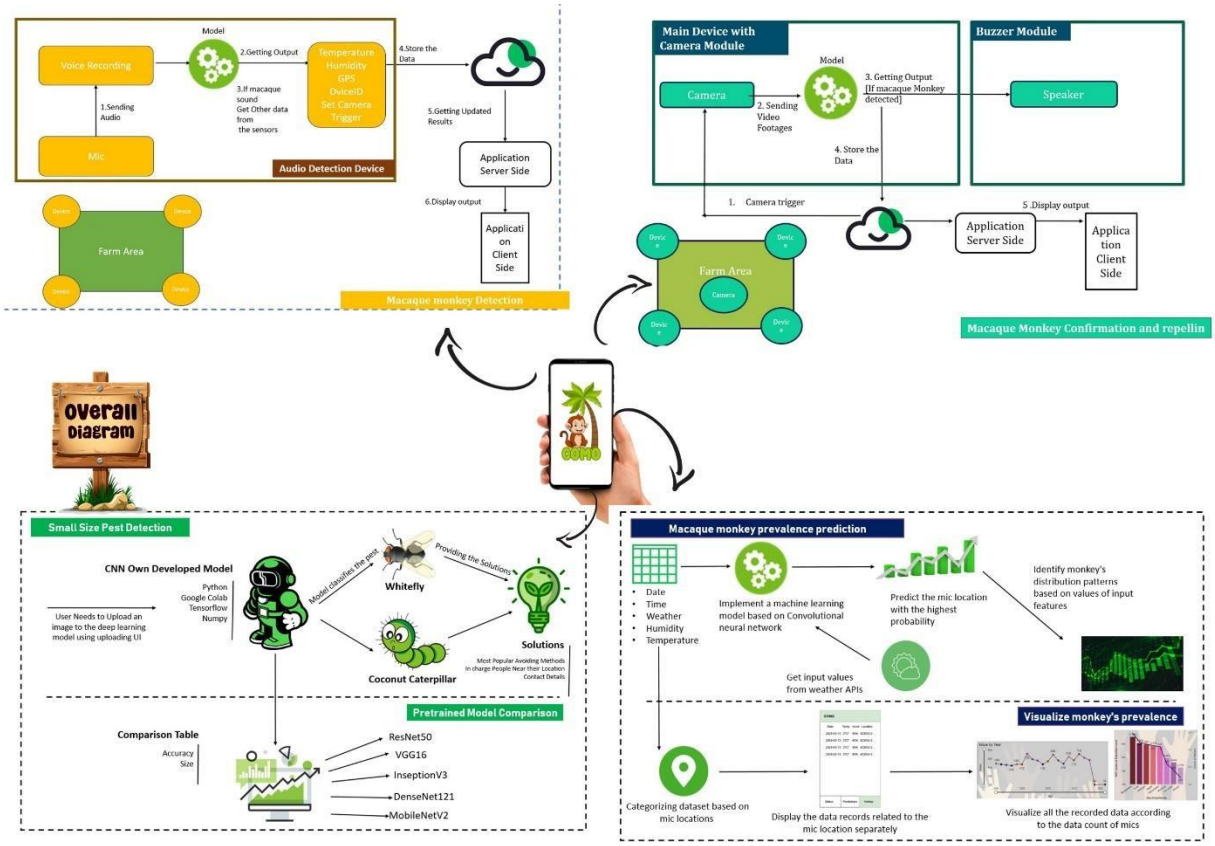
The methodology proposed for detecting the presence of macaque monkeys in agricultural environments involves the continuous monitoring of environmental sounds using a specially designed device. This device operates 24 hours a day, filtering out natural background noise using a predefined volume threshold limit. Detection is triggered when sounds surpassing this threshold, set at 50 decibels, are identified.

Upon detection, the system initiates recording of 4-second audio clips for further analysis. These audio clips are then subjected to a sound classification algorithm, specifically Recurrent Neural Networks (RNN) LSTM, known for its effectiveness in distinguishing macaque monkey sounds from ambient noise. To train the RNN(LSTM) algorithm, a dataset comprising approximately 2100 audio recordings, including 1050 macaque sounds and 1050 ambient noises, is utilized.

During the preprocessing stage, 75% of the dataset is separated for training purposes, while the remaining 25% is allocated for testing the algorithm's accuracy and reliability. This division ensures the robustness of the sound classification algorithm by providing sufficient data for training and validation. Upon successful identification of macaque sounds, supplementary information such as temperature, humidity, device ID, and location are captured concurrently. This contextual data is crucial for understanding the environmental conditions surrounding macaque activity and aids in subsequent confirmation processes. Furthermore, the captured audio clips, along with the supplementary contextual data, are stored securely in the cloud for further analysis and reference. This cloud-based storage system allows for efficient retrieval and management of data, facilitating subsequent confirmation processes and system optimization.

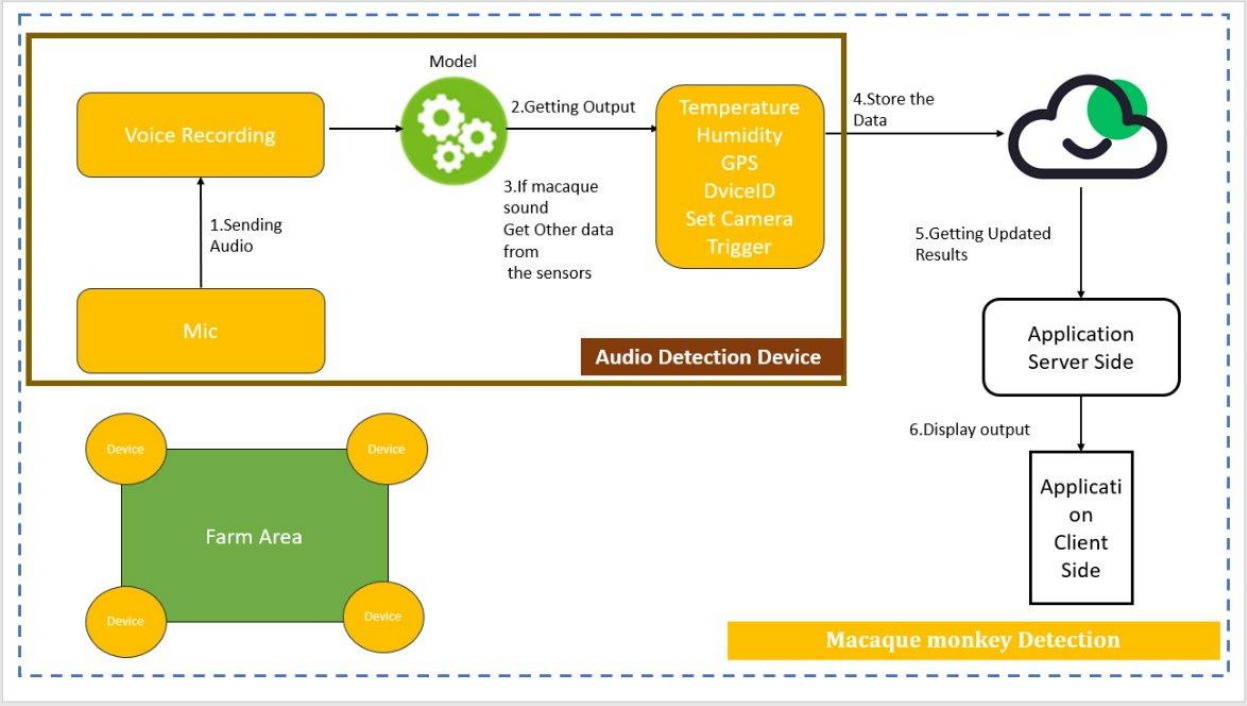
The proposed methodology integrates advanced technology with sound scientific principles to develop a reliable and effective system for detecting macaque monkey presence in agricultural settings. By employing cutting-edge techniques such as RNN algorithms and leveraging comprehensive datasets, the system aims to enhance the accuracy and reliability of macaque detection, ultimately contributing to improved pest management and agricultural sustainability.

3.1 OVERALL SYSTEM

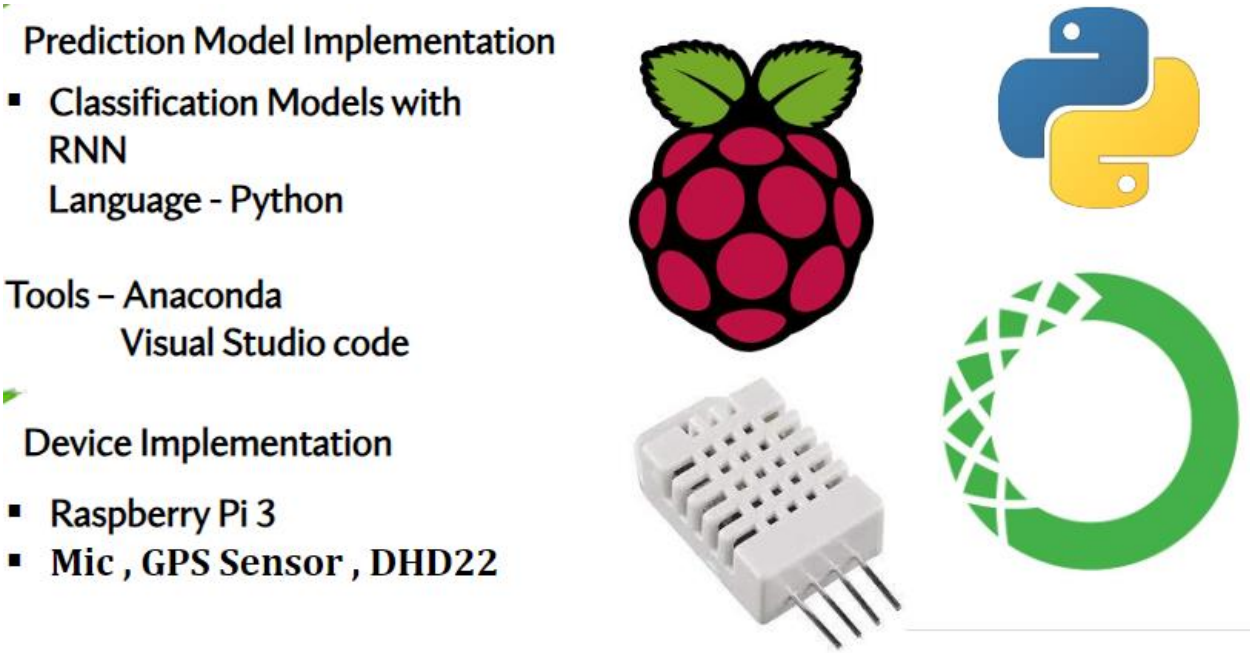


In many villages, farmers are struggling with a serious problem: macaque monkeys are causing extensive damage to their crops. The traditional method of scaring them away, often involving shooting, isn't effective, especially when dealing with large groups of monkeys. Additionally, it raises ethical concerns about animal welfare. To address this issue more efficiently and compassionately, we propose a new solution based on sound technology. By strategically placing sound sensors throughout the area, we can detect the unique sounds made by macaque monkeys when they arrive. Advanced algorithms analyze this data quickly and accurately, distinguishing monkey noises from other background sounds. When we confirm the presence of macaques, speakers emit high-frequency, high-decibel sounds, effectively discouraging the monkeys from staying on our property. This comprehensive system not only detects and repels macaques but also provides valuable insights into their behavior patterns. By studying this data, we can identify trends in their movements and preferred entry points, allowing us to optimize our preventive measures. This proactive approach offers a sustainable, long-term solution to the macaque monkey problem, protecting our land and livelihoods.

3.2 ARCHITECTURE



Tools and software used.



3.3 DATA COLLECTION

For data collection, multiple locations including the Sri Lankan Zoo, Bisodola Falls, and Munangala Forest in Sri Lanka were visited. Manual recordings of macaque sounds were conducted in these areas, along with visits to coconut farming lands. A total of 1040 macaque sound clips and 1040 ambient noise recordings were collected from these diverse environments. This extensive dataset provides a comprehensive foundation for training and validating the sound classification algorithm, ensuring its accuracy and reliability in detecting macaque presence in agricultural settings.

3.4 DATA PROCESSING AND STORAGE

In the data preprocessing stage for macaque sounds, several steps are typically undertaken to prepare the collected audio clips for further analysis and storage;

- Noise Reduction: Apply noise reduction techniques to remove any background noise or interference from the recordings, ensuring that only the macaque sounds are retained for analysis. For that Audacity is used.

- Segmentation: Divide the audio clips into smaller segments, typically of uniform duration, to facilitate processing and analysis. This step helps in standardizing the data and extracting relevant features for classification. For that Audacity is used.

- Feature Extraction: Extract relevant features from the segmented audio clips, such as frequency components, amplitude variations, and spectral characteristics. These features serve as input variables for the sound classification algorithm.

- Normalization: Normalize the extracted features to ensure consistency and comparability across different audio clips. Normalization helps in removing biases and ensuring that the algorithm operates effectively on the entire dataset.

- Data Augmentation: Augment the dataset by applying transformations such as pitch shifting, time stretching. Data augmentation helps in improving the robustness and generalization ability of the sound classification algorithm.

- Labeling: Assign appropriate labels to the preprocessed audio data, indicating whether each segment contains macaque sounds or ambient noise. Accurate labeling is essential for training and validating the classification algorithm.

- Storage: Store the preprocessed audio data, along with their corresponding labels and any additional metadata, in a suitable data format. This may involve organizing the data into a structured database or storing it in a cloud-based storage system for easy access and retrieval.

By performing these preprocessing steps, the macaque sound data is transformed into a format that is suitable for training and testing the sound classification algorithm.

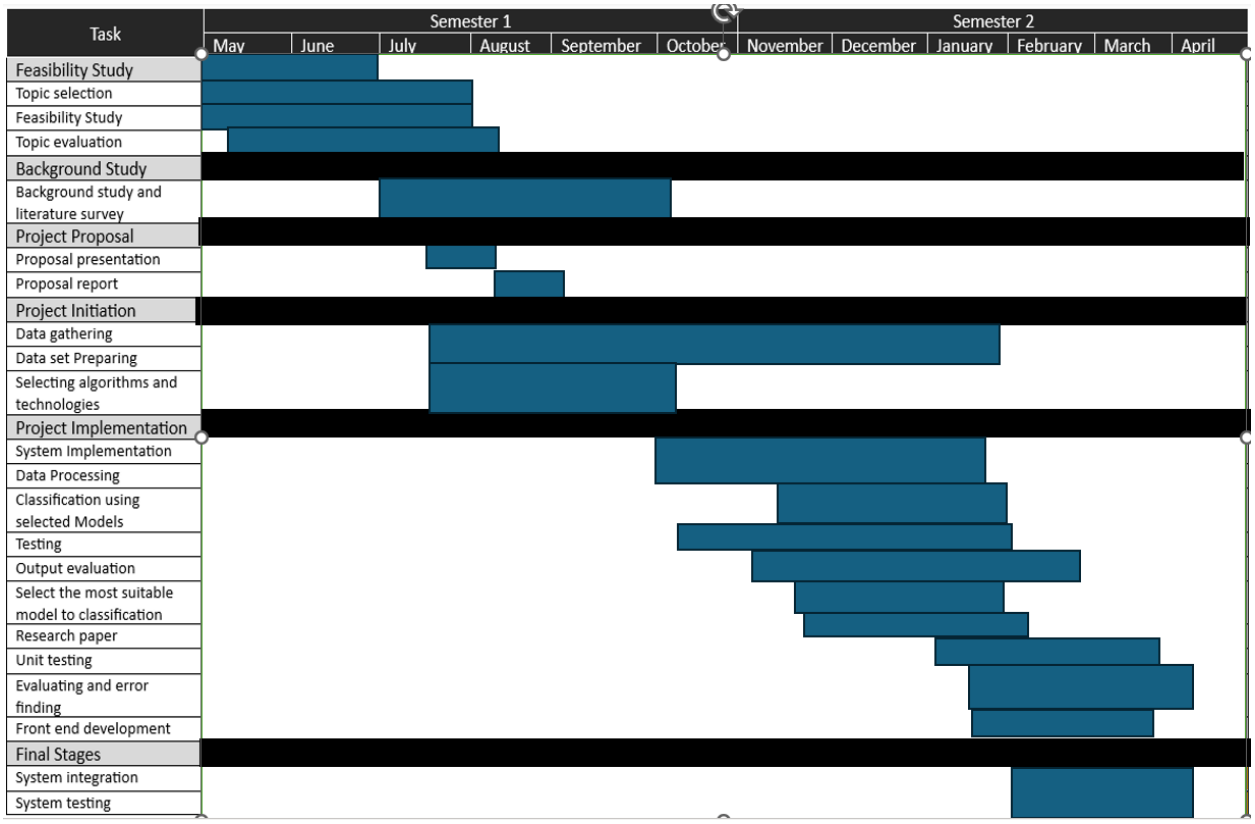
3.5 MACHINE LEARNING MODULE

The machine learning module you utilized is a Recurrent Neural Network (RNN) with Long Short-Term Memory (LSTM) architecture. This type of neural network is particularly well-suited for sequential data analysis, making it a suitable choice for audio analysis tasks. In your case, you employed this RNN-LSTM model to analyze the audio data collected from macaque sounds and ambient noise recordings.

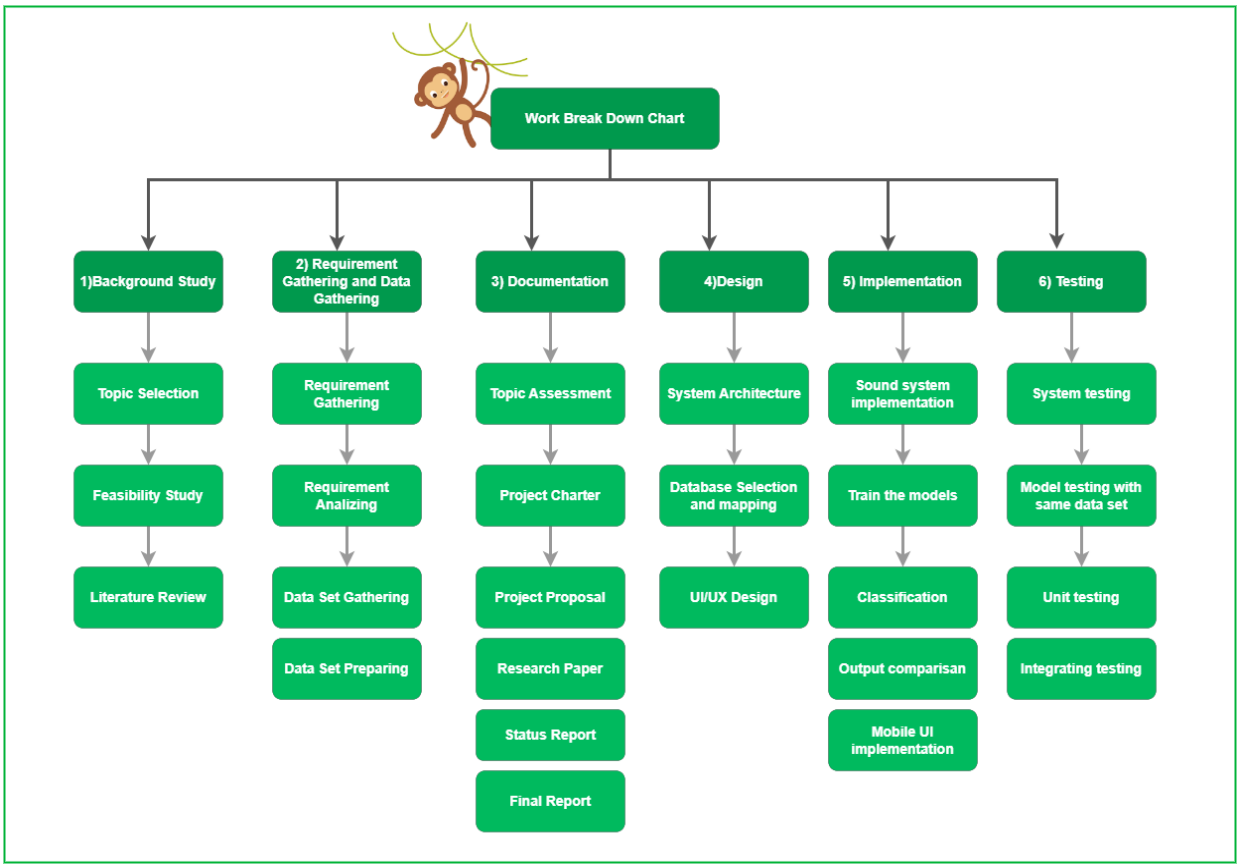
The LSTM units within the RNN architecture enable the model to capture long-term dependencies and temporal patterns present in the audio data. This is crucial for detecting and distinguishing macaque sounds from background noise accurately. Additionally, the use of the 'sigmoid' activation function and 'binary_crossentropy' loss function, along with the 'adam' optimizer, ensures that the model is trained to classify audio segments into macaque or non-macaque categories effectively.

By training the RNN-LSTM model on the provided dataset, aimed to leverage its ability to learn complex temporal relationships inherent in audio signals. This allows the model to effectively differentiate between macaque vocalizations and other environmental sounds. Ultimately, the trained model can be deployed on a Raspberry Pi board for real-time audio analysis, enabling the detection of macaque presence in agricultural settings.

3.6 GRANTT CHART



3.7 WORK BREAKDOWN CHART



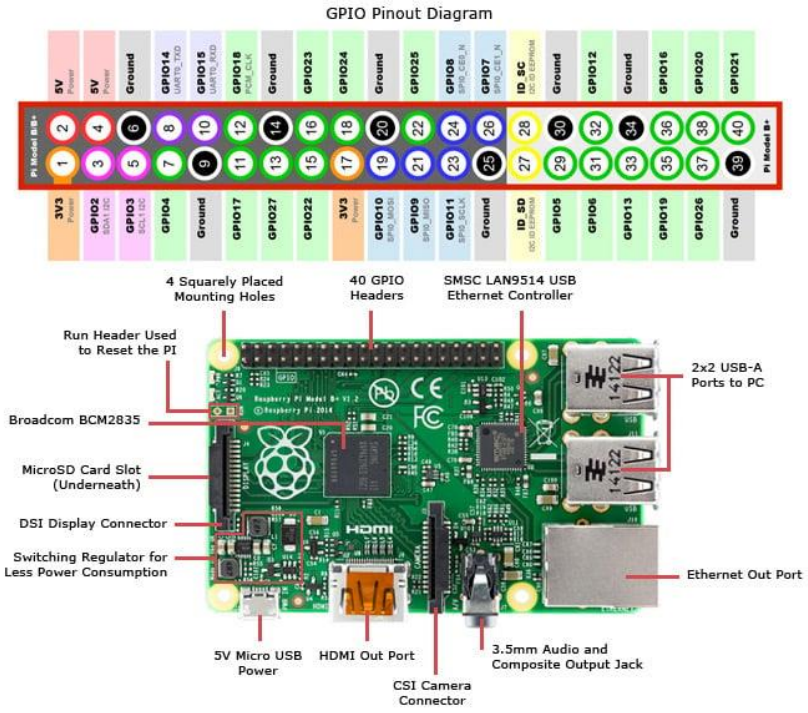
4. HARDWARE SOLUTION

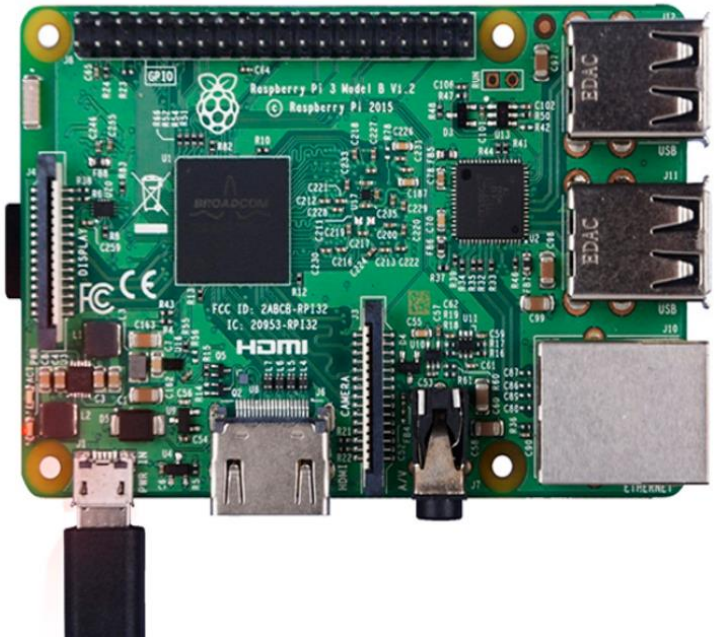
4.1 HARDWARE USED

- **Microphone (Mic):**

The microphone serves as the primary input device, capturing audio signals from the surrounding environment. It typically utilizes analog communication, converting sound waves into electrical signals that can be processed by the Raspberry Pi. The microphone's sensitivity and frequency response are crucial for accurately detecting macaque vocalizations amidst background noise.

- **Raspberry Pi 3 Model B Board:**





The Raspberry Pi is a single-board computer renowned for its versatility and affordability. It acts as the brain of the macaque detection system, running algorithms for sound analysis and coordinating the operation of other hardware components. Communication with peripherals such as sensors and actuators is facilitated through GPIO pins, enabling real-time interaction with the physical world.

- **LED Screen:**

The LED screen provides visual feedback and user interaction, displaying relevant information such as system status, detected macaque activity, and environmental data. It typically utilizes digital communication protocols like HDMI or SPI (Serial Peripheral Interface) to interface with the Raspberry Pi, allowing for seamless integration and control.

- **Buck Converter:**

The buck converter is a voltage regulator that steps down the voltage from the power source to the level required by the Raspberry Pi and other components. It ensures stable and efficient power

supply, converting excess voltage into usable power while minimizing heat dissipation. Communication with the power source is typically achieved through wired connections or soldered terminals.

- **Cooling Fan:**

The cooling fan helps dissipate heat generated by the Raspberry Pi and other components during operation. It utilizes digital communication methods such as PWM (Pulse Width Modulation) to adjust fan speed based on temperature readings, ensuring optimal cooling performance while minimizing power consumption and noise levels.

- **NEO GPS Sensor:**

The NEO GPS sensor provides accurate positioning data, allowing the system to track the geographical coordinates of the device. It communicates with the Raspberry Pi via UART serial communication protocol, transmitting location updates at regular intervals. The GPS data can be utilized for mapping macaque activity hotspots and optimizing system deployment in agricultural areas.

- **DHT22 Temperature and Humidity Sensor:**

The DHT22 sensor measures ambient temperature and humidity levels, providing crucial environmental data for analysis and monitoring. It communicates with the Raspberry Pi using digital communication protocols such as I2C or GPIO, transmitting sensor readings for real-time processing. The temperature and humidity data enable the system to assess environmental conditions and their impact on macaque behavior and crop damage.

4.2 FUNCTIONAL REQUIREMENTS

- The system must accurately detect macaque vocalizations amidst background noise.
- It should analyze audio signals in real-time to determine the presence of macaque monkeys.
- The system should be able to distinguish between macaque vocalizations and other environmental sounds.
- The system should process data from sound sensors, GPS sensors, and environmental sensors to identify patterns in macaque behavior.

- The system must provide real-time monitoring of macaque activity, environmental conditions, and system status.

- All hardware components should be seamlessly integrated with the Raspberry Pi and communicate effectively using digital communication protocols.

- The system should be compatible with various environmental conditions and able to operate reliably in outdoor settings.

- The system must efficiently manage power consumption to ensure long-term operation without interruption.

- It should utilize power-saving mechanisms and regulate voltage levels to optimize energy efficiency.

- The system should provide a user-friendly interface for farmers to monitor macaque activity and access system data.

- The system should be scalable to accommodate different farm sizes and configurations.

4.3 NON-FUNCTIONAL REQUIREMENTS.

- It should be able to process audio and sensor data efficiently, even during peak periods of activity.

- The system should have high reliability, with minimal downtime or system failures.

- It should be resilient to environmental factors such as temperature variations, humidity, and physical damage.

- The system should be scalable to accommodate changes in farm size or layout.

- It should be able to handle an increasing number of sensors and devices without significant performance degradation.

- The system should be easy to maintain and update, with modular components that can be replaced or upgraded as needed.

- It should have built-in diagnostics and logging capabilities to facilitate troubleshooting and maintenance tasks.

- The system should be compatible with a variety of hardware components and software platforms.

- The system should minimize its environmental footprint, with efficient power management and energy consumption.

- The system should comply with relevant regulations and standards for agricultural equipment and wildlife management.

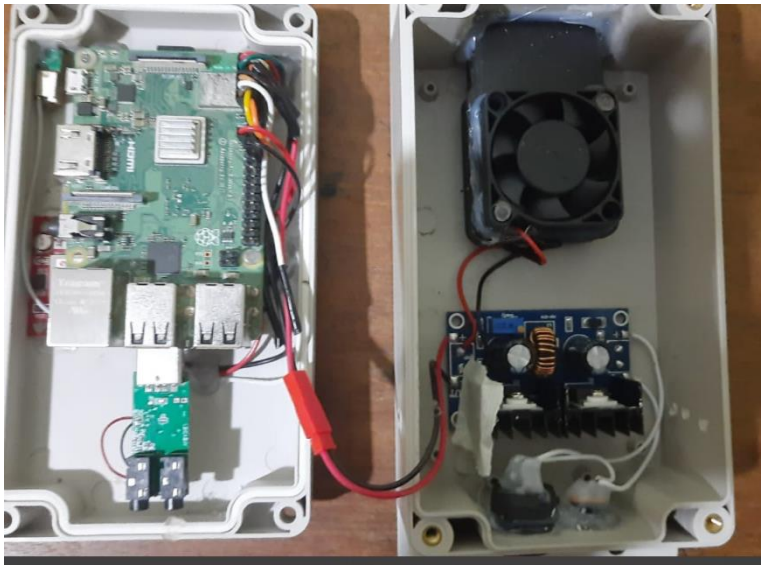
- It should adhere to ethical guidelines for animal welfare and environmental protection.

4.4 SYSTEM REQUIREMENTS

- Mobile device
- Internet Connection
- Database Connection

4.5 IMPLEMENTATION

The implemented device



When sound surpasses 50 threshold, sound detect screen displays and 4 second sound clip will be recorded.

Sound is analyzing. This time get to predict the sound belongs to macaque monkey or not.

Display when sound predicted as a macaque sound

5. RESULTS AND DISCUSSION

After a comprehensive assessment, the Recurrent Neural Networks (RNN) was used as the optimal model for detection of the macaque sounds by filtering the ambient noises. While the 1D Convolutional Neural Network (CNN1D) displayed good accuracy in manual testing, CNN1D implementation in the device did not display good results. Consequently, RNN was chosen. In the high noisy background and calm environments different macaque sounds played and resulted values were differed in wide range. In the noisy background, sound detection threshold limit increased and recording time of the audio was decreased as 3 seconds and checked the results. Results were better than the previous one.

6. COMMERCIALIZATION ASPECTS OF THE PRODUCT

6.1 COMMERCIAL POTENTIAL

- Market Demand:

There is a growing demand among farmers for effective solutions to mitigate crop damage caused by macaque monkeys. The inability of traditional methods, such as shooting, to address this issue adequately creates a demand for alternative, humane, and efficient solutions.

- Crop Protection:

Agricultural crops represent a significant investment for farmers, and protecting them from wildlife damage is crucial for ensuring profitability. A macaque detection system offers farmers a proactive approach to safeguarding their crops, reducing losses and increasing yields.

- Sustainability:

With increasing emphasis on sustainable agriculture practices, there is a demand for solutions that minimize environmental impact while effectively managing pest threats. A macaque detection system aligns with sustainability goals by offering a non-invasive method of wildlife management.

- Cost Savings:

The use of a macaque detection system can lead to cost savings for farmers by reducing the need for manual surveillance, hiring of guards, and crop losses due to macaque damage. Over time, these savings can outweigh the initial investment in the system.

- Technology Adoption:

As technology becomes more accessible and affordable, farmers are increasingly willing to adopt innovative solutions to address agricultural challenges. A macaque detection system leverages advancements in sensor technology, data analytics, and automation to provide an effective pest management solution.

- Potential for Expansion:

Beyond macaque detection, the underlying technology and infrastructure of the system can be adapted for detecting other wildlife threats or monitoring environmental conditions. This versatility expands the potential market for the system beyond macaque-infested areas.

6.2 BUSINESS POTENTIAL

- Product Development:

  Developing and commercializing a robust macaque detection system involves designing hardware components such as sensors, microcontrollers, and communication devices, as well as software for data analysis and system control. This presents an opportunity for companies to innovate and differentiate their products in the market.

- **Market Demand:**

There is a growing demand from farmers and agricultural stakeholders for effective solutions to mitigate crop damage caused by macaque monkeys. By addressing this demand, a business offering a macaque detection system can tap into a potentially lucrative market.

- **Revenue Streams:**

Businesses can generate revenue through various channels, including the sale of hardware components, software licenses, installation and maintenance services, and subscription-based monitoring solutions. Additionally, there may be opportunities for partnerships with agricultural organizations, government agencies, and conservation groups.

- **Scalability:**

As the adoption of macaque detection systems increases, businesses have the opportunity to scale their operations and expand into new markets. This scalability allows for continued growth and diversification of revenue streams over time.

- **Competitive Advantage:**

Companies that pioneer innovative technologies and solutions in the field of macaque detection can gain a competitive advantage in the market. By offering superior performance, reliability, and ease of use, businesses can differentiate themselves from competitors and capture market share.

- **Environmental Impact:**

Businesses that prioritize sustainability and environmental responsibility in their operations can appeal to environmentally conscious consumers and stakeholders. A macaque detection system that minimizes the need for lethal methods of pest control aligns with these values and can enhance the company's brand reputation.

- **Research and Development:**

Continued investment in research and development can drive innovation and product improvement, keeping the business at the forefront of the market. This ongoing commitment to innovation ensures the company remains competitive and relevant in a rapidly evolving industry.

7. REFERENCE LIST

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