ENHANCING SUSTAINABLE COCONUT CROP PROTECTION THROUGH MACHINE LEARNING-DRIVEN INTEGRATED STRATEGIES

Project ID: 2023-24-074

Final Report

Analyzing data to elaborate on macaque monkey prevalence and behavior patterns.

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DECLARATION OF CANDIDATE AND SUPERVISOR

I declare that this is our work, and this proposal does not incorporate without acknowledgmentany 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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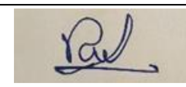
Senanayake P.M.	IT20606756	

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

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Signature of Supervisor: Date

(Mr. Vishan Jayasinghearachchi)

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Signature of Co-supervisor: Date

(Mr. Samadhi Rathnayake)

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ABSTRACT

Agricultural communities around the world are confronted with a range of challenges that threaten the stability of their livelihoods and the economic well-being of their communities. In numerous rural areas, the persistence of pests presents a formidable obstacle to successful crop cultivation and economic prosperity. One such village grappling with this issue serves as the focal point of the research presented here. Inhabitants of this village contend with an ongoing and pressing threat posed by pests that inflict severe damage upon their crops, thus jeopardizing both individual incomes and community-wide economic sustainability. Among these pests, macaque monkeys have emerged as a particularly significant problem, manifesting a propensity for ravaging fruits, vegetables, grains, and flowers. The consequences of their foraging activities extend beyond direct crop losses, encompassing additional damage from trampling and the inadvertent destruction of plants. Consequently, farmers who heavily depend on these crops for their primary source of income endure substantial financial losses, creating a cascade of economic reverberations that affect the entire community.

In response to this critical concern, the overarching objective of the research project detailed in the provided abstract is to address the agricultural pest-related challenges faced by the village. Specifically, the focus of this study is directed towards investigating the behavior patterns of macaque monkeys, which have proven to be a notable source of crop damage. The ultimate aspiration of this research endeavor transcends its immediate scope. Beyond providing a practical framework for addressing the issues presented by macaque monkeys, the study seeks to stimulate broader contemplation within the farming community about the safeguarding of cultivated lands. By furnishing farmers with the insights, they need to adapt and respond effectively to pest-related threats, the research endeavors to contribute to the long-term viability and sustainability of agricultural practices in the village.

Keywords – Crop protection, Macaque monkey, Deep learning, Prevalence, Behavior patterns, Future prediction

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LIST OF THE ABBREVIATIONS

Abbreviation	Description
ML	Machine Learning
UI	User Interface
DB	Database
ARIMA	Autoregressive Integrated Moving Average
IDE	Integrated Development Environment
MSE	Mean Squared Error

Table 1 – List of abbreviations

1. INTRODUCTION

1.1. Background Study

In the village that led to this research, residents grapple with the persistent threat of pests that ravage their crops. Macaque monkeys have emerged as a significant problem, inflicting direct losses on fruits, vegetables, grains, and flowers. Their foraging activities, such as trampling and knocking down plants, exacerbate the situation, leading to substantial financial losses for farmers who rely on these crops as their primary source of income. The impact of these agricultural pests is profound, as farmers struggle to protect their crops and maximize production. Financial losses incurred due to crop damage affect the livelihoods of individuals and the overall economic well-being of the community. Consequently, addressing these issues and finding effective solutions becomes imperative to ensure the sustainability of agricultural practices in the village. The overall research project aims to identify and implement appropriate pest control measures that can mitigate the damages caused by macaque monkeys and other agricultural pests. Here is the responsibility assigned to me is to study the behavior patterns of macaque monkeys which are a significant problem for crop damage. The objectives are to give a broad idea to the farmer by identifying the patterns of their arrival or their prevalence and to inform them in advance of their expected arrival in the coming periods. There, it is explained which times of the year there is more risk from them, and whichdirections have caused more damage to the cultivated land, clearly indicating the risk to the cultivated land from them in the coming quarters and explaining whether there is any increase in theirgrip. By this, the farmer is expected to be prepared for the risk he faces. The major goal of this researchis that this study will help the farmer to think further about the safety of the crops in the cultivatedland.

A study examining abnormal behavior in old-world monkeys discovered that macaques had higher levels of abnormal behavior than baboons, emphasizing species-specific distinctions in abnormal behavior [01]. This study stressed the need to understand species-specific patterns of anomalous behavior when assessing animal welfare.

The intra-specific variance in social behavior of Barbary macaques was investigated, exhibiting considerable behavioral diversity within and between non-human primate species [02]. Factors underlying intra-specific behavioral variability were explored, allowing for a better understanding of social behaviors in macaques.

According to research on aging-related behavioral patterns in Tibetan macaques, age does not affect social behavior in male Tibetan macaques, however, old female macaques exhibit specific affiliative and agonistic behavioral patterns [03]. This study focuses on affiliation and aggressive behaviors in elderly macaques, emphasizing matriarchal culture and age-related behavioral changes in Tibetan macaques.

Furthermore, behavioral markers are critical for assessing macaque welfare, as behavior is a major criterion for determining individual animal welfare [04]. To ensure the well-being of macaques, specialists working with them must do quantitative assessments of their positive and negative behaviors.

This research highlights the need to study data on macaque monkey prevalence and behavior patterns to improve our understanding of species-specific behaviors, welfare inspections, and interactions within macaque populations.

1.2. Literature Review

The phenomenon of agricultural pest infestation has long been a matter of concern for farming communities worldwide. In numerous locales, including the village under consideration for this research, the persistent threat of pests has consistently posed a formidable challenge to crop production and, by extension, the economic well-being of the community.

One recurring antagonist in this struggle is the macaque monkey, which has increasingly emerged as a significant agricultural pest. These primates have shown a remarkable ability to inflict direct damage upon a wide variety of crops, including fruits, vegetables, grains, and flowers. Such foraging activities, involving trampling and destruction of plants, exacerbate the impact of their presence, leading to substantial economic losses for farmers who heavily depend on these crops for their livelihoods.

This issue is not confined to the individual level; rather, the ripple effects extend to the larger community. The severe financial losses accrued from crop damages disrupt the socio-economic balance of the community, affecting both individual farmers and the overall economic stability of the village. These losses underscore the urgent need for effective pest management strategies that can mitigate the destruction inflicted by macaque monkeys and other agricultural pests.

In recent literature, studies have begun to shed light on the complex interplay between agricultural practices and pest populations. Researchers have delved into the behavioral patterns of macaque monkeys, exploring their foraging habits, movement dynamics, and temporal presence. These studies have revealed insights into the macaque monkeys' preferred crops, periods of heightened activity, and patterns of movement across agricultural landscapes. However, despite these efforts, there remains a crucial gap in translating these insights into actionable information that can empower farmers to better protect their crops. The research project outlined in the introduction seeks to bridge this gap by providing farmers with proactive and actionable insights. By understanding the behavioral patterns of macaque monkeys and their impact on crops, this study aims to offer farmers the knowledge needed to anticipate and prepare for potential risks. The identification of specific periods during which the risk of macaque monkey presence is elevated, as well as historical data on directions that have historically seen the most damage, willenable farmers to make informed decisions about crop protection measures.

For example, among the limited studies conducted on macaque monkey's behavioral patterns, a study conducted by Mr. Agustin Fuentes states as follows. Assessing and controlling the risk of disease transmission can be significantly aided by having a thorough grasp of the contexts and patterns of interactions between humans and macaques. In terms of interactions between people and macaques, the Padangtegal Monkey Forest in Bali, Indonesia, and the Upper Rock Nature Reserve in Gibraltar have both been subjected to a fair amount of research. The interaction patterns between people and macaques in various locations are outlined in this article, together with information on the environmental, cultural, and demographic differences between locals and visitors. Bite rates, the significance of food in aggressive interactions, and the circumstances surrounding the interactions were different across these two sites. Similarities included overrepresentation by adult male macaques in interactions and a substantial impact by local cultural and demographic factors. These similarities and differences are interpreted as resulting from differences in macaque species and behaviors, and human demography, culture, and behavioral patterns.

Considering the limited studies that have been done on macaque monkey's behavioral patterns, they have only done this related study. Because of that, the value of the study that we have focused on here is well reflected.

Our research's central objective is to empower farmers with the tools they need to bolster their resilience against the challenges posed by agricultural pests. By providing practical guidance based on scientific findings, this study aims to enable farmers to take a more proactive stance in safeguarding their crops and livelihoods. This literature review underscores the importance of such research endeavors in addressing the pressing issue of agricultural pest management and highlights the potential positive impact on farming communities.
The literature study for assessing data to expound on macaque monkey prevalence and behavior patterns includes several major studies.

- <u>Behavioral patterns and neural pathways in macaques:</u>

  A study on how social network size affects brain circuits in macaques revealed a complex link between social interactions and neural circuits [05]. This study emphasizes the significance of comprehending the neurological foundation of social behavior in macaques.

- Social housing and behavioral changes in rhesus macaques:

  A research review on macaques, specifically rhesus macaques, highlights the significance of social housing and social changes in laboratory settings. Harem or multi-male/multi-female groups are recommended to recreate the natural social environment [06].

- Neural signs of natural behavior in sociable macaques:

  A study on free socially interacting macaques discovered that monkeys perform species-typical behaviors, with grooming being the most common. Transitions between behaviors are highly structured, forming two major emotional contexts [07].

- Abnormal Behavior in Rhesus Monkeys:

  Research on self-injurious behavior in rhesus monkeys has shed light on its origin, physiology, and treatment. Proper housing and social settings are crucial for preventing aberrant behaviors [06].

- Age-related behavioral tendencies in Tibetan macaques:

  A study on affiliative and agonistic behaviors in old Tibetan macaques found that they had fewer grooming partners, fewer monkeys in proximity, and milder forms of aggression, indicating age-related behavioral changes in this species [03].

- Disease Ecology and Transmission Dynamics:

  Macaques are susceptible to a variety of infectious illnesses, which affect both primate and human health. Jones-Engel et al. (2008) and Wolfe et al. (2018) studied disease ecology and transmission dynamics in macaque communities, including the spread of zoonotic infections. This research highlights the need to monitor macaque health and establish disease prevention strategies between macaques and people.

Some information about the issue of applying data analysis to forecast monkey incursion on cultivated fields depending on environmental factors can be found in the search results. The literature, however, is scant and does not specifically address the subject. The interactions between farmers and monkeys, the financial effects of monkey damage to commercial agriculture, and the geographical patterns of conflict between humans and wildlife in forest agricultural environments are the main topics of the studies. One study on the relationship between farmers and monkeys in Guangxi, China, for example, relied on farmers' and conservation workers' accounts of monkey crop raiding [8] – [9]. The financial consequences of monkey damage on Puerto Rico's commercial agriculture were measured in a different study. For example, the amount of crops lost by commercial farmers in southwest Puerto Rico between 2002 and 2006 because of monkey damage. Farmers moved from growing fruits and vegetables to hay and pastureland to prevent damage from monkeys, which reduced the value of losses [10].

Taita Hills, Kenya, is home to a variety of primate species, including Old World [11] monkeys, whose spatial patterns reveal a complex interaction in various environments, highlighting the diverse range of human-monkey interactions in the World. Research on macaques combines behavioral observations with data analysis to understand environmental elements like habitat, social structure, and resource availability [8]. This study examines macaque species' behavior in old-world monkey species and captive-bred cynomolgus [9] macaques. Research on Japanese macaques has revealed their behavior in both provisioned and nonprovisional wild environments [12]-[13]. A survey of literature on the relationship between environmental circumstances and monkey behavior can provide valuable insights into the behavior of these animals in various settings.

The literature provides important insights into the relationship between farmers and monkeys as well as the financial effects of monkey damage on commercial agriculture, even though it does not specifically address the use of data analysis to predict monkey attacks on cultivation fields based on environmental conditions. Additional relevant information might be found in future studies that focus especially on the application of data analysis for this purpose.

This research collectively helps to better understand macaque behavior patterns, deviant behaviors, social dynamics, and the implications of species-specific variances in behavior. The literature emphasizes the necessity of analyzing data to get insights into macaque prevalence and behavior patterns for various research and welfare purposes.

1.3. Research Problem

The research problem at hand centers on the lack of a comprehensive and integrated framework to answer critical questions related to macaque monkey infestations in agriculture: "When will monkeys arrive?", "From which direction will they come?", and "How will their future presence unfold?". Despite existing research on macaque monkey behavior and distribution, there is a notable gap in the development of predictive models that address these questions collectively.Current research fails to offer farmers accurate predictions about the timing of macaque monkey arrivals, the geographical routes they might take, and the potential trajectory of their presence.

Furthermore, the existing visualization methods have not effectively translated complex monkey movement and behavior patterns into actionable insights for farmers. The challenge lies in devising visualization techniques that can not only depict macaque monkey distribution and movement but also project potential future scenarios. Bridging this gap requires the synthesis of predictive modeling and advanced data visualization to provide farmers with holistic answers to the question "When Monkeys come, in which direction, how will the future be?"

The research problem at hand is the lack of an integrated approach to predict and mitigatefuture risks posed by macaque monkey infestations in agricultural settings. While insights intomacaque behavior and distribution have been gathered, there is a dearth of comprehensive predictive models that combine these behavioral patterns with ecological and environmental variables to forecast the likelihood and severity of future infestations. Additionally, the challenge liesin developing effective data visualization techniques that can accurately represent the complexmovement dynamics and behavior of macaque monkeys in a format that is easily interpretable and actionable for farmers. Addressing this research problem requires the development of predictivemodels that incorporate behavioral patterns and environmental factors, alongside the creation of advanced visualization methods that enhance farmers' understanding and preparedness in managing agricultural pest risks.

1.4. Research Gap

There is a research gap in integrating analysis of macaque monkey presence and behavior patterns to accurately predict future risks to farmers. While some studies have focused on understanding macaque monkey behavior and its correlation with crop damage, there is a lack of comprehensive predictive models that can translate these insights into actionable predictions for farmers. Furthermore, data visualization techniques have not been used to demonstrate macaque monkey distribution and behavior, requiring more sophisticated visual representations that can effectively convey complex movement patterns and potential crop risk areas. This gap highlights the opportunity to develop integrated approaches that not only analyze macaque monkey behavior but also provide farmers with practical tools to proactively address agricultural pest threats.

	Research 1	Research 2	Research 3	Research 4	Research 5	Proposed System
Predict the behavior	✗	✓	✗	✗	✗	✓
Summarize the previous data and show the distribution	✗	✗	✗	✗	✗	✓
User interface to visualize the behavior patterns	✗	✗	✗	✗	✗	✓
Usage of real data	✓	✓	✓	✓	✓	✓
Real time visualizing	✗	✗	✗	✗	✗	✓

Figure 1. - Research Gap

2. OBJECTIVES

2.1. Main Objectives

- Provide farmers with a comprehensive understanding of macaque monkey distribution through careful analysis of recent data. This analysis will clarify the spatial patterns of monkey movement and their distribution. By providing a detailed overview of macaque monkey distribution, this objective empowers farmers to proactively prepare for potential threats.

- To determine if there is an observable increase in macaque monkey arrivals over time. By scrutinizing historical data and employing statistical methods, this aspect aims to discern any escalation patterns in macaque monkey infestations. This knowledge is vital for predicting potential surges in macaque monkey activity and adjusting pest management strategies accordingly.

- Studying the available data to predict the future threat of macaque monkey arrivals.By leveraging predictive modeling techniques and integrating variables such as historical data, environmental conditions, and potential behavioral shifts, this objective aims to provide farmers with actionable forecasts of when and where macaque monkey infestationsare likely to occur. This predictive insight equips farmers with the knowledge needed to implement preemptive measures, minimizing the impact of crop damage and financial losses.

2.2. Specific Objectives

- Collect and pre-process data obtained from sound sensors and cameras deployed in the agricultural fields to accurately capture macaque monkey activity. Summarize the data to extract relevant information about monkey presence, such as timestamps and sound sensor identifiers.
- Analyze the collected data to discern recurring patterns in the arrival of macaque monkeys. Identify patterns and temporal correlations in their behavior, enabling the identification of preferred arrival times, days, and locations.

- Design and implement a machine learning module that utilizes historical data to predict future macaque monkey arrivals and behavior. Train the model to recognize patterns in their past activities and apply it to forecast potential infestations during upcoming periods.

- Integrate the developed machine learning module with a user-friendly interface that offers predictions to farmers about upcoming macaque monkey arrivals and their behavior patterns. Provide clear and actionable insights to empower farmers to take preventive measures in advance.

3. METHODOLOGY

3.1. Research Area

In several villages, farmers are facing a significant issue of macaque monkeys damaging their crops. The current method employed to drive away the monkeys involves shooting, which is ineffective when dealingwith a large herd of macaque monkeys. Moreover, this approach poses risks to animal lives. In response, amore humane and effective system is proposed to drive away these animals and mitigate crop damage. Toaddress the issue of macaque monkeys encroaching on our land, we have devised a solution involving a sound system. Sound sensors strategically positioned throughout the area detect the macaque monkeys' arrival by analyzing their distinct sounds. Advanced algorithms quickly process the data, distinguishing monkey vocalizations from other noises. Once the presence of macaque monkeys is confirmed, speakers emit high-frequency and high-decibel sounds designed to deter them from staying on our property. This comprehensive system not only detects and repels macaque monkeys but also identifies patterns in their entry and exit behavior. By analyzing this data, we gain insights into their movement patterns and preferred entry points, allowing us to optimize our preventive measures. This proactive approach effectively protectsour land and offers a long-term solution to the macaque monkey problem.

As a grant, by studying the problem areas, the solution to this problem was started based on an identified area. Solutions are sought through grant components identified as solutions to the problem.

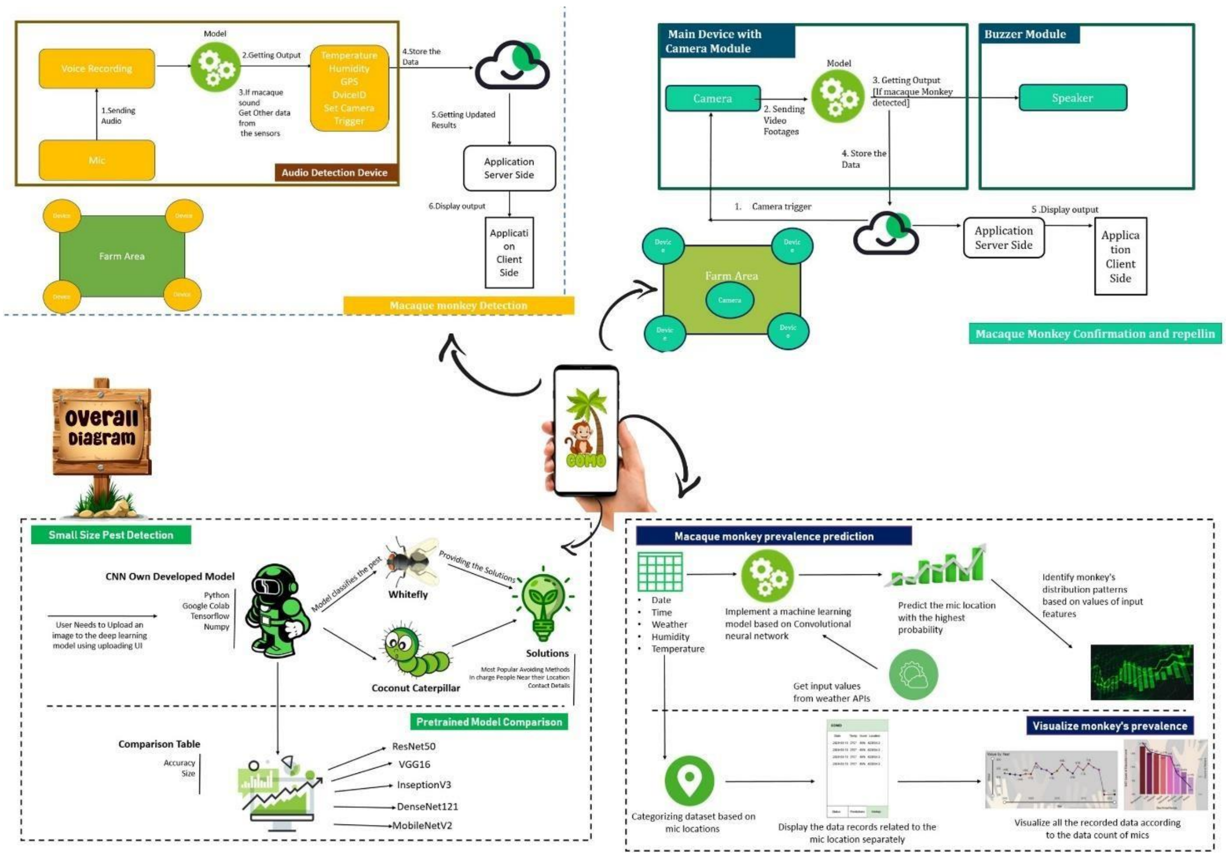

Figure 2. – Overall System Diagram

3.2. Research Architecture

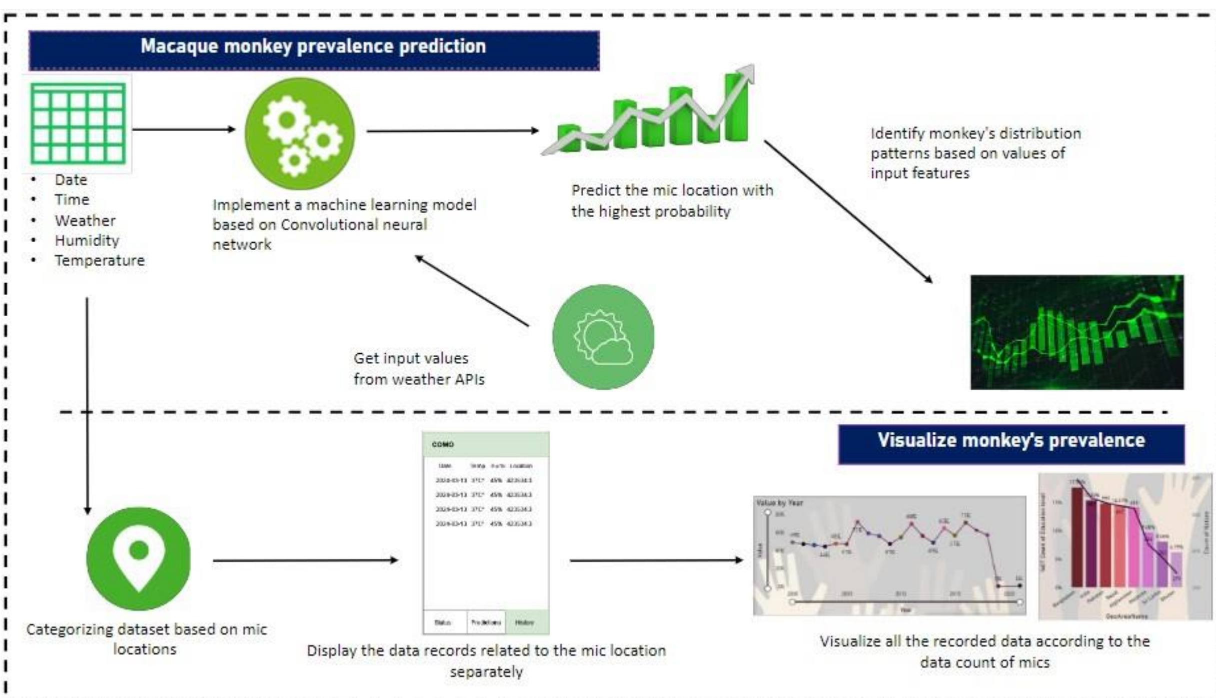

Figure 3. – Overall Component Diagram

The research architecture for the comprehensive macaque monkey pest management system consists of interconnected components, ensuring effective data collection, analysis, and predictive modeling. The architecture is designed to offer farmers actionable insights to safeguard their crops and livelihoods.

Here, the study of the monkey's behavior patterns, the identification of the factors affecting their visits and behavior and thereby making predictions is done as a grant. The purpose of the grant was to identify and implement a machine learning module based on influencing environmental factors to identify patterns and correlations between those factors. Studying those patterns predicts their presence in future times. Also, recognize the monkey's visitation patterns and visualize them. The aim is to provide the farmer with a comprehensive analysis of the arrival patterns and the environmental factors affecting it.

3.3. Data Collection

- Sound Sensors: Deploy a network of sound sensors in agricultural fields to capture audio data indicating macaque monkey presence.
- Cameras: Install cameras to capture visual information that complements the sound sensor data, aiding in accurate identification of macaque monkey behavior.

Using the data obtained by the sound sensor and cameras, the amount of data needed to operate the module was collected based on the details at the time the data was recorded. Further study identified factors such as environmental temperature, atmospheric humidity, and time of day as factors affecting their visits. In addition, the weather conditions at the time the data was collected, and the geographic location of the device used to collect the data are also collected.

Real-world data has been used to collect this data and for that, a suitable crop area with this problem has been used and about 900 amounts of data related to the cultivated land were collected under those data features.

Date	Time (24h)	Humidity(%)	Weather	Temperature (C)	Location
2/8/2023	17	78.25	Sunny	27	6.867831, 79.967030
2/8/2023	17	79.34	Sunny	28.6	6.867818, 79.967296
2/8/2023	9	71.81	Sunny	29.1	6.867831, 79.967030
2/8/2023	11	68.31	Windy	29.8	6.867831, 79.967030
5/8/2023	10	68.72	Cloudy	29.3	6.867451, 79.967261

Figure 4. - Data collection

Field Location

Figure 5. - Device Locations

Coordinates	Mic Station
6.867831, 79.967030	MIC 01
6.867818, 79.967296	MIC 02
6.867818, 79.967501	MIC 03
6.867690, 79.967585	MIC 04
6.867536, 79.967425	MIC 05
6.867451, 79.967261	MIC 06
6.867603, 79.967033	MIC 07

Figure 6. -Mic Stations Coordinates

3.4. Data Pre-processing and Storage

- Data Pre-processing: Encoding the data collected by the devices according to the geographical location, and converting the data recorded periods to a specific time frame.
- Data Storage: Store the processed data in a suitable database for further analysis. An online database was chosen because of the periodic data collection and the need to collect more data and draw more optimal conclusions through the module using real-world data.

3.5. Pattern Analysis and Feature Extraction

- Time Series Analysis: Analyze the integrated data to identify patterns in macaque monkey arrivals, including time of day, day of the week, weather conditions, and the device location.
- Feature Extraction: Extract relevant features from the data, such as timestamps, and spatial coordinates.

3.6. Machine Learning Module

- Training Data Preparation: Utilize historical data to train a machine learning model capable of predicting future macaque monkey arrivals and behavior patterns.
- Model Selection: Choose an appropriate machine learning algorithm, such as time series forecasting or classification, to suit the prediction task.
- Model Training: Train the selected model using the preprocessed data and extracted features.

3.7. Prediction and Visualization Layer

- Prediction Interface: Develop a user-friendly interface for farmers to input parameters and receive predictions.
- Visualization Tools: Create visualizations, such as heatmaps and time series graphs, to help farmers interpret macaque monkey distribution and behavior patterns.

3.8. Gantt Chart

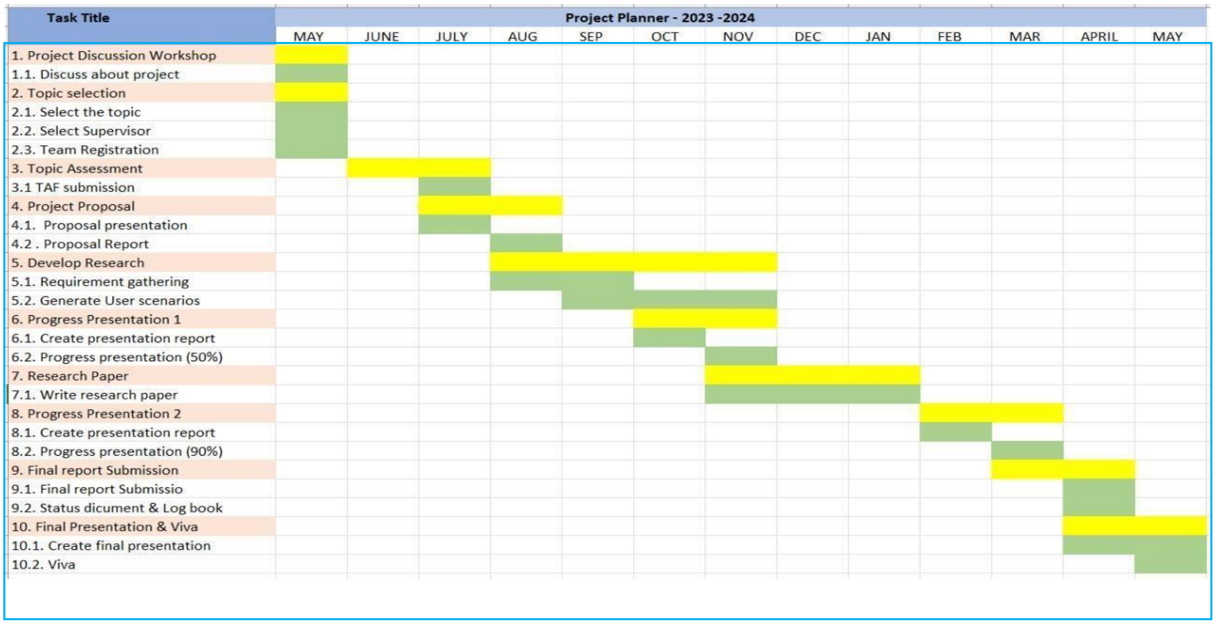

Figure 7. - Gantt Chart

3.9. Work Breakdown Structure

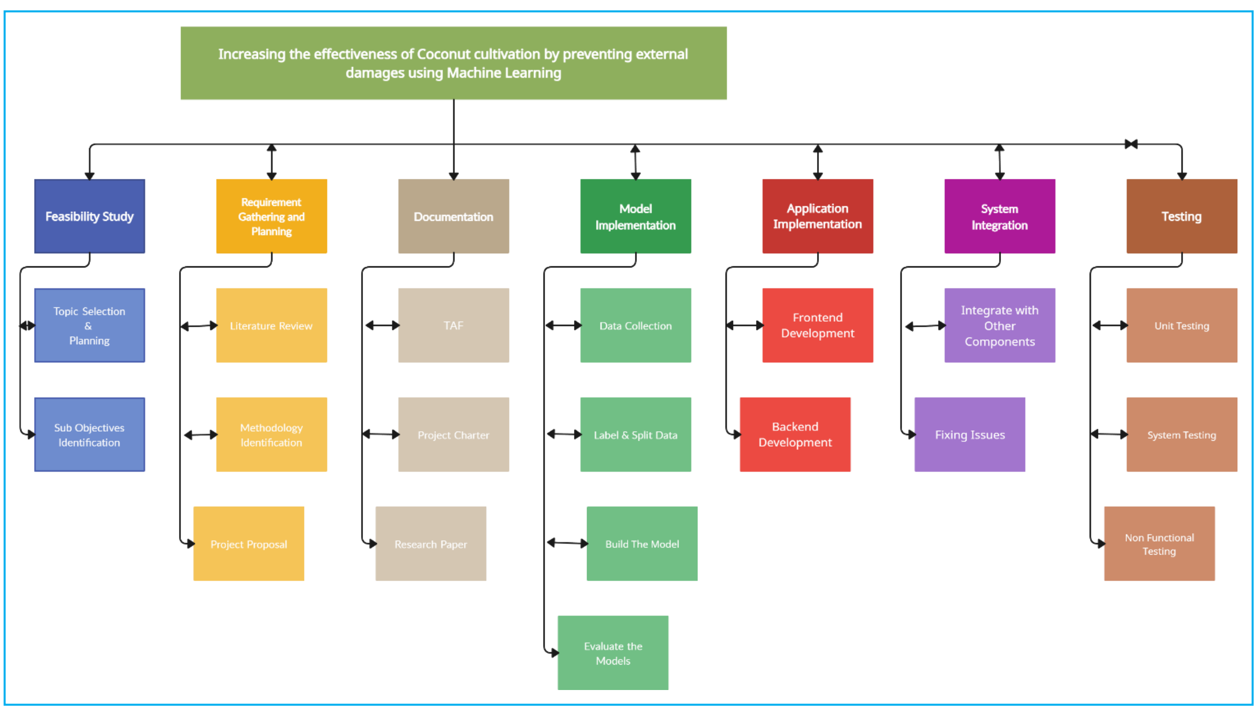

Figure 8. – Breakdown Chart

4. SOFTWARE SOLUTIONS

4.1. Functional Requirements

- Feature Extraction - Time domain extraction.
- Machine Learning Model - Implement a suitable machine learning algorithm or model.
- Behavior Prediction and Forecasting - Deploy the trained model to predict the macaque monkey behaviors based on their arrival patterns.
- Visual User Interface - Develop a user-friendly interface to interact with the system to obtain behavioral predictions and analysis results.
- Model Updates - Implement a mechanism to update and retrain the machine learning model periodically to accommodate changes in macaque monkey behavior patterns.

4.2. Non - Functional Requirements

- Accuracy: The system should achieve high accuracy in recognizing and classifying monkey behaviors based on their sounds to ensure reliable results.
- Real-time Responsiveness: For real-time applications, the system should respond quickly to new audio inputs and provide predictions promptly.
- Scalability: The system should be scalable to handle large volumes of macaque monkey arrivals data and accommodate behaviors in the future.
- Resource Efficiency: Optimize the system to use computational resources efficiently, especially if it's deployed on resource-constrained devices or in a real-time setting.
- Compatibility: The system should be compatible and support integration with different platforms or environments.

- Documentation and Maintainability: Provide comprehensive documentation and ensure that the codebase is maintainable and well-organized for future updates and enhancements.
- Ethical Considerations: Consider ethical aspects related to data collection, usage, and potential impact on wildlife conservation and research.

4.3. System Requirements

- Mobile device
- Internet Connection
- Database Connection

5. IMPLEMENTATION

5.1. Tools and Technologies

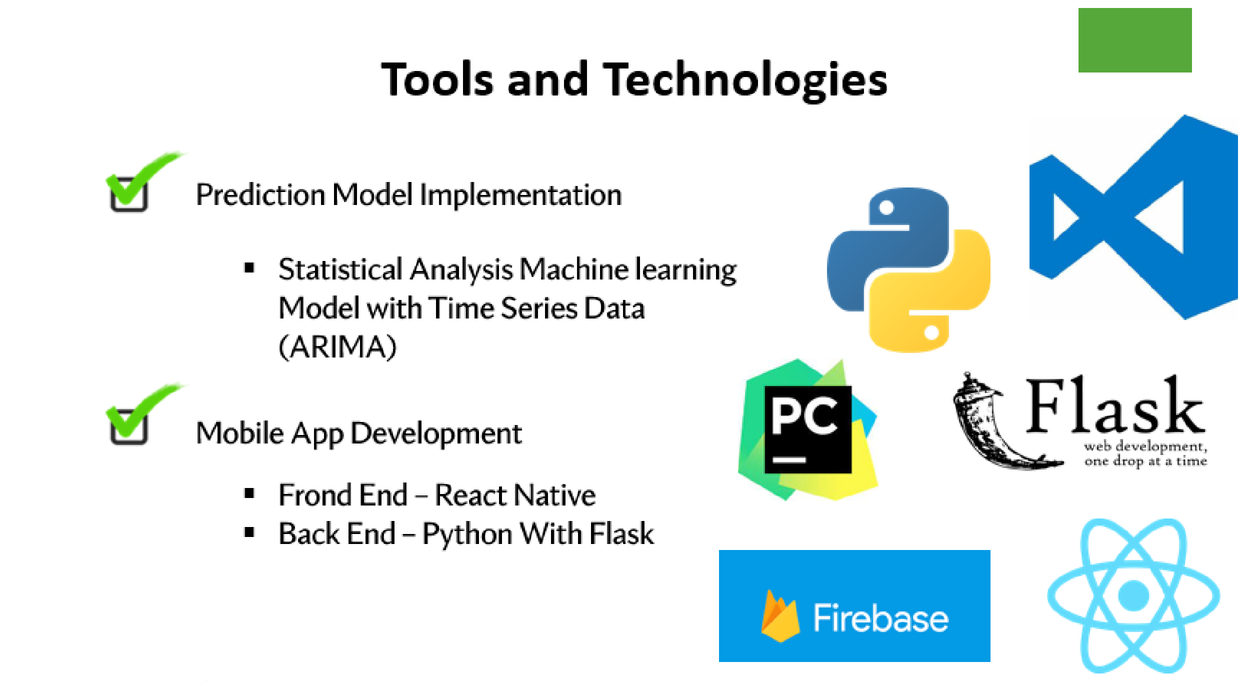

Figure 9. – Tools and Technologies

- PyCharm:

PyCharm is a powerful integrated development environment (IDE) specifically designed for Python programming. It offers a wide range of features such as code completion, debugging tools, and intelligent code analysis, making it an essential tool for Python developers to write, test, and debug their code efficiently.

- Python with Flask Backend:

Python with Flask is a popular combination for building web applications. Flask is a lightweight and flexible micro-framework that allows developers to quickly create web applications with Python. It provides essential tools for routing, request handling, and templating, making it ideal for developing backend services that power web applications.

- React Native Frontend:

React Native is a framework for building cross-platform mobile applications using JavaScript and React. It allows developers to write code once and deploy it on both iOS and Android platforms, saving time and effort. With its component-based architecture and hot reloading feature, React Native enables developers to create high-performance and visually appealing mobile apps.

- Firebase Database:

Firebase is a mobile and web application development platform that provides a variety of services, including a real-time NoSQL database. Firebase Database offers features like real-time synchronization, offline data support, and secure data storage, making it an excellent choice for building responsive and scalable applications. By integrating Firebase Database with Python, Flask, and React Native, developers can create dynamic and interactive applications with real-time data updates and seamless user experiences.

5.2. Model Implementation

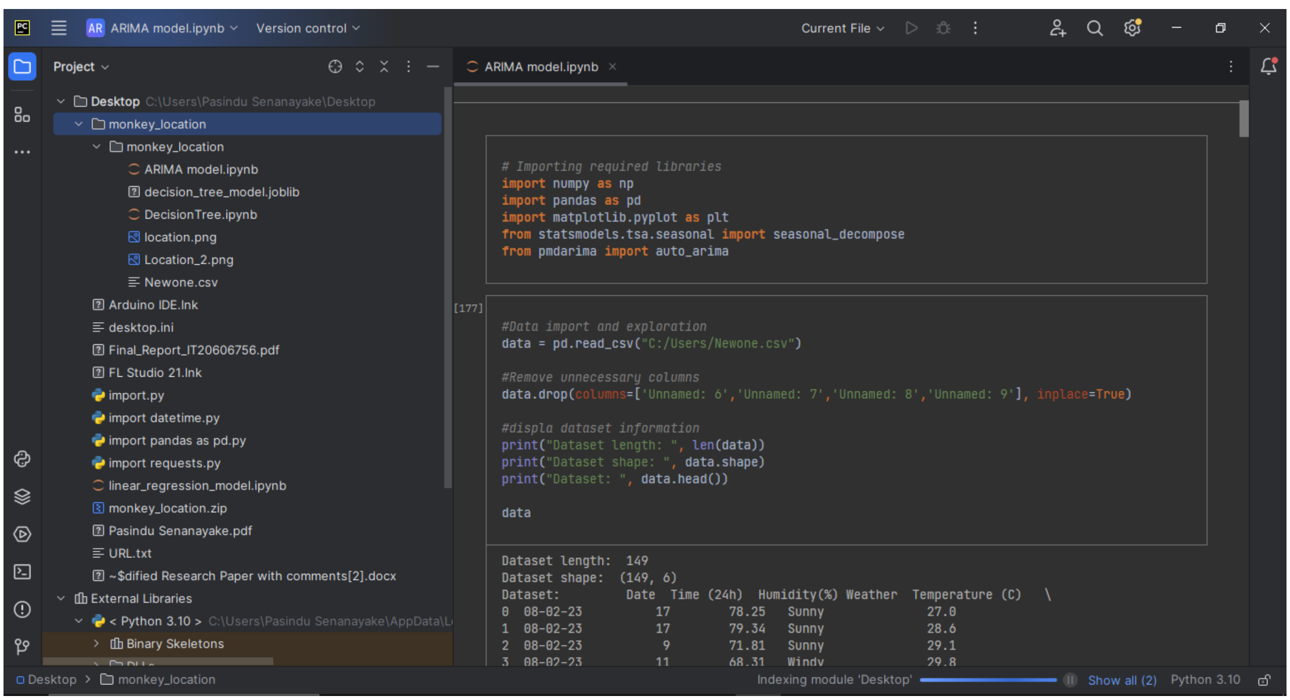

Figure 10. Model Implementations

5.3. Mobile Application Implementation

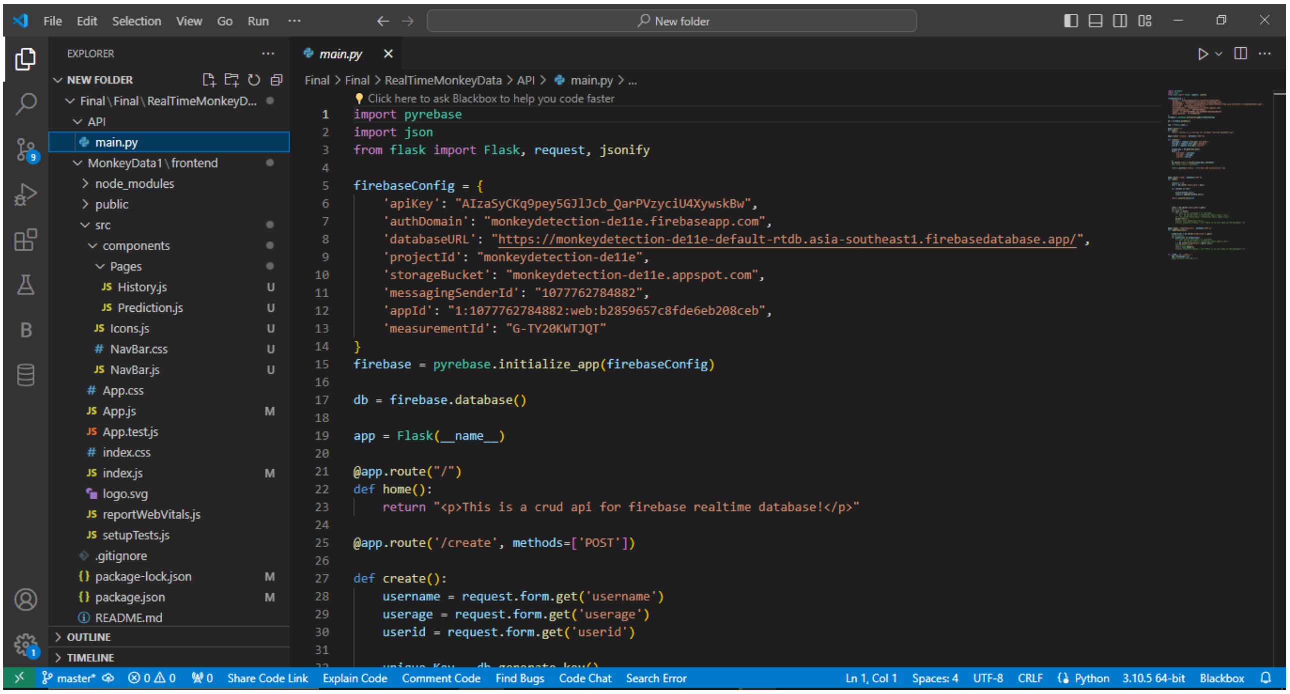

Figure 11. Backend Implementation

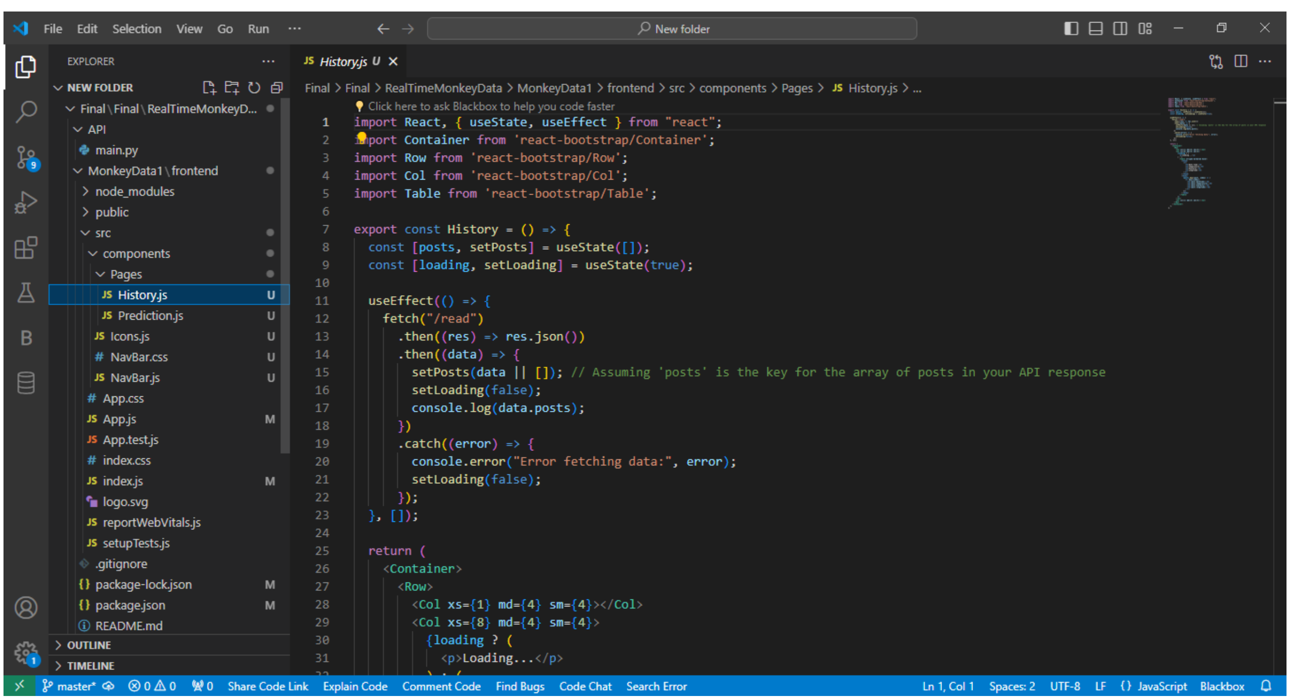

Figure 12. Frontend Implementation for History UI

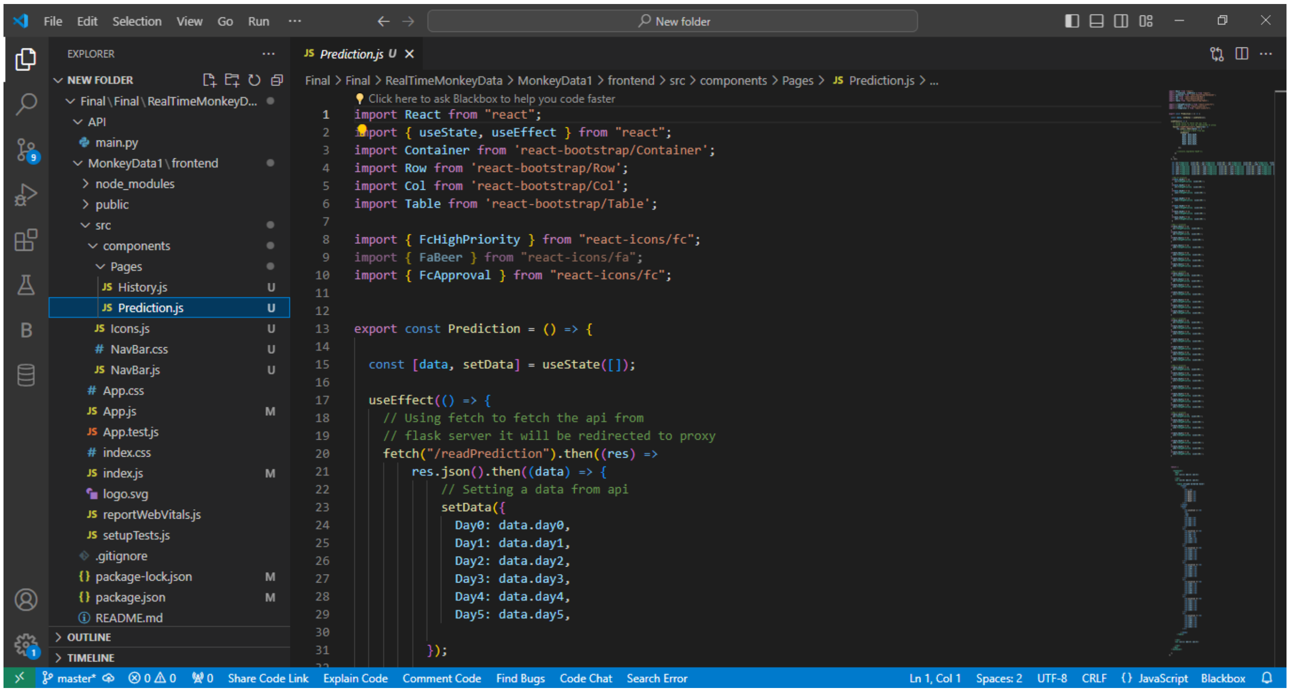

Figure 13. Frontend Implementation for Prediction UI

6. USER INTERFACES

Figure 14. Home UI

Figure 15. Future Arrival UI

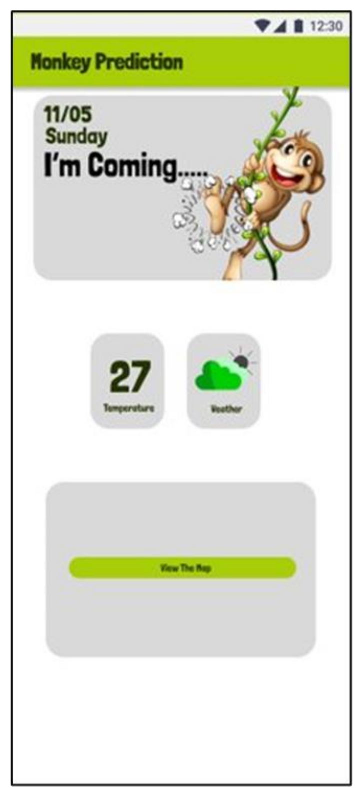

Figure 16. Future Visitations UI

Figure 17. Future Predictions UI

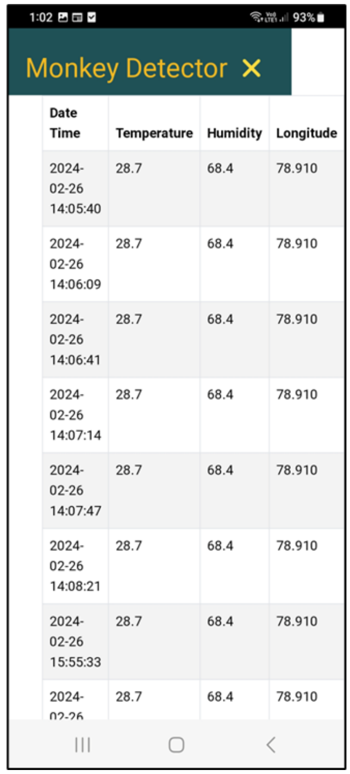

Figure 18. History Attacks UI

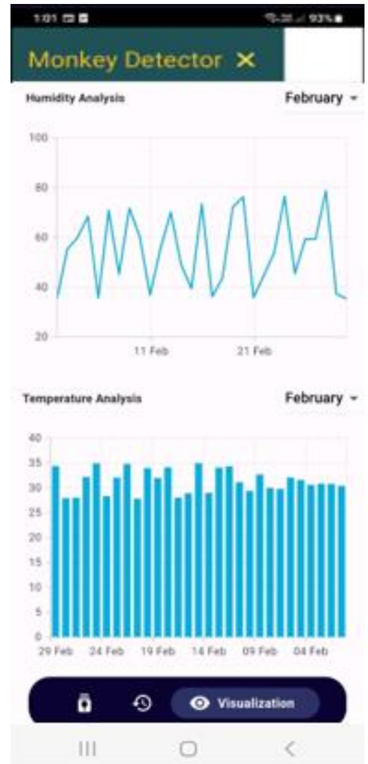

Figure 19. Visitations patterns UI

7. RESULTS AND DISCUSSION

Climate change has emerged as a significant threat to primates, including monkeys, apes, lemurs, lorises, and tarsiers. The study indicates that these species will experience 10% more warming than the global average, with some species facing increases of more than 1.5 degrees Celsius in annual average temperature for every degree of global warming. The most extreme hotspots, covering 3,622,012 square kilometers, are found in Central America, the Amazon, southeastern Brazil, and portions of East and Southeast Asia, where 67 species, including the ursine howler monkey, black howler monkey, and Barbary macaque, are expected to be exposed to the highest magnitude of climate change.

The ARIMA model analysis predicts that a quarter of all primate habitats will experienceprolonged heat extremes under the Paris Agreement's 2-degree Celsius warming scenario This could lead to long periods of extreme heat, causing dehydration and overheating in primates, forcing them to rest and stay in the shade during the hottest times of the day, reducing their foragingand mating activities. Species living in the Brazilian Amazon, along the north coast of Venezuela,the center of equatorial Africa, the African east coast, and the northwest coast of Madagascar willbe most affected.

Human activities, such as habitat destruction, infrastructure development, hunting, and the illegal pet trade, further compound the challenges faced by macaque populations. These activities have already cut back primate populations, and climate change will likely increase the duration and intensity of extreme weather events, such as cyclones and droughts, putting more pressure on the survival of already struggling species.

The study emphasizes the importance of considering conservation issues, such as habitat loss, in future primate conservation efforts. Nature reserves have helped maintain populationsof wild animals, but the borders of wildlife reserves and protected areas are usually fixed and noteasy to move. Future temperature increases could alter the habitat within a protected area so that it is no longer suitable for the primate. Therefore, future primate conservation should include predicted temperature changes in combination with the other issues that primates face.

No.	Model	Mean Squared Error
1	ARIMA	1.23
2	LSTM	1.41

Table 1 – COMPARISON OF TIME SERIES FORECASTING MODELS FOR THE PREDICTION OF MACAQUE MONKEY ARRIVALS

No.	Model	Avg. Accuracy
1	Decision Tree	0.60
2	Random Forest	0.56

Table 2 – OTHER PREDICTIVE MODELS COMPARISON

The research's objective was to compare the performance of many models to determine which one was the most accurate. The models were assessed using mean squared error (MSE) and average accuracy in the research (Table 3). The mean square error (MSE) of 1.239 suggests that the ARIMA model's predictions are, on average, 1.239 units off from the actual values. This implies that the model is doing well and has a comparatively modest average error.

Interesting patterns of incidence and behavior in communities of macaque monkeys were found via data analysis. The study discovered that several factors, such as natural humidity, human activity, climatic change, and the appropriateness of the macaque's habitat, influence the predominance of macaques. The habitats of macaques are shifting due to climate change; they are being pushed over temperature thresholds and may see changes in species distribution. Certain macaque monkey species are spending more time on the ground due to environmental changes, which are affecting their behavior and social structures. The problems that macaque populations confront are made worse by human activities like infrastructure development and habitat degradation.

The study attempted to gain a better understanding of these intricate connections and macaque populations in the face of environmental change and human effects by utilizing the ARIMA model to examine historical data and forecast future events. The seasonal and trend components of the data can be captured by the ARIMA model, which is especially helpful when evaluating time series data that exhibit distinct seasonal trends.

The results of the study emphasize how crucial it is to consider how human activity and environmental change may affect macaque populations. The capacity of the ARIMA model to precisely forecast future trends and patterns in the data offers insightful information for management plans and conservation initiatives. By comprehending the intricate relationships that macaques have with their surroundings, scientists can create more successful conservation strategies that account for both human activity and climate change.

8. COMMERCIALIZATION ASPECTS OF THE PRODUCT

8.1. Commercial Potential

- Market Analysis:

  Conduct thorough market research to understand the demand for agricultural pest management solutions.

  Identify target markets, such as regions with significant macaque monkey populations and reliance on agriculture.

  Analyze existing competitors and their offerings to identify unique selling points.

- Value Proposition:

  Clearly articulate the benefits of the system to potential customers, emphasizing accurate predictions, proactive pest management, and reduced crop losses.
  Highlight the user-friendly interface, real-time alerts, and data visualization capabilities that empower farmers.

- Product Positioning:

  Position the system as a comprehensive and intelligent solution that combines dataanalysis, machine learning, and predictive modeling for effective pest management.
  Differentiate the system from traditional methods by offering proactive insights and actionable recommendations.

8.2. Business Potential

- Market Demand:

  Agriculture remains a vital sector in many regions, making the demand for pest management solutions a constant requirement.
  The system caters to the demand for advanced, technology-driven tools that offer a comprehensive approach to pest management.

- App Licensing:

  Licensing Fees: Offer different tiers of licensing for the system, granting users access to its features based on their chosen plan.
  One-time Purchase: Farmers can opt for a one-time purchase of the app license, gaining access to the system's capabilities with a single payment.
  Feature Differentiation: Create tiered plans with varying features. For instance, a basic plan might provide predictive alerts, while a premium plan includes advanced data visualizations and historical trend analyses.

- Subscription Model:

  Recurring Revenue: Implement a subscription-based model where farmers pay a recurring fee to continue using the system.
  Tiered Subscription: Offer multiple subscription levels, each providing a different level of access and support.
  Benefits: Subscribers could enjoy benefits like automatic updates, priority customer support, and access to new features as they are developed.

- Pay-Per-Use Points:

  Usage-based Pricing: Introduce a pay-per-use model, where farmers are charged based on the frequency and extent of their system usage.
  Flexibility: This model accommodates users with varying needs. Farmers can pay only for the services they actively use.

Data Usage: Charge based on the amount of data processed, encouraging efficient use of the system's resources.

9. CONCLUSION

The behavior and prevalence patterns of macaques must be studied to improve integrated machine learning-driven tactics for the protection of coconut crops. Through the utilization of machine learning algorithms and historical data analysis, scientists can discern behavioral patterns shown by macaque monkeys and forecast their frequency in various regions. This information empowers farmers to anticipate any harm to their crops and implement proactive remedies.

Real-time data on macaque monkey behavior and environmental elements (such as temperature change and human activity) that influence it may be obtained by integrating machine learning algorithms with IoT sensors and other technologies. Using this knowledge, specialized crop protection techniques may be developed, such as modifying habitat, using certain pesticides, or changing planting times.

By determining the locations where macaque populations are most likely to interact with crops and creating mitigation plans for these interactions, research on macaque monkey behavior and prevalent patterns may also help guide conservation efforts. For instance, by modifying macaques' habitat or employing deterrents to change their behavior, researchers can lessen crop damage by developing tactics based on their understanding of macaque social behavior.

In conclusion, improving sustainable coconut crop security using machine learning-driven integrated solutions requires research on macaque monkey behavior and prevalent patterns. Researchers can give farmers the vital information they need to make decisions regarding crop protection and conservation initiatives by utilizing machine learning algorithms and Internet of Things devices.

10. FUTURE WORK

Future research should concentrate on data analysis to elucidate the prevalence and behavioral patterns of macaque monkeys. This might entail keeping an eye on macaque populations in agricultural contexts to spot arrival or prevalence patterns, as well as alerting farmers to regions of high risk and anticipated arrival periods. To further understand macaque social behaviors, studies should also look at variables behind intra-specific behavioral variability and species-specific patterns of anomalous behavior when evaluating animal wellbeing.

In conclusion, creating successful plans for controlling macaque populations and guaranteeing their well-being requires a knowledge of macaque behavior. Researchers may help farmers and animal welfare experts make informed decisions by studying data on macaque behavior patterns. This will ultimately improve both the sustainability of agricultural operations and the well-being of macaques.

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Thank you!