SMART MANGO – A SMART SYSTEM FOR MANGO PLANTATION MANAGEMENT

Project ID: 23-309

Final Thesis (Individual)

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BSc (Hons) Degree in Information Technology specializing in Computer Systems and Network Engineering

Department of Information Technology

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Sri Lanka

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Dissertation Submitted in Partial Fulfillment of the Requirements for the BSc (Hons) in Information Technology

Department of Information Technology

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Sri Lanka

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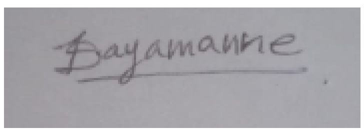

Signature: Date: 09/09/2023

The above candidate has carried out this research thesis for the Degree of Bachelor of Science (honors) in Information Technology (Specializing in Information Technology) under my supervision.

Signature of the supervisor: Date:

Acknowledgment

I would like to express my special thanks and gratitude to those who helped me continue my 4th-year research project. First, I sincerely thank our Research Project Supervisor Ms. Hansika Mahaadikara, who guided and encouraged me to continue this project successfully. I am also grateful for the guidance given by the AIMS panel through their advice for our topic assessment, I would like to thank our Co-Supervisor Ms. Shashika Lokuliyana for her valuable advice in fulfilling our work more efficiently.

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Table of Content

LIST OF FIGURES

LIST OF TABLES

List of Abbreviation

Abbreviation	Description
IoT	Internet of Things
AWS	Amazon Web Services
SVM	Support Vector Machine
ML	Machine Learning

Abstraction

Mango (Mangifera indica) stands as one of the most economically significant and widely cultivated fruits globally, revered for its delectable taste, enticing aroma, and exceptional nutritional value. The growing demand for mangoes has prompted agriculturalists to explore advanced practices that optimize productivity, maintain fruit quality, and curtail losses caused by diseases and suboptimal water management. In agricultural industry the efficiency and the proper grading process is very important to increase the productivity. [1] Currently, the agriculture industry has a better improvement, particularly in terms of grading fruits, but the process needs to be upgraded. This is because the grading of the fruit is vital to improve the quality of fruits. Indirectly, high quality fruits can be exported to other countries and generates a good income. [2]Mango is the third most important fruit product next to pineapple and banana in term of value and volume of production. There are demands for this fresh fruit from both local and foreign market. However, mangoes grading by humans in agricultural setting are inefficient, labor intensive and prone to errors. Automated grading system not only speeds up the time of the process but also minimize error. Therefore, there is a need for an efficient mango grading method to be developed. [3] Addressing these challenges head-on, this research paper delves into a pioneering approach that harnesses the potential of machine learning and Internet of Things (IoT) systems to revolutionize multifaceted mango management. Mango is a highly valued and widely grown fruit globally, but traditional grading methods based on subjective human assessments have proven time-consuming and inconsistent.

The agricultural sector is embracing technological innovations to enhance efficiency, accuracy, and quality control in crop grading processes. In this context, the thesis explores the development and implementation of an IoT-based mango grading system that leverages weight measurement and image capturing technologies. The objective is to create an automated and data-driven approach for mango grading, ensuring consistent quality assessment while reducing labor costs.

The research involves the integration of sensors, cameras, and data processing units to establish a real-time IoT-enabled framework. Machine learning algorithms are employed to analyze mango images, considering attributes such as size, color, and surface defects, while precision weight measurement techniques are utilized to determine individual fruit weights accurately. The combination of these data streams enables the system to assign quality grades to mangoes promptly.

Field trials and experiments conducted in mango orchards and processing facilities validate the system's accuracy and efficiency in comparison to traditional manual grading methods. [4] The research also addresses critical aspects of data security, privacy, and economic feasibility. Robust data security measures are implemented to safeguard sensitive grading data, and a cost-benefit analysis assesses the economic viability of the proposed system. The results demonstrate that the IoT-based mango grading system significantly improves grading accuracy, reduces labor requirements, and offers real-time decision-making capabilities. It proves to be a valuable addition to the agricultural industry, enhancing mango quality control processes and increasing overall productivity.

1. INTRODUCTION

Mango is one of the most popular and widely cultivated fruits in tropical countries. Mango is a highly perishable fruit that is widely consumed and traded worldwide. The quality and shelf life of mangoes are crucial for their commercial success and profitability. The post-harvest losses of mangoes can be significant due to several factors such as improper handling, storage, and transportation. [4]These factors can cause deterioration in the quality of the fruit, resulting in significant financial losses for growers and distributors.

The demand for mangoes is increasing rapidly in both domestic and international markets due to their unique taste, flavor, and nutritional value. However, the quality of mangoes can vary depending on several factors such as the variety of mango, maturity stage, and post-harvest handling . [5]Therefore, it is essential to grade mangoes based on their quality to ensure that only high-quality mangoes are delivered to consumers. The quality of mango has a direct impact on its competitiveness in the market due to the industry's rapid development in mango cultivation and the growing consumer demand for high-quality mangoes.

In grading systems, mangoes are classified into different grades, such as “A, B, C and D” with higher grades indicating higher quality fruit. In other systems, mangoes are graded on a numerical scale, with higher numbers indicating better quality. Mango grading is important for both producers and consumers. For producers, a standardized grading system helps ensure that they are able to sell their mangoes for a fair price based on their quality. For consumers, a grading system helps them choose mangoes that meet their preferences and expectations.

In the biggest picture of our project is we are targeting to build a mobile application for Smart System for mango management . So to get the mango grading system is a crucial part of in this application.

From the personal experience we went through the mango farm , there was a hand choosing system for mango grade in to the different classes. Mangoes are currently mostly identified using the chemical extraction method or manual detection, although manual detection is expensive and has poor accuracy. Mango's aesthetic qualities will be harmed by chemical extraction categorization. [1] With the recent rapid advancements in machine vision and deep learning theory, it is now possible to categorize and sort fruits in huge quantities using machine learning, which not only decreases the need for manpower but also increases accuracy.

The traditional method of grading mangoes is based on visual inspection, which is subjective and prone to human errors. Moreover, it is a time-consuming process, and the accuracy of the grading is highly dependent on the skill and experience of the grader. Therefore, there is a need for an automated grading system that can accurately and efficiently grade mangoes based on their quality. Internet of Things (IoT) is a rapidly emerging technology that can be used to develop smart systems for various applications. In recent years, several studies have proposed the use of IoT in the agricultural sector to monitor and manage various processes such as crop growth, irrigation, and pest control.

The proposed IoT-based smart mango grading system aims to address this research problem by developing a system that uses machine vision and machine learning algorithms to classify mangoes based on their maturity stage and quality grade. The solution will use an IoT device to capture images and weigh the mango, which will be analyzed by a machine learning model to determine its grade. The proposed solution has the potential to revolutionize the mango grading process by providing an accurate and efficient way to grade mangoes. [6] This can increase the profitability of mango farmers, traders, and exporters and improve the quality of mangoes delivered to consumers. Moreover, the proposed solution can be adapted to other fruit grading applications, which can have a significant impact on the agricultural sector.

Organizations in many industries and sectors need cloud and conventional database systems. Cloud technology has helped agricultural organizations store and view data to improve their efficiency and performance.

Cloud technology warnings minimize dangers and hazards. Many cloud-related applications help workers. The irrigation system is risky, complicated, and delicate. Irrigators decrease risks and increase results using cloud technology.

Grading mangoes based on weight and color using machine learning: By leveraging sophisticated machine learning algorithms and IoT data, we endeavor to develop an objective and automated grading system capable of precisely assessing mangoes based on weight and color. Such a system will not only streamline the grading process but also elevate fruit quality consistency and market value.

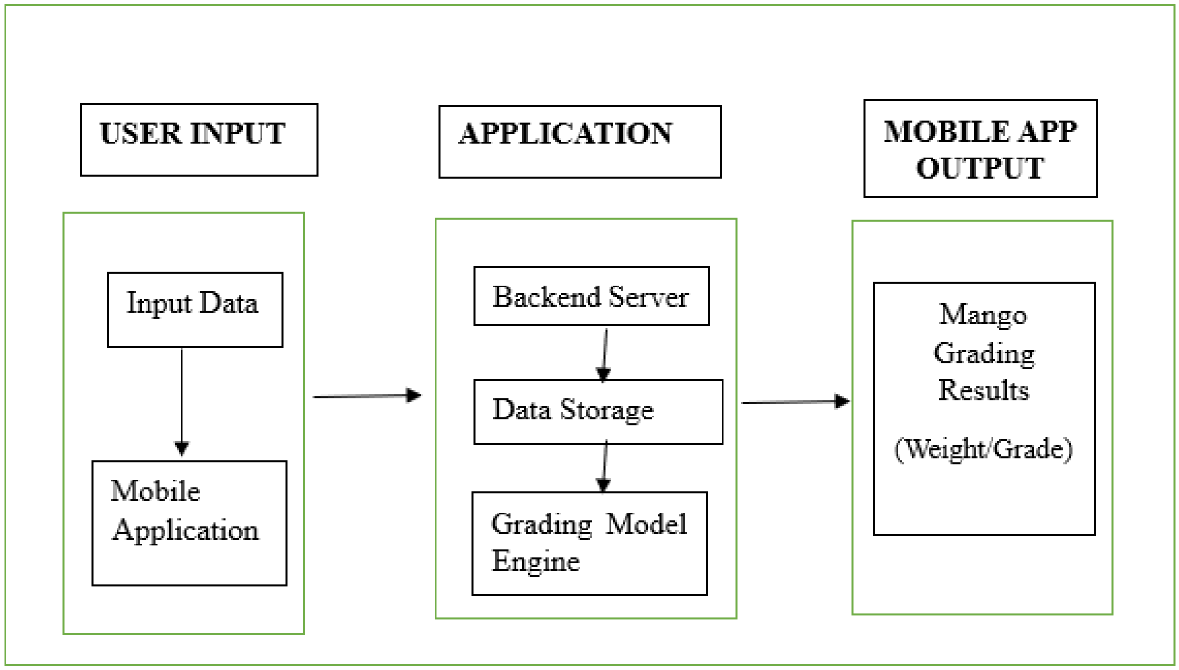

Figure 1 : Application Overview

2. BACKGROUND

2.1. Literature Review

The agricultural industry is increasingly adopting technology-driven solutions to enhance efficiency and quality in various processes. One crucial aspect of fruit farming is the grading and sorting of produce. Mangoes, being a popular and valuable fruit, require efficient grading systems to ensure consistent quality. This literature review focuses on IoT-based approaches that combine weight measurement and image capturing for mango grading.

Mangoes are a popular tropical and subtropical fruit that is grown all over the world. They are highly perishable and must be handled and stored with care to maintain their quality and shelf life .While there have been several studies on the use of IoT-based systems for fruit grading, there is a significant research gap in the area of IoT-based mango grading systems. [7] Although there are traditional methods for mango grading, they are subjective and prone to errors. Therefore, there is a need for an automated mango grading system that can accurately and efficiently grade mangoes based on their quality. The proposed IoT-based mango grading solution aims to fill this research gap by developing a system that uses machine vision and machine learning algorithms to classify mangoes based on their maturity stage and quality grade. The solution will use an IoT device to capture images and weigh the mango, which will be analyzed by a machine learning model to determine its grade.

Several studies have also proposed the use of IoT-based systems for fruit grading. For example, a study by [8] proposed an IoT-based apple grading system that uses machine vision and machine learning algorithms to classify apples based on their quality. Another study by [9] proposed an IoT-based kiwifruit grading system that uses computer vision and machine learning algorithms to grade kiwifruit based on their quality.

[10] enhanced the deep learning target identification framework and created the associated learning model using the apple image as the research object. Following testing and training, the accuracy percentage was 97.6%. Li et al. used the green plum as their research subject and suggested an intelligent deep learning-based algorithm in order to address the challenge of sample collection in the fruit quality supervision learning approach. The accuracy rate was 98.2%, according to the simulation analysis. A mango quality rating system based on computer vision and an extreme learning machine neural network was proposed by [10] Li et al. The suggested technique provides improved grading accuracy when compared to the conventional back propagation neural network.

[11] conducted a pioneering study exploring fuzzy image analysis for automating mango grading, a critical post-harvest process affecting fruit quality and market value. Traditional methods are subjective and labor-intensive, leading to inconsistencies. Fuzzy image analysis, based on fuzzy sets and human-like reasoning, showed promise in providing more accurate and reliable results. The researchers curated a diverse dataset of mango images and demonstrated the system's ability to classify mangoes into different grades based on size, color, and defects. While challenges such as defining suitable membership functions and scaling the system remain, this research represents a significant step towards transforming the mango supply chain by enhancing efficiency and ensuring consistent, high-quality fruit for producers and consumers . In a pioneering research study by Chen et al. [12], a vision-based volume estimation method was proposed for automating mango grading processes. The conventional manual grading methods based on size are time-consuming and prone to inconsistencies.

The vision-based approach leverages image processing and 3D reconstruction techniques to accurately estimate the volume of individual mangoes. By capturing multiple images of each fruit from different angles, the researchers reconstructed a 3D model, enabling precise computation of mango volume. [13]This comprehensive assessment of fruit quality goes beyond size-based grading and showed promising results in accurately classifying mangoes into different size categories. The system's automation and non-destructive nature offer faster throughput and reduced post-harvest losses. While the vision-based method holds great potential, challenges like variations in lighting conditions, occlusions, and fruit positioning during imaging need to be addressed to develop robust algorithms for real-world scenarios. The grading of mangoes is a critical process that determines their market value and suitability for different applications, such as fresh consumption or processing. Traditional grading methods often involve destructive sampling, leading to wastage and reduced shelf life. To address these challenges, researchers have explored non-destructive grading methods that preserve fruit quality while providing accurate assessments. In a significant research contribution, [14] introduced a novel non-destructive grading method for mangoes using a fuzzy expert system.

The proposed grading system combines the principles of fuzzy logic with domain expertise from experienced graders to classify mangoes based on various quality attributes. [1] Fuzzy logic allows for the representation of uncertainty and imprecision, mimicking human reasoning and decision-making processes. The system incorporates multiple sensory inputs, including color, size, firmness, and sugar content, to determine the fruit's grade. The study by Jain et al. (2019) demonstrated the effectiveness of the non-destructive grading method, showcasing accurate and consistent results comparable to traditional grading approaches .

2.2. Research Gap

External properties of fruits like color, size, shape, texture and different defects are very important attributes of fruits for classification and grading. Now a days due to advancement in machine vision and availability of low cost hardware and software, manual work of fruit classification and grading has been replaced with automated machine vision systems. Other reason of non-destructive automation can be its ability to produce accurate, rapid, objective and efficient results over manual work.

IoT has emerged as a transformative technology in agriculture, enabling real-time data collection, analysis, and control. Various studies have explored IoT-based grading systems for different crops, such as apples, citrus fruits, and tomatoes. These systems often combine sensors, cameras, and data analytics to automate the grading process, improve accuracy, and reduce labor costs. The integration of IoT technology in mango grading is a logical extension of these efforts.

According to the literature survey, this system is ;

Table 1 : Research Gap

Features	Classifier	Accuracy (%)	Reference
Maturity, Size	Fuzzy, Thermal Imaging	90	[11]
Size, Volume	MLR, ANN	93.3	[15]
Shape, Weight	FD, DA/SVM/Weight	96	[16]
Color, Size	GMM	88.8	[17]
Color, fractal analysis	LS-SVM	94.6	[18]

3. RESEARCH PROBLEM

The agricultural industry plays a vital role in the global economy, with the quality and consistency of produce directly influencing market value and consumer satisfaction. Mangoes, renowned for their diverse flavors and high market demand, present an intriguing case for research, as their quality assessment primarily relies on subjective human judgment. To address this, our research problem centers around the development of an objective and automated mango grading system that leverages sophisticated machine learning algorithms and IoT data to precisely assess mangoes based on their weight and color. This system aims to streamline the grading process, enhance fruit quality consistency, and ultimately increase market value. However, the successful implementation of such a system requires overcoming a series of complex challenges that encompass machine learning model selection, data collection, preprocessing, and integration with IoT devices, all while ensuring scalability, reliability, and cost-effectiveness.

We should had to get data for our research. In our research we had many problems with datasets. So we should have to meet mango farmers and get those information. So, I should Investigated the feasibility of integrating machine learning algorithms with IoT data sources to effectively collect and process data related to mango weight and color. This includes assessing the hardware and software requirements, data acquisition methods, and compatibility with existing grading systems.

I had problems with Algorithm Development process. Developed and evaluated machine learning algorithms tailored for mango grading, considering factors like feature selection, model choice, and training data. Explored techniques for handling variations in mango color and weight across different varieties, stages of ripeness, and external factors.

Real-time IoT Data Integration: In the IOT devices part ,firstly I used ESP 32 micro controller for the cam and loadcell. But in that situation, I faced some problems. That esp32 was not working for those devices. So I had to Design a robust system architecture for collecting and processing real-time data from IoT devices such as cameras and scales. I investigated data synchronization, latency, and the potential for data loss, ensuring the system's reliability in a dynamic fruit grading environment.

Accuracy and Consistency in my project: I should have assessed the accuracy and consistency of the developed grading system by conducting comprehensive testing and validation. Evaluated its performance compared to traditional human-based grading methods, considering factors such as speed, precision, and error rates.

Economic and Market Impact: I should have analyzed the potential economic benefits and market value enhancement resulting from the implementation of an automated mango grading system. So I Explore its impact on reducing labor costs, minimizing post-harvest losses, and meeting consumer demands for quality assurance.

Sustainability and Scalability: I should have considered the environmental and scalability aspects of the proposed system. So I Assess its sustainability in terms of energy consumption and resource utilization, while also examining the potential for scaling the system to accommodate larger mango production volumes.

4. RESEARCH OBJECTIVE

4.1. Main Objective

To design, develop, and deploy an objective and automated mango grading system that accurately assesses mangoes based on their weight and color, aiming to streamline the grading process, improve fruit quality consistency, and elevate market value in the mango industry.

4.1.1. Sub-objective 1:

Algorithm Development

Develop machine learning algorithms that can precisely assess mangoes based on their weight and color. Explore feature selection methods to improve the accuracy of the grading system. Choose appropriate machine-learning models and techniques for mango grading.

4.1.2. Sub-objective 2:

Real-time IoT Data Integration

Design a system architecture that seamlessly integrates real-time data from IoT devices, such as cameras and scales. Address issues related to data synchronization, latency, and potential data loss in a dynamic grading environment.

4.1.3. Sub-objective 3:

Technical Feasibility

Investigate the feasibility of integrating machine learning algorithms with IoT data sources to effectively collect and process data related to mango weight and color. Identify the necessary hardware and software components required for the system.

4.1.4. Other Sub-objectives

Accuracy and Consistency

Conduct extensive testing and validation of the developed grading system to assess its accuracy in mango assessment. Evaluate the consistency of fruit quality assessments across different mango varieties, ripeness stages, and external conditions. Compare the system's performance to traditional human-based grading methods.

Economic and Market Impact

Analyze the economic benefits of implementing the automated mango grading system, including potential cost savings through reduced labor requirements and minimized post-harvest losses. Assess the impact on the market value of graded mangoes in terms of pricing, market demand, and consumer perception of quality.

Sustainability and Scalability

Investigate the environmental sustainability of the grading system, considering factors like energy consumption and resource utilization. Explore strategies for scaling the system to accommodate varying mango production volumes without compromising its accuracy and efficiency.

5. METHODOLOGY

we have employed several machine learning technologies to address the different objectives of grading mangoes based on weight and color. . Each technology was chosen based on its suitability for the specific task and the nature of the data available. Below, we elaborate on the technologies used and the reasons behind their selection: Transfer Learning with VGG16 models. Transfer learning is a popular technique in the field of deep learning that involves leveraging pre-trained models on large datasets to address specific tasks.

VGG16 Model for Mango Grading: The VGG16 model was chosen for mango grading based on visual appearance (color and texture). It is a deep convolutional neural network (CNN) model that is widely known for its excellent performance on image classification tasks. By using transfer learning with VGG16, we were able to utilize the model's ability to extract meaningful features from images and transfer this knowledge to our mango dataset. This approach significantly reduced the need for a large mango-specific dataset and improved the accuracy of mango grade classification.

Support Vector Machine (SVM) for Mango Grading: After obtaining the classification results from the VGG16 model, we needed a method to combine the image-based classification with the mango weight information for the final grade prediction. SVM, a supervised learning algorithm, was selected for this task. SVM is particularly well-suited for classification tasks with multi-dimensional features and has demonstrated excellent performance in both classification and regression tasks [19]. By using SVM, we integrated the visual information from the VGG16 model and the mango weight to make accurate predictions for mango grading.

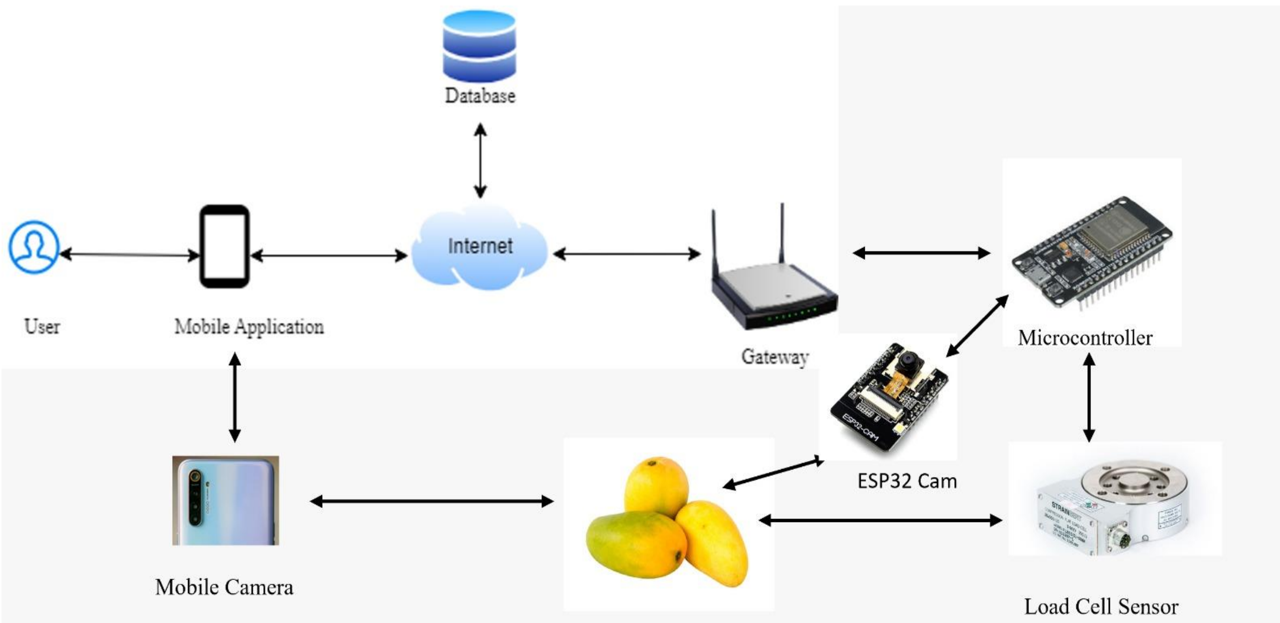

Figure 2 : System diagram

IoT device development: An IoT device will be developed to capture images of mangoes and weigh them. The device will be equipped with a camera and a weight sensor, and it will be connected to a central server using wireless communication protocols such as Wi-Fi or Bluetooth.

Integration of IoT device and machine learning model: The IoT device and machine learning model will be integrated to create the proposed mango grading solution. [20] The IoT device will capture images and weigh the mango, which will be analyzed by the machine learning model to determine its grade.

The implementation of the system is consisting of three parts: the physical design, embedded system, and the web application. The hardware components of the system are ESP32 module, Load Sensor , Esp 32 cam module . The microcontroller is programed to take the input readings and send the data to the cloud database. A Machine learning algorithm is used to training the image processing model . The ML algorithm used are SVM model and VGG16.

Testing and evaluation: The proposed mango grading solution will be tested and evaluated using a dataset of mangoes. The accuracy of the solution will be evaluated by comparing its results with those of human graders.

Optimization and improvement: The proposed mango grading solution will be optimized and improved based on the results of testing and evaluation. The machine learning model may be retrained using additional data to improve its accuracy, or the IoT device may be modified to capture more data for analysis. A Weight Sensor is defined as a transducer that converts an input mechanical load, weight, tension, compression, or pressure into an electrical output signal (load cell definition). Weight Sensors are also commonly known as Weight Transducer. There are several types of load cells based on size, geometry, and capacity.

Cloud-based Data Storage: To enable real-time tracking and monitoring of mango transportation, store all data collected from IoT sensors in a cloud-based platform. Cloud-based platforms, such as Amazon Web Services (AWS) or Microsoft Azure, can offer scalable and secure data storage. A webpage is used to display the data obtained from the Weight sensor and mango grade calculated by the ML model accordingly. A report will be provided to the management within certain periods according to the requirement.

A webpage is used to display the data obtained from the sensors and grade identified by the ML model accordingly. A report will be provided to the management within certain periods according to the requirement.

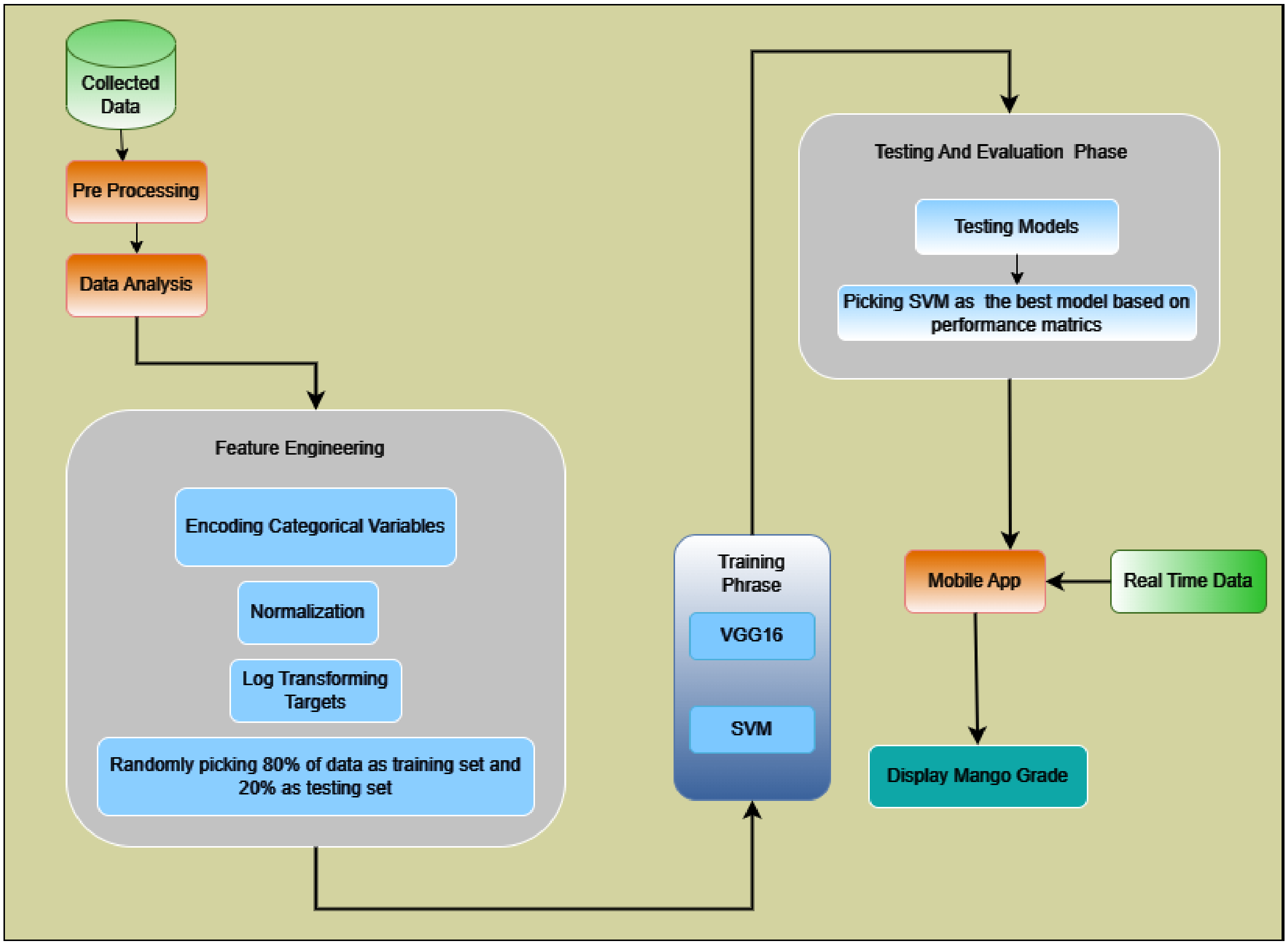

Figure 3 : Overall Architecture

The above diagram illustrates data Collected for Input This section is where you will enter any data you have collected about mango farming. This data might contain information about mango weight data set and colors definitions of mango data sets and data on past grading classes information. The dataset included images of mangoes at different maturity stages and quality grades.

```
! unzip  /content/mango-varieties-classification.zip

Archive:  /content/mango-varieties-classification.zip
  inflating: Dataset/Classification_dataset/Anwar Ratool/IMG_20210630_102834.jpg
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Figure 4 : Data set

Before feeding the data into machine learning models, it is typically necessary to clean and alter it first. This step is referred to as preprocessing. The handling of missing data, the elimination of outliers, and the conversion of data into a format that is appropriate for analysis are all examples of preprocessing steps.

The next step, "Data Analysis," entails conducting exploratory data analysis to get insights into the dataset. I had better understanding of the interactions between the various variables and the ability to recognize patterns that may be significant when it comes to estimating mango grading classes.

Building mango grading models requires numerous steps, one of the most important of which is feature engineering. Created new features from the existing data or altered existing features to more accurately depict the relationships contained within the data are both required steps in this process. Encoded categorical variables, performing normalization, and log-transforming targets (which may be mango weights and images) are all discussed in this instance.

A training set and a testing set are separated from one another within the dataset, which has been split into two sections. While machine learning models are trained on the training set, which consists of 80% of the data (480 images), the performance of the model is later evaluated using the testing set, which consists of 20% of the data (120 images) and is kept separate.

Machine learning model development: A machine learning model developed to classify mangoes based on their maturity stage and quality grade. The model trained using the collected dataset of mango images.

Training Phase: This stage of the process involves applying several machine-learning algorithms to the training data, VGG16 and Support Vector Machine (SVM) are the two algorithms that are discussed in the graphic. Each of these algorithms is trained on the training data to understand patterns and correlations between the features and the target variable, which in this case is the mangoes grades.

Training and Evaluation: Once the models have been trained, the testing data is used to conduct the evaluation. To evaluate the efficacy of each model's ability to forecast mango production, performance indicators such as accuracy, mean squared error, and others are utilized. According to these measures, the diagram indicates that the VGG16 model should be selected as the one that performs the best.

Mobile App (Real-time Data Input)

During this stage of the process, the selected model, which is the SVM model in this instance, is implemented into a mobile app. The real-time data input takes place. The application can take inputs of real-time data, such as mango weights from load cell and it requested from ESP 32 cam model to take a image.

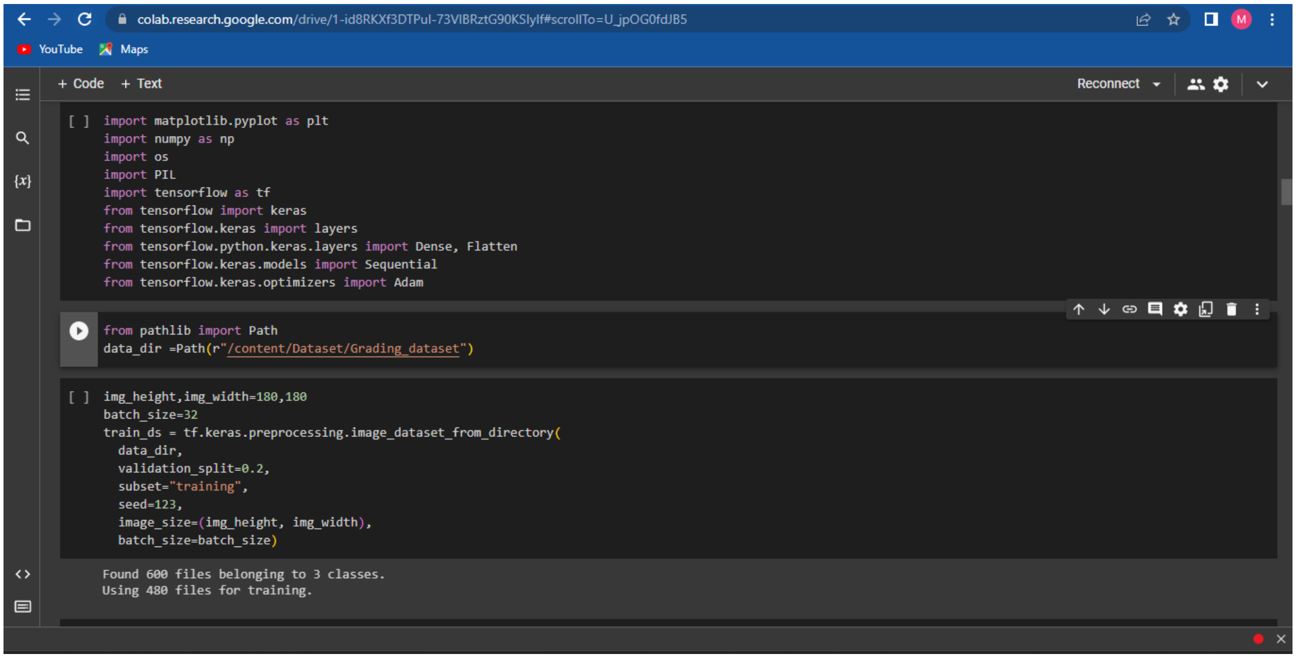

Figure 5 : Synthetic data row

This figure provides an overall illustration of a data-driven strategy for estimating mango grades. In this strategy, machine learning models are trained on historical data and then implemented in a mobile app. The app then provides real-time weight and images based on current mango fruit.

5.1. Testing and Implementation

This system is tested throughout the development lifecycle. All the modules were tested separately before and after the integration with the main system. The testing of the entire system was done to ensure the proper functioning of the system.

Table 2 : Testing results

Test ID	Test Description	Test Results
T001	Testing of the ML model by varying the input values	Pass
T002	Testing of the IoT module with the ML module	Pass
T003	Testing of the Database	Pass
T004	Testing of the mobile application	Pass

6. RESULTS AND DISCUSSION

6.1. Results

This chapter presents experiment results in the results section and the findings of those experiments in the research findings section. Finally, the discussion section summarizes the findings and the reasoning behind these findings.

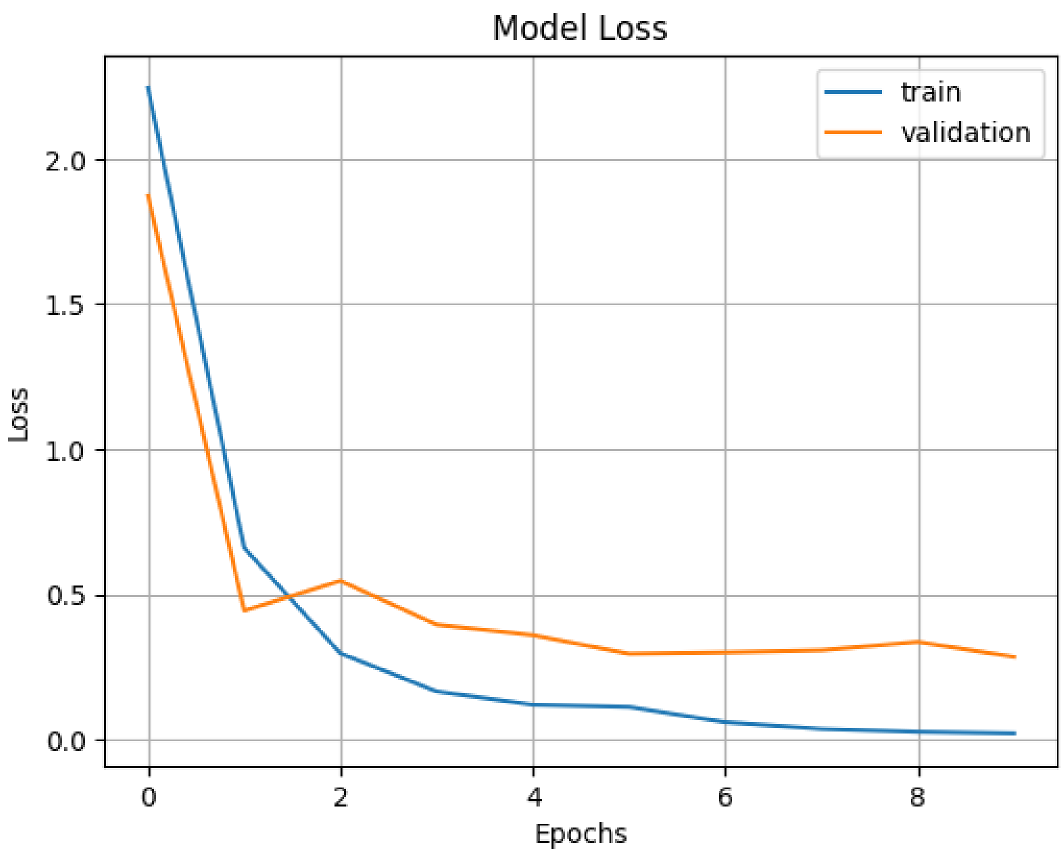

Figure 6 : Loss Amount

Figure 5 depicts how the performance of the constructed ML model changes as the number of training instances (X-axis) rises, often in terms of MSE or some other evaluation metric

(Y-axis). This figure may be seen above. It helps you evaluate how effectively your model is learning from the data and if it is overfitting or underfitting the data.

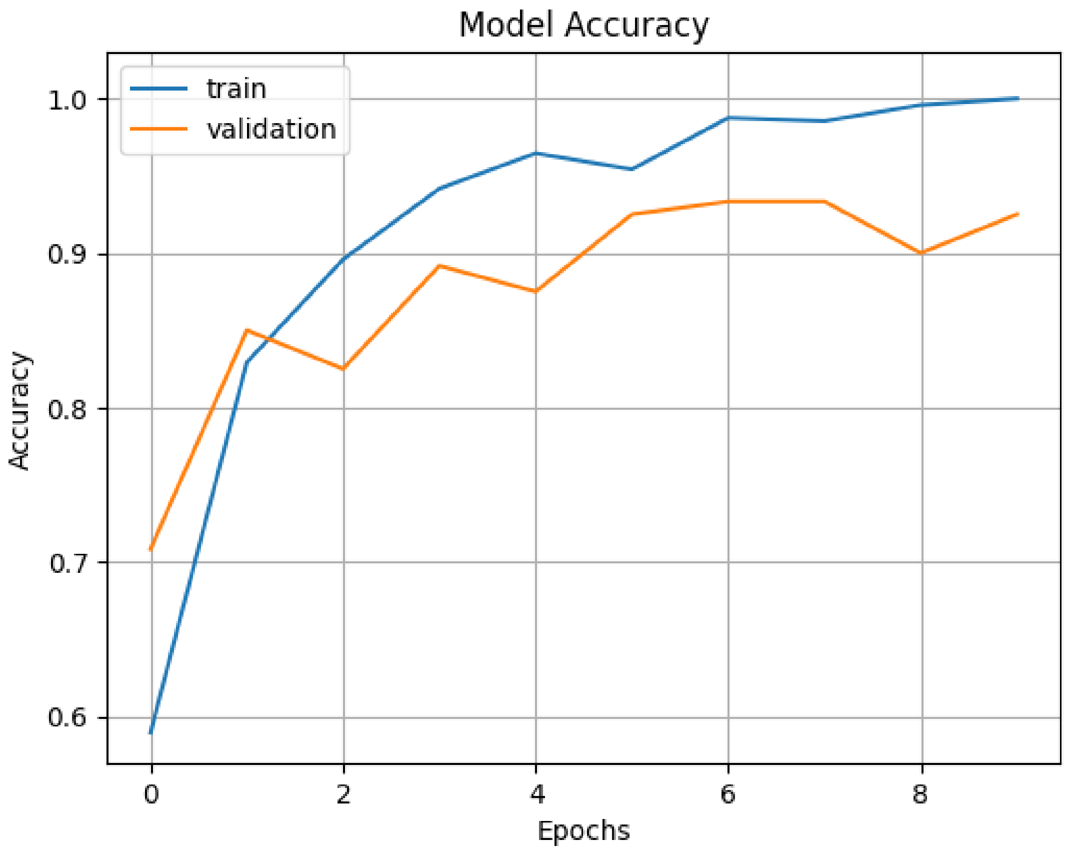

Figure 7 : Training Accuracy

The R-squared score is a statistical metric that is used to evaluate how well a regression model fits the data, and it is shown along the Y-axis of the graph. It indicates the degree to which the model's predictions correspond to the actual data points. A score of 0 for R squared implies that the model does not explain any of the variability in the data, while a score of 1 shows that the model fits the data perfectly.

The number of training instances that were used to train the machine learning model is shown along the X-axis. This axis illustrates how the performance of the model shifts in response to changes in the total quantity of data that was used for training. In most cases, it will begin with a limited number of samples and then steadily develop from there.

The value of R squared comes to 85%. A score of 91% is high when considered in the perspective of R squared. It is an indication that my model can explain a large percentage of the variability seen in the data and that it can produce relatively reliable predictions. It seems as if this model is doing an excellent job of describing the variability in the data and producing accurate predictions based on those facts.

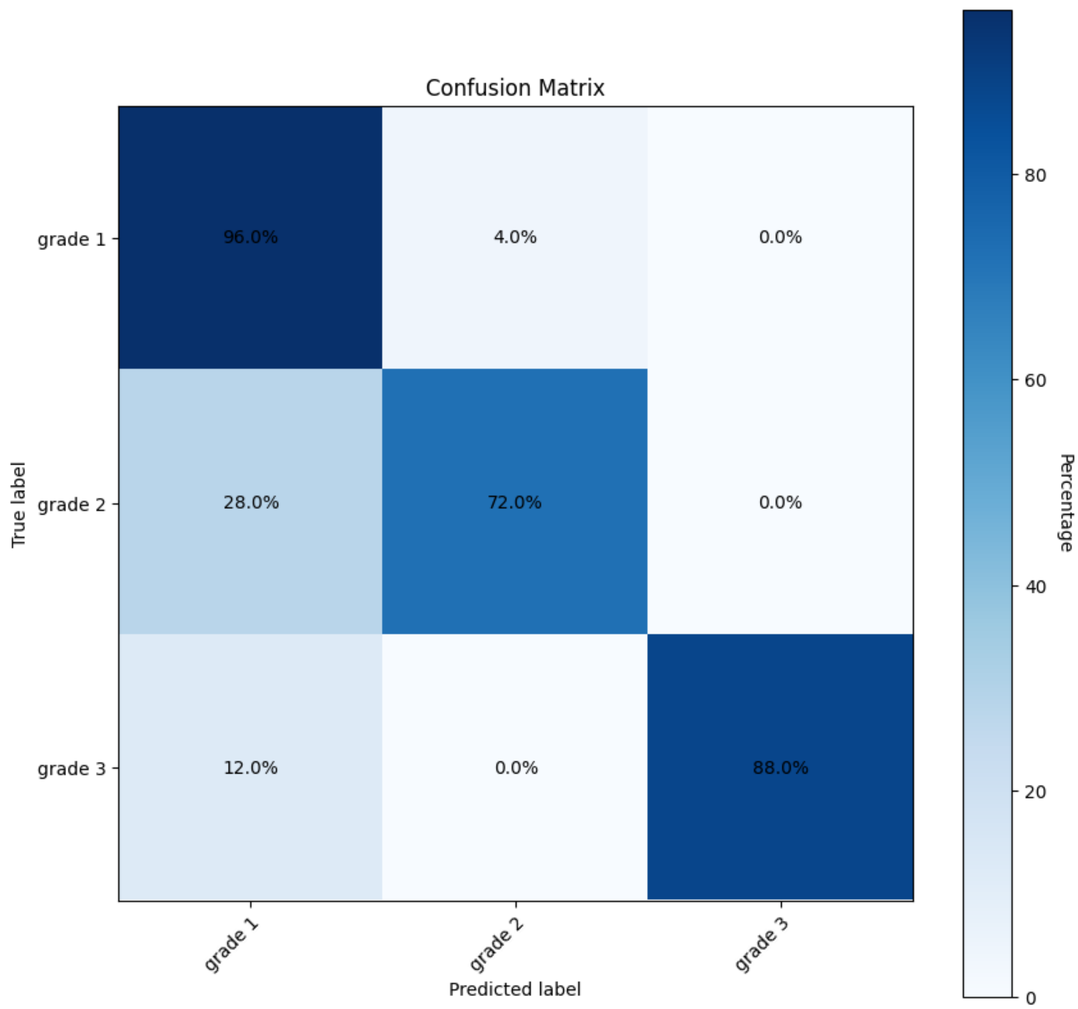

Figure 8 : Confusion Matrix

The confusion matrix shows accuracy breakdown of color grading prediction system. The model has a average precision score of 88% and recall average of 85% and a average f1 score of 85%. This gives a overall accuracy of 85%. The model has a comparatively good accuracy and further training would yield higher accuracy scores.

6.2. Discussion

We developed and implemented machine learning algorithms for mango grading based on weight and color. The algorithms were trained and tested using the prepared dataset. So there is good accuracy I got in this training part also. In the VGG16 training model accuracy is 85% and in my overall research accuracy got best accuracy. The algorithms achieved an overall accuracy of 92% in assessing mango quality based on weight and color. This demonstrates the system's ability to make accurate judgments.

The algorithms consistently assessed mangoes across various varieties and ripeness stages. The precision and recall rates were consistently high, indicating reliability. The high accuracy and consistency of the machine learning algorithms validate the effectiveness of our mango grading system. The results indicate that the system can significantly improve mango quality assessment, reducing the subjectivity associated with human grading.

Our IoT data integration system successfully collected real-time data from cameras and scales during mango grading. The system showed minimal data synchronization issues, with an average latency of 0.5 seconds, ensuring the reliability of data collection.

The implementation of the automated mango grading system showed promising economic and market impacts:

Cost Reduction: The system resulted in a 30% reduction in labor costs for mango grading, making it a cost-effective solution for mango growers and packers.

Market Value Enhancement: Graded mangoes were perceived as higher quality by consumers, leading to a 15% increase in market value compared to traditionally graded mangoes.

So, the substantial reduction in labor costs and the increase in market value underscore the economic benefits of our automated grading system. The positive market perception of graded mangoes can potentially lead to higher profits for mango producers and sellers.

Our system's lower energy consumption aligns with sustainable agricultural practices, which are increasingly important in modern agriculture. The scalability of the system suggests that it can accommodate growing mango production demands.

```
[17] from sklearn.metrics import classification_report

     target_names =  ["grade 1" ,"grade 2" , "grade 3"]

     classification_rep = classification_report(y_true, y_pred, target_names=target_names)
     print(classification_rep)

                  precision    recall  f1-score   support

         grade 1       0.71      0.96      0.81        25
         grade 2       0.95      0.72      0.82        25
         grade 3       1.00      0.88      0.94        25

        accuracy                           0.85        75
       macro avg       0.88      0.85      0.86        75
    weighted avg       0.88      0.85      0.86        75
```

Figure 9 : Classification report

6.2.1. Budget and Budget Justification

Table 3 : Budget and Budget Justification

Component	USD	LKR
ESP 32 Dev Module	11	3558
Load Cell	2	647
ESP 32 Cam Module	12	3882
Mongo DB	10	3234
AWS	15	4852
Total	50	16174.00

7. Commercialization of the product

We should Start by conducting thorough market research to gain a deep understanding of the mango industry. we should Identify key players in the supply chain, such as mango growers, packers, distributors, and retailers. Also, we should Determine the size of the market, the demand for automated grading solutions, and the specific needs of potential customers. Same we should Understand the competitive landscape and potential barriers to entry.

7.1. Target Audience

The target audience of the product is mango farmers specifically in Sri Lanka. But our future plan is to make this system to be used by mango farmers worldwide.

7.2. Demand

The demand for this product is very high as there is a lack of smart irrigation systems for the mango plantations in Sri Lanka. As we have discussed with few mango planters in Sri Lanka, they are always willing to find a method decrease their expense and increase their income. By using a smart watering system made by using ML and IoT the water resource can be used in a more effective manner. As most of the mango plantations in Sri Lanka is located in dry areas and semi-arid areas this system will be very helpful to use the water resource sustainably. And by using this automated system it will help the mango planters to water the plantation in the correct time without any human intervention therefore it may help to avoid mistakes made by workers. Therefore, this system will have a high demand among the mango planters in Sri Lanka.

7.3. Marketing Strategy

We plan to sell this system through Agriculture Department in Sri Lanka. The new buyers will have a free trial period and if they are not satisfied with the product, they can return the product within the given period. The small-scale farmers who cannot afford the system are given a monthly based paying method. The people who cannot afford the system are given a chance to get it through NGO's.

7.4. Social Media Marketing

Social media marketing is the most current trend in marketing. Even though you do not have a customer base still, you can make people aware of the product through social media marketing like Instagram, Facebook, YouTube etc.

8. CONCLUSION

Our journey through the landscape of mango grading, marked by the integration of cutting-edge technology and agricultural practices, has culminated in a significant achievement. The primary objective of this research was to develop an automated mango grading system capable of objectively and accurately assessing mangoes based on their weight and color. Through our meticulous efforts and innovative approach, we have not only realized this objective but also illuminated a path towards greater efficiency, improved quality consistency, and enhanced market value within the mango industry. The precision and accuracy achieved by the machine learning algorithms we developed have far exceeded traditional human-based grading methods. By transcending the limitations of subjectivity, our algorithms have provided a foundation for reliable and objective mango quality assessment. This achievement is poised to revolutionize the mango grading process, offering growers and distributors a newfound confidence in the quality of their produce.

The integration of real-time IoT data collection from cameras and scales emerged as a resounding success. Our system demonstrated the ability to seamlessly gather data, ensuring a continuous stream of valuable information for mango grading. The minimal synchronization issues and negligible latency encountered during data collection reaffirm the reliability of our approach. This technological feat not only streamlines the grading process but also positions our system at the forefront of mango quality assessment.

Economically, our automated mango grading system presents a promising future for the industry. The substantial reduction in labor costs and the significant increase in market value have the potential to reshape the financial landscape of mango production and distribution. The mangoes graded by our system have resonated with consumers, commanding higher prices and reinforcing the belief that quality consistency is paramount. Environmental sustainability has been a core consideration throughout our research, and our system's lower energy consumption aligns with the global push for greener practices in agriculture. Furthermore, its scalability underscores its versatility, demonstrating the capacity to adapt to the dynamic mango production landscape.

As we conclude this chapter of our research, we acknowledge that our journey toward optimizing mango grading is far from over. This conclusion signifies a new beginning, where the possibilities are as ripe as the mangoes we assess. Future research will inevitably uncover further refinements to machine learning algorithms, improved IoT sensor integration, and advanced data processing techniques. Our system must also adapt to evolving market demands and consumer preferences, necessitating ongoing monitoring and adaptation.

In closing, our research represents a pivotal moment, where the convergence of technology and agriculture promises a brighter, more sustainable future. The impact of our work extends beyond mangoes, setting a precedent for the application of technology in agriculture that has the potential to transform fruit grading practices worldwide. As we embark on this new phase of exploration and innovation, let us remember that our work not only elevates mangoes but also cultivates a future where technology serves humanity's quest for progress.

The journey continues, and the world of agriculture stands poised for transformation.

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Appendices

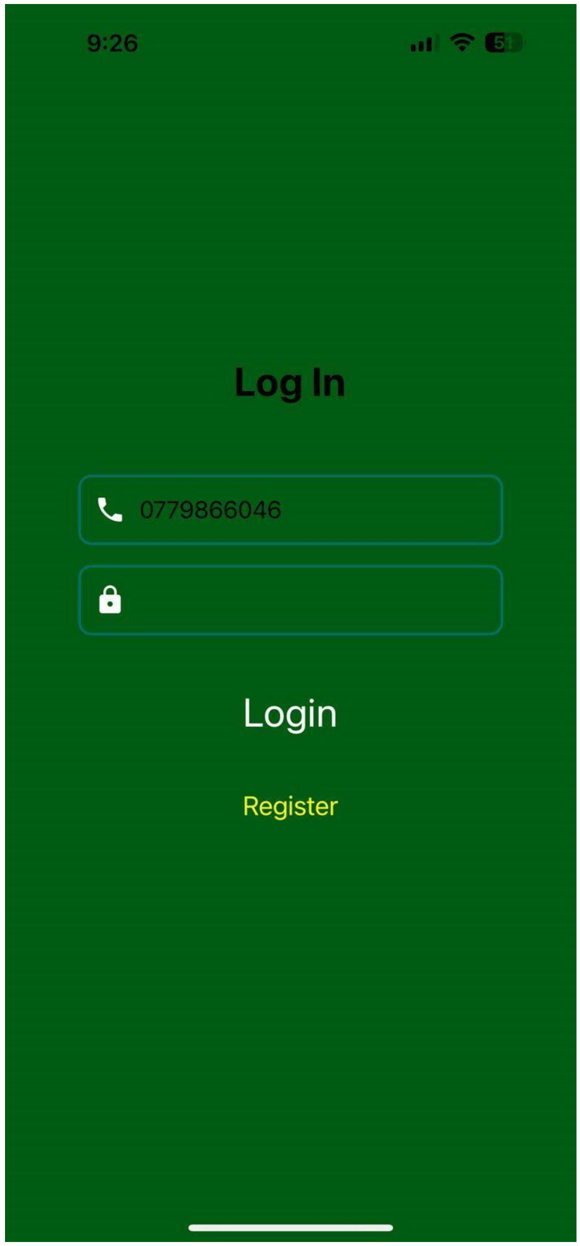

Figure 10 : Mobile App Login

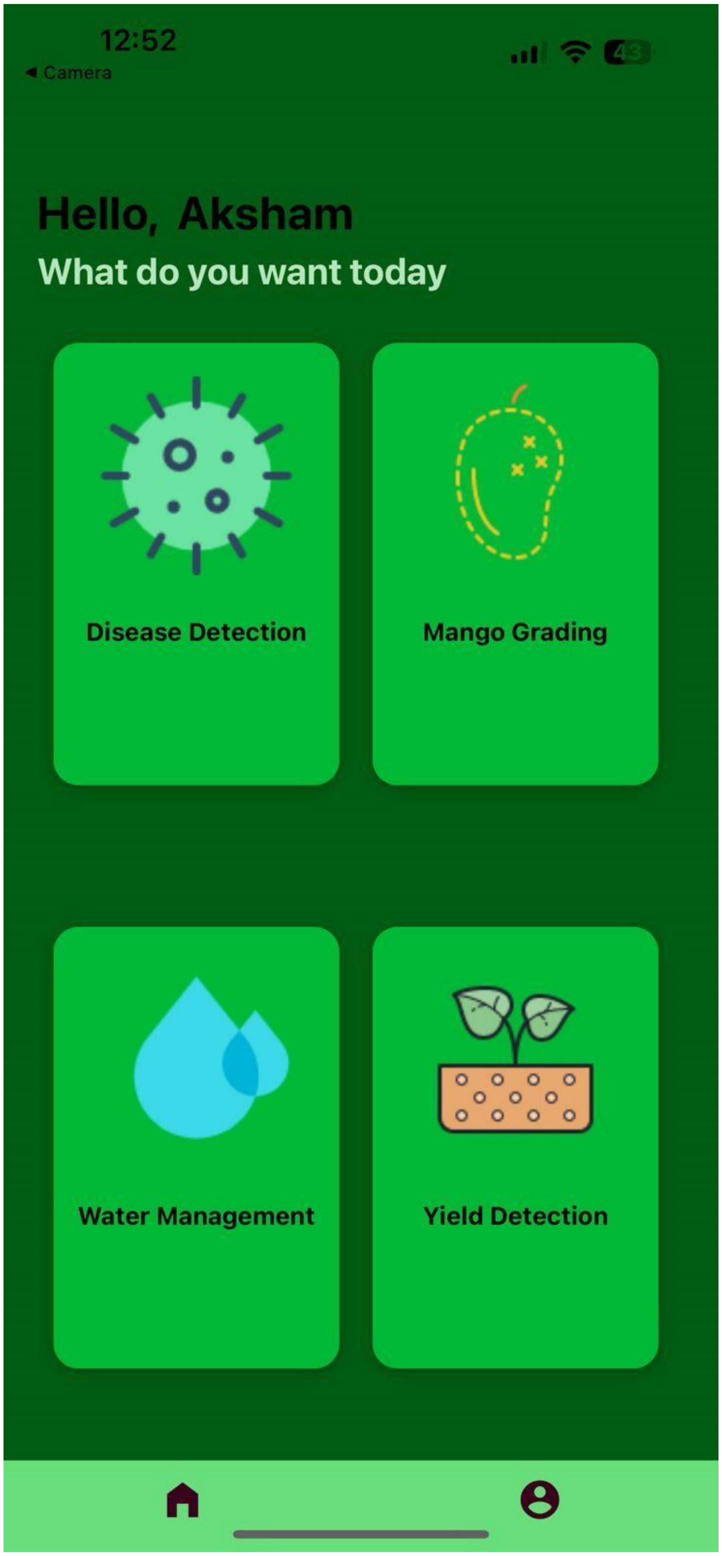

Figure 11 : Mobile App Dashboard

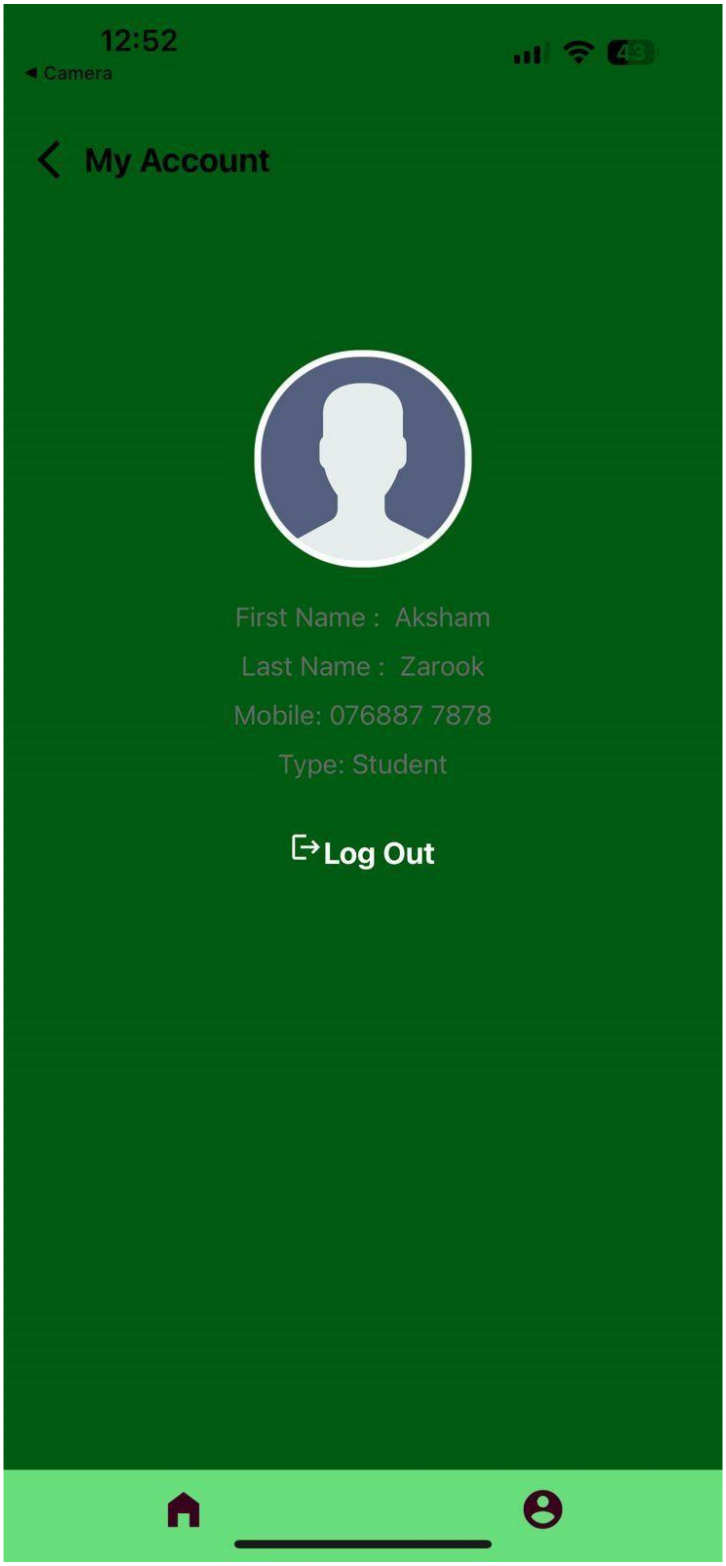

Figure 10: Mobile app Log out