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FruitTech: A Cloud-Based Fruits Grading Machine Using Convolutional Neural Network

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ABSTRACT

Ensuring fruit quality is essential for farmers, especially for rambutan and calamansi, two widely grown fruits in the Philippines. However, traditional manual sorting methods are often inconsistent, time-consuming, and prone to errors, leading to post-harvest losses. This study developed FruitTech: A Cloud-Based Fruit Grading Machine, which uses Convolutional Neural Networks (CNNs) to classify fruits based on their appearance and quality automatically. The system was built using an Agile development approach, combining machine learning, cloud computing, and hardware automation. A CNN model was trained to analyze fruit images, identifying characteristics like ripeness, size, and defects. The system also includes real-time sorting mechanisms, SMS notifications, and data visualization tools, giving farmers instant access to grading results. Testing was conducted through alpha and beta phases, followed by an evaluation using ISO/IEC 25010 and UTAUT to assess system performance and user acceptance. Results showed that FruitTech significantly improved accuracy, efficiency, and ease of fruit grading, reducing the need for manual labor while providing farmers with a more reliable and accessible solution. Users responded positively to the system's functional suitability, security, and usability, confirming its potential for real-world agricultural applications.For future improvements, researchers could expand the system to grade other fruit types, enhance image analysis in different lighting conditions, and integrate IoT or hyperspectral imaging for detecting internal defects. Developing an offline and portable version would also make FruitTech more accessible to farmers in remote areas.

INTRODUCTION

Rambutan (Nephelium lappaceum) and calamansi are tropical fruits that hold cultural and economic importance in the Philippines. These fruits are widely consumed in Filipino households and serve as key agricultural exports. Rambutan, known for its sweet taste and distinct hairy skin, is a popular delicacy, while calamansi, a small citrus fruit with a tangy flavor, is commonly used in cooking, beverages, and traditional remedies. In agricultural provinces like Oriental Mindoro, the production of these fruits thrives due to favorable climate and soil conditions, contributing to local livelihoods and the economy.

However, maintaining quality control in rambutan and calamansi production remains a significant challenge. For rambutan, factors such as ripeness, discoloration, and bruising affect market value, while calamansi is assessed based on size, ripeness, and visible defects that impact shelf life. Manual grading relies heavily on human judgment, which can vary significantly, leading to inconsistent quality assessments (Kumar *et al.,* 2020). Human errors during sorting can result in misclassification, affecting both farmers and consumers (Mushiri & Tende, 2020). These inefficiencies lead to post-harvest losses, reduce profitability for farmers.

To address these challenges, FruitTech: A Cloud-Based Fruit Grading Machine using Convolutional Neural Networks (CNN) is designed to automate the sorting and grading process for rambutan and calamansi. CNNs excel in image classification tasks, effectively distinguishing between different fruit types, ripeness levels, and damage statuses. For instance, a study reported a classification accuracy of 95.83% for identifying tomatoes using CNNs (Joshi *et al.,* 2024). By utilizing CNN, an advanced machine learning technique, the system analyzes key visual indicators such as color, texture, and shape to assess fruit quality with high accuracy. The use of CNNs has been shown to achieve over 97% accuracy in detecting good versus bad quality tomatoes, demonstrating their reliability in quality assessment (Sharma *et al.,* 2024). Also in mango grading it achieved a 98% accuracy rate in detecting defects such as rot and bruises, demonstrating its effectiveness in quality assessment (Kona *et al.,* 2024). This ensures a more consistent and efficient grading process while minimizing human error and reducing labor costs.

FruitTech integrates hardware for capturing real-time images of fruits and a cloud-based platform for processing and analyzing these images. The system includes automated features such as defect detection, ripeness classification, and real-time sorting. Additionally, it provides SMS notifications and data visualization tools, allowing farmers to monitor trends, generate reports, and make data-driven decisions. By modernizing the fruit grading process, FruitTech aims to reduce post-harvest losses, improve efficiency, and help farmers meet international quality standards.

This study seeks to develop a reliable and user-friendly FruitTech platform that bridges the gap between traditional farming practices and modern technology. By promoting sustainable agriculture and improving

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efficiency, the system has the potential to enhance the livelihoods of farmers in Oriental Mindoro and strengthen the market presence of rambutan and calamansi both locally and globally.

MATERIALS AND METHODS

Development Method

To ensure FruitTech met the needs of farmers, the development team conducted interviews with key stakeholders and agricultural experts. The system was built using the Agile Development Model, allowing for continuous improvements based on real-world feedback (Fey *et al.,* 2023). At its core, FruitTech uses a Convolutional Neural Network (CNN) to analyze fruit quality, classifying rambutan and calamansi based on visual indicators like color, texture, and shape. The system processes images through preprocessing techniques such as resizing and normalization to improve accuracy (Zhang *et al.,* 2021). The final grading results are accessible via a cloud-based platform and SMS notifications for real-time updates.

During the planning and design phases, the team established a clear roadmap, identified essential hardware and software components, and gathered a comprehensive dataset from online sources and local farmers. The system architecture integrated Raspberry Pi, Arduino Mega, and high-resolution cameras for image capture and fruit sorting. A user-friendly web interface was developed using HTML, Bootstrap, and PHP, while MySQL handled data storage. TensorFlow Lite optimized CNN deployment, ensuring efficient classification.

The system underwent rigorous testing phases, including alpha testing for internal evaluation, beta testing with farmers for real-world usability, and final system testing to measure accuracy, speed, and reliability (Li *et al.,* 2022). After testing, hands-on demonstrations and structured feedback sessions were conducted with stakeholders, refining the system based on user insights. Farmers and agricultural experts contributed valuable feedback, leading to improvements in grading accuracy, user experience, and system reliability. As a result, FruitTech became a more efficient, user-friendly, and scalable solution for modernizing fruit quality assessment.

Development Tools

FruitTech integrates both hardware and software tools to deliver an efficient and automated fruit grading system. The hardware setup features a Raspberry Pi as the main processor and an Arduino Mega to control components such as a high- resolution camera, servo motors, conveyor belts, infrared sensors, and load cells— ensuring precise fruit detection, grading, and sorting. An LCD display offers real- time monitoring, while voltage regulators, relays, and protection circuits maintain system stability. On the software side, the web interface was developed using HTML, Bootstrap, and PHP, with MySQL managing user profiles and grading records. Fruit classification is powered by a Python-based Convolutional Neural Network (CNN), optimized with EfficientDet Lite and TensorFlow Lite for fast and accurate image processing. Tools like Visual Studio Code and PHPMyAdmin aided in development and debugging, with compatibility ensured for Google Chrome and Mozilla Firefox. Together, these tools make FruitTech a practical, reliable, and user-friendly solution for modern agricultural needs.

Testing and Evaluation

The system was presented, demonstrated, and used by the participants to assess its functionality. The system was evaluated according to ISO/IEC 25010 standards to assess its quality attributes. A total of 100 respondents participated in the survey, selected through a cluster sampling procedure. The survey questions were self-administered, closed-ended, and provided in both English and Filipino to be accessible to the various participants. Google Forms gathered responses from remote IT experts, and in-person participants completed paper questionnaires. Responses were analyzed using a 4-point Likert scale, where a score of 4.00–3.50 indicated "Strongly Agree," 3.49–2.50 "Agree," 2.49–1.50 "Disagree," and 1.49–1.00 "Strongly Disagree," ensuring structured and quantifiable data for system evaluation. The identity of the participants was kept hidden to preserve anonymity throughout the study.

ISO/IEC 25010

The system evaluated using ISO/IEC 25010 follows a quality model specifying eight essential features for a complete software quality assessment. These include Functional, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability, and Portability, all crucial for evaluating the system's overall quality. Each feature ensures the system can meet user needs, perform efficiently, integrate seamlessly with other systems, and maintain security and reliability. This comprehensive evaluation helps guarantee the system's effectiveness, adaptability, and long-term usability in real-world environments.

Table 1: Component of ISO/IEC 25010 Questionnaire

Criteria	Indicator
Functional Suitability	Provides all necessary features for effective power consumption monitoring.
	Accurately performs intended functions related to monitoring power consumption.
	Functionalities are suitable for effectively monitoring power consumption.
Performance Efficiency	Responds to user queries and real-time data requests within an acceptable timeframe
	Utilizes network bandwidth without causing noticeable slowdowns.

	Handles substantial data volumes without compromising responsiveness.
Compatibility	Coexists with other systems in a shared environment without affecting performance.
	Integrates seamlessly with external devices and services, supporting its core objectives.
Usability	Uses familiar and appropriate terminology for understanding power consumption data.
	Allows users to monitor power consumption easily, set alerts, authenticate securely with OTP, and generate reports.
	Features a visually appealing user interface design.
Reliability	Continues to operate smoothly even in the presence of faults, ensuring consistent performance.
	Remains consistently accessible during regular usage hours. Recovers efficiently from incidents or outages, minimizing data loss and downtime.
Security	Protects the confidentiality of electricity consumption data and personal information. Ensures the accuracy and constancy of electricity consumption data. Securely traces user actions, maintaining accountability and system transparency.
Maintainability	Adapts well to different consumer needs and preferences. Efficiently assesses and identifies necessary changes for accurate monitoring and clear reporting. Implements automated testing mechanisms to ensure the system's durability and stability.
Portability	Effectively adapts to different hardware, software, and operational environments while maintaining core functionalities. Offers seamless web accessibility, allowing users to access features without installation. Replicates existing software solutions in similar operational environments, providing real-time monitoring.

RESULTS AND DISCUSSIONS

System Interface

The succeeding screenshots show the system output of the eVolta. The first part of the presentation is the admin and the other part is the client side. This includes registration and login to access the application according to their role. The following figures display the said outputs.

The following screenshots show the system output of the FruitTech. It also shows features, including data visualization, report generation, SMS notifications, automated sorting, and a user-friendly interface to enhance the fruit grading process.

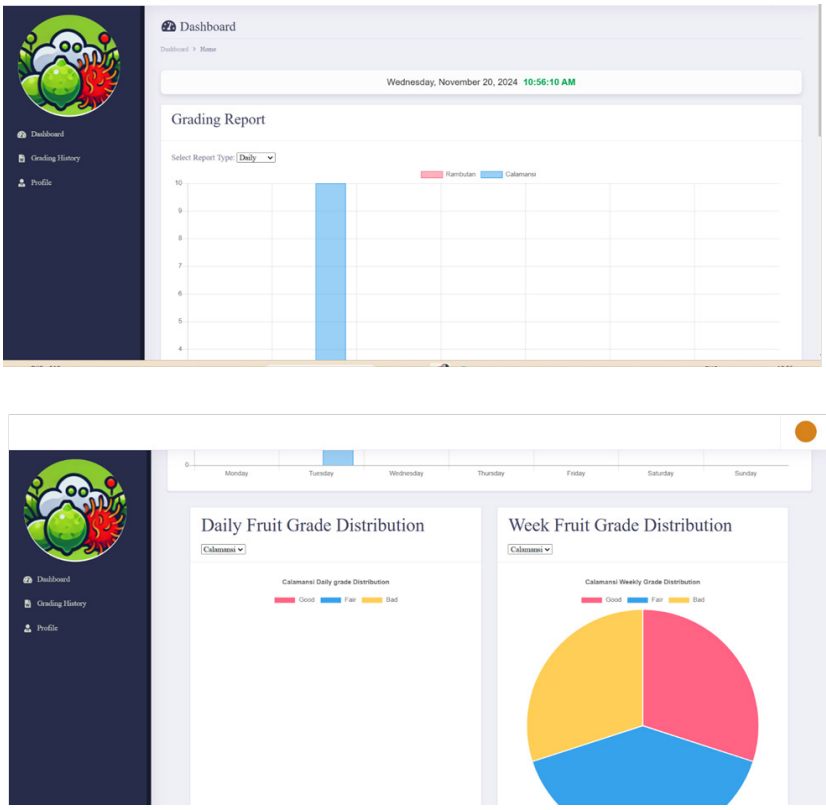

Figure 1: Dashboard Page

The system's dashboard page is displayed, featuring a grading report with options to view data on a daily, weekly, or monthly basis. Additionally, it presents the daily fruit grading distribution as well as the weekly fruit grade distribution.

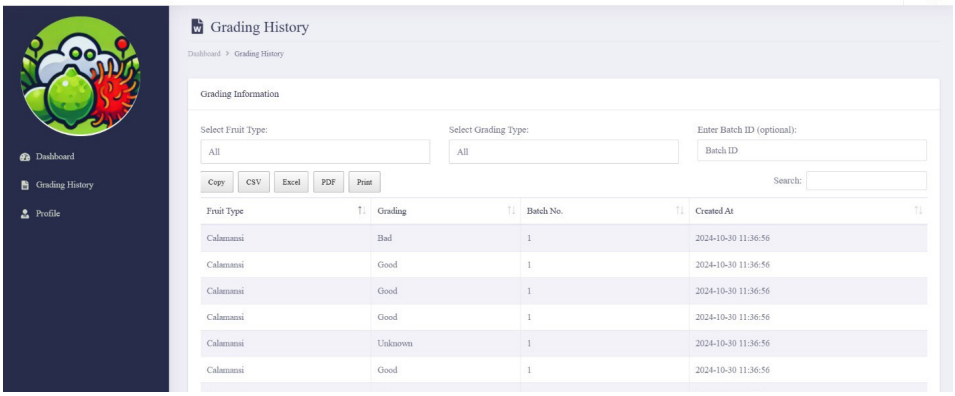

Figure 2: Grading History

The image shows in figure 2 is the grading history page of a web-based system, featuring a table that displays fruit grading information. Users can filter the data by selecting fruit type, grading type, and optionally entering a batch ID. The page also includes options to export the data in various formats such as CSV, Excel, PDF, or print the report. The table lists the fruit type, grading, batch number, and the creation timestamp for each entry, providing a detailed view of the grading history in an organized and user-friendly layout.

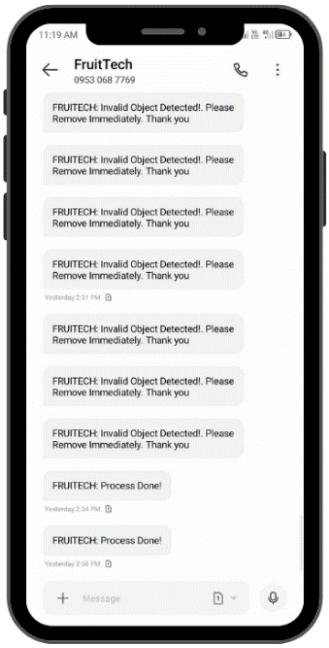

Figure 3: SMS Notification

The image shows in figure 3 is the mobile phone displaying a series of text messages from a system called FruitTech. The messages indicate an issue where an "Invalid Object" was detected, with a request to "Please Remove Immediately. Thank you." These warning messages appear multiple times, followed by two messages stating "Process Done." The phone is displaying these notifications as part of a process, possibly related to the system's fruit grading or sorting operation.

The table 2 provides an evaluation of the system based on the ISO/IEC 25010 software quality model criteria. Among the criteria, functional suitability achieved the highest mean score of 3.483, indicating strong agreement from respondents on the system's ease of adaptation to different environments. Portability followed closely with a mean of 3.431, emphasizing its reliability in protecting data and maintaining system integrity. Conversely, performance efficiency scored the lowest mean of 3.233, suggesting room for improvement in optimizing the system's speed and resource utilization. The overall mean score of 3.390 reflects a general agreement on the system's quality across all assessed criteria, demonstrating

Table 2: Summary Result of Evaluation using ISO/IEC 25010

Criteria	Mean	Rank	Verbal Interpretation
Functional Suitability	3.483	1	Agree
Performance Efficiency	3.233	8	Agree
Compatibility	3.414	4	Agree
Usability	3.370	7	Agree
Reliability	3.374	6	Agree
Security	3.424	3	Agree
Maintainability	3.412	5	Agree
Portability	3.431	2	Agree
Overall Mean	**3.393**		

satisfactory levels of functional suitability, compatibility, usability, reliability, maintainability, and portability, with portability identified as the most significant attribute.

CONCLUSION

The findings of this study demonstrate that FruitTech successfully automated the grading process for calamansi and rambutan, utilizing a cloud- based platform integrated with machine learning. The system effectively analyzed fruit quality based on appearance and physical defects, providing real-time feedback and data visualization to support informed decision-making among farmers. Additionally, the inclusion of SMS notifications and automated sorting mechanisms streamlined the grading and handling process, reducing labor costs and improving efficiency. The system was evaluated using ISO/IEC 25010 and UTAUT, confirming its reliability, usability, and strong potential for adoption in the agricultural sector.

To enhance FruitTech's capabilities, future improvements should focus on expanding its applicability to other fruit varieties, improving image preprocessing for better accuracy, and integrating advanced sensors for detecting internal fruit defects. Developing an offline version would ensure accessibility in rural areas with limited internet connectivity, while incorporating IoT-enabled real-time monitoring could further optimize system performance. Additionally, making FruitTech portable and energy-efficient through solar or battery-powered solutions would increase its adoption among small-scale farmers. These advancements will strengthen the system's impact on modernizing fruit grading, ensuring greater efficiency, accessibility, and accuracy in agricultural practices.

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