Introduction

In the Philippines, the coconut industry is a significant agricultural sector, with 69 of the 82 provinces producing coconut. (Department of Science and Technology, 2022). Harvesting coconuts is done for a variety of purposes. Seed nuts typically take seven to nine months to grow from the flower opening before it matures, which results in the sweetest and tastiest coconut water. It takes ten to thirteen months for seed nuts to mature from the flower opening such that the kernel is thick enough for commercial usage in copra, coconut milk, and other food products derived from it.(Harvesting and Post-Harvest Management, 2016). However, the time-consuming and manual procedure of identifying coconut maturity is one of the major obstacles these growers must overcome. Farmers have historically had to physically climb trees or use visual estimation from the ground, which results in inefficiencies, poor decisions, and a higher risk of accidents at work (Cabaluna et al., 2024). Properly assessing the ripeness of coconut fruit is still A challenging task that affects the quality of the final product and customer satisfaction (Lertchuwongsa Noppon & Parinyavuttichai Nipon, 2021).

Considering harvesting coconuts usually involves climbing trees, it is regarded as one of the riskiest agricultural vocations in the Philippines. Harvesting the so-called tree of life might cause workers to suffer serious injuries or perhaps die because of the tree's height and structure.(Novelero & Dela, 2022). Once at the top, the climber uses their harvesting knife to tap the nut in the lowest bunch to make sure it is mature(Kumar et al., 2023). By eliminating the need for physical climbing investigation, AI-based on-tree coconut maturity detection can assist farmers in determining their preferred time of harvest, saving money on labor. AI-powered systems are a promising answer for coconut farming, since studies have shown that deep learning models such as YOLOv8 can successfully detect coconuts with a Mean Average Precision (mAP50) of 99.5% (Cabaluna et al., 2024). Farmers may increase productivity and improve the quality of their goods by putting in place a system that analyzes photos, determines when coconuts are mature, and estimates the preferred ideal time for the farmers to harvest.

This study aligns with the University R&D Agenda, Thrusts, and Priorities by contributing to agricultural innovation through the application of information system and communication technology, specifically mobile application development and expert systems. The development of an AI-powered solution for in-tree coconut maturity detection supports the priority of modeling and simulation in agricultural decision-making. Additionally, the project promotes sustainable farming practices by optimizing natural resource utilization and minimizing labor-intensive and hazardous harvesting methods. By developing a mobile application, the research ensures that small-scale farmers in rural areas can access modern agricultural technology.

Statement of the Problem

* High Risk in Manual Coconut Maturity Assessment – Farmers frequently climb tall coconut trees to assess maturity by tapping the fruit, exposing them to significant risks of falls and injuries (Harvesting and Post-Harvest Management, 2019; Kumar et al., 2023).
* Lack of On-Tree Maturity Detection Solutions – Most studies focus on detecting maturity after the coconuts have been harvested (Cabaluna et al., 2024). This creates a significant gap in the estimation of pre-harvest, on-tree maturity, which could lower the risk of climbing investigations and increase harvesting effectiveness.
* Limited Availability of On-Tree Classification – Existing datasets primarily consist of images of harvested coconuts(260 images) leading to models that may not generalize well to real-world conditions where factors like lighting, background interference, and obstruction of tree canopies affect accuracy (Cabaluna et al., 2024). A diverse dataset capturing on-tree coconuts from multiple angles and environmental conditions is needed for better model performance.

Objective of the Study

Main Objective:

* Develop and implement a smartphone-based AI system that utilizes computer vision to accurately assess the on-tree maturity of coconuts(Premature, Mature), eliminating the need for manual tapping and climbing, thereby enhancing safety, efficiency, and decision-making for farmers.

Specific Objectives:

* Collect a diverse dataset of on-tree coconut images from multiple angles, lighting conditions, and environmental settings to improve model robustness.
* Implement and compare different deep learning architectures such as CNN, YOLOv8, and MobileNetV3 to determine the most suitable model for coconut maturity classification.
* Develop an Android Mobile Application without needing access of the internet to provide farmers with immediate detection and maturity predictions by uploading images and receiving instant analysis.
* Evaluate the System's Performance by measuring accuracy, recall, and precision compared to manual assessment.
* Conduct field testing with local farmers to evaluate the usability and reliability of the mobile application.

Scope and Limitations of the Study

#### This study focuses on developing an AI-based on-tree coconut maturity detection system using a machine learning model optimized for smartphones. The dataset will consist of manually collected images from coconut farms in [Tiaong, Quezon], supplemented with publicly available images from online sources to enhance model generalization. Data collection will take place over two months, capturing images under different lighting conditions, angles, and environmental factors.

The study will utilize CNN for maturity assessment, categorizing coconuts into three maturity levels: premature, mature and overmature. Preprocessing techniques such as image augmentation will be applied to improve model accuracy. The system will be integrated into an Android-based application, allowing farmers to assess coconut maturity by capturing images with their smartphones. Performance evaluation will be conducted using metrics such as Mean Average Precision (mAP), accuracy, and inference time, ensuring the model's effectiveness in real-world conditions.

#### Limitations:

* The system will only classify coconuts into three categories: premature, mature and overmature.
* The study will not include post-harvest quality assessment .
* The model is optimized for smartphone-based detection and does not utilize drones or specialized agricultural sensors, which may limit large-scale farm automation.
* The study will focus more on the low-end smartphones and not on high-end smartphones for farmers' utilization, since performance may vary on low-end smartphones due to hardware constraints, processing power, and camera quality differences but more affordable for the users.
* The study will focus more on classifying coconut maturity on the trees less than 40 to 60ft. Because of some factors such as lighting conditions, weather variations, occlusions from leaves and especially for the low-end smartphones may affect detection accuracy.

Project Requirements

Software

* + Programming and Other Languages
    - Python – a widely used programming language and essential in areas such as data science, data analysis, machine learning, data engineering, web development, software development, and more (Kosourova, 2024).
    - HTML – Hypertext Markup Language (HTML) is a fundamental scripting language that web browsers use to display pages on the World Wide Web (Hayes, 2024).
    - CSS – stands for Cascading Style Sheets, is a language used to design and style elements written in markup languages like HTML (Domantas, 2023).
    - JavaScript – A scripting language used to create and manage dynamic website content, such as elements that move, refresh, or change on the screen without the need to manually reload the web page (Morris, 2023).
  + IDEs:
    - Jupyter Notebook – A powerful tool for developing and sharing data science projects. It lets you combine code, visuals, text, and other media into one document, making the workflow clear and easy to follow (Dataquest, 2024).
    - Visual Studio Code – a fast, free code editor that covers nearly every aspect of the software development lifecycle (Heller, 2022).
  + Version Control System
    - Git – a free, open-source tool for managing source code that helps multiple developers work together on projects of any size by keeping track of changes (Perveez, 2024).
    - GitHub – a web-based version control for software developers used for collaboration (Lutkevich, 2024)
  + Frameworks
    - Python 3.11 – the latest major version of the Python programming language, packed with new features and performance improvements (Python.org, 2024).
    - TensorFlow 2.18 – an open-source library compatible with Python, designed for building machine learning applications and neural networks (Yegulalp, 2024).
    - OpenCV – a highly efficient open-source library for performing image processing tasks in computer vision (Rzechowski, 2023).
  + Python Libraries
    - NumPy – an open-source library for Python that supports mathematical and scientific computing (Bigelow, 2024).
    - Pandas – a Python library used for working with and manipulating tabular data (Chugh, 2023).
    - Scikit-Learn – specializes in machine learning tools, encompassing mathematical, statistical, and general-purpose algorithms that underpin numerous machine learning technologies (Rouse, 2019).

Review of Literatures and Study

Recent studies have explored AI-driven approaches for coconut maturity classification, particularly using deep learning models like YOLOv8 and CNNs. Cabaluna et al. (2024) developed a YOLOv8-based detection system for mature coconuts, achieving 99.5% accuracy, yet emphasized the need for more diverse datasets and real-world deployment. Similarly, Novelero & Dela (2022) explored on-tree coconut detection using UAV images, highlighting deep learning's effectiveness in automating agricultural processes. Despite these advancements, environmental factors such as lighting variations, background clutter, and occlusions remain challenges, affecting model accuracy (Parvathi & Tamil Selvi, 2021).

Research also underscores the role of CNNs in coconut maturity assessment, leveraging their ability to extract hierarchical features from both visual and acoustic data for improved classification (Abadies et al., 2024). Kumar et al. (2023) reviewed the status and feasibility of automated coconut harvesters, emphasizing the need for AI-driven solutions to enhance efficiency. While existing AI models demonstrate high accuracy, further dataset expansion, real-world testing, and mobile-based implementations are needed to ensure usability for farmers in rural settings.

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