**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.

**Analysis and Design Process**

In this area, the researchers and programmers listed all the problems we are trying to solve along with the solution that will be present in our system. These are as follows:

* High Risk in Manual Assessment – Farmers often climb tall coconut trees—sometimes up to 70 meters high—to assess fruit maturity by tapping the coconuts, which exposes them to a significant risk of falls and injuries (Harvesting and Post-Harvest Management, 2019; Kumar et al., 2023). Implementing an automated system for detecting coconuts at such heights can eliminate the need for manual climbing, thereby reducing the risk of injury.
* 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.

To summarize, the researchers and developers examined the problems and risks associated with the traditional method of assessing coconut maturity. In response, the system was designed to eliminate these risks by automating the assessment process using object detection. By uploading images to the system, users receive a preprocessed output: a cropped 1x1 image where all coconuts are enclosed in bounding boxes and labeled according to their maturity stages.

A diagram of a computer

AI-generated content may be incorrect.To better visualize the data flow of the system, **Figure 1** illustrates the data flow that the system follows. The user uploads a single image and clicks “Analyze.” After a brief processing period, the system returns a cropped image in which each coconut is enclosed in a bounding box and accurately labeled based on its maturity stage.

**Figure 1: Data Flow Diagram**

**A diagram of a computer

AI-generated content may be incorrect.**

**Figure 2: Class Diagram**

Figure 2 illustrates the modular design of the system, where the classes are divided into distinct components. Initially, the system analyzes and processes the input image. Once the image is ready, the YOLOv5 model is loaded into the system. The next class in the process takes the preprocessed image and draws the bounding boxes around the detected coconuts, also counting the total number of coconuts present. Following this, the system invokes the YOLOv5 model to predict and localize the coconuts within the image. After detection, each identified coconut is classified into one of three maturity stages: Stage 1, Stage 2, or Stage 3. These stages represent different developmental phases of the coconut, based on predefined visual characteristics. Finally, the processed image, now annotated with bounding boxes and the corresponding maturity classifications, is prepared for output display, providing the user with a clear and informative visual result.

**Implementations**

**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).

**System’s Testing**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Test Case ID** | **Test Case Title** | **Preconditions** | **Test Steps** | **Test Data** | **Expected Result** | **Actual Result** | **Status** |
| TC001 | Verify coconut detection with valid image | The user has access to the app | 1. Select a valid image (good\_coconut.jpg)  2. Click Analyze | Image: good\_coconut.jpg | Image is previewed, analysis returns maturity stages, total count, average confidence score | Image previewed; maturity stages detected | Pass |
| TC002 | Analyze button click without selecting an image | App is loaded in the browser | 1. Do not upload any file  2. Click Analyze | No file selected | Alert: "Please select an image first!" | Alert shown | Pass |
| TC003 | Upload unsupported file format | App is ready for upload | 1. Upload file assignment.pdf  2. Click Analyze | File: assignment.pdf | Text Output: "Failed to read image." | Error message shown | Pass |
| TC004 | Upload image with no coconuts | App is running | 1. Upload image potholel.jpg  2. Click Analyze | Image: pothole.jpg | 0 coconuts detected | No detection returned | Pass |
| TC005 | Detect coconuts in high-resolution image | App is working normally | 1. Upload a 4000x3000 image of coconuts  2. Click Analyze | Image: highresolution\_coconut.jpg | Detection completes; system doesn’t crash | Works as expected | Pass |
| TC006 | Upload blurry coconut image | App is ready | 1. Upload blurry\_coconut.jpg  2. Click Analyze | Image: blurry\_coconut.jpg | System attempts, returns confidence score | Works as expected | Pass |
| TC007 | Detect multiple coconuts in complex scene | App is functional and running | 1. Upload crowded\_coconuts.jpg  2. Click Analyze | Image: crowded\_coconuts.jpg | Accurate counts for Stage 1, 2, and 3 maturity levels | Accurate counts returned | Pass |
| TC008 | Refresh page state | App is initially used with a successful upload | 1. Upload valid image  2. Click Analyze3. Refresh browser page | Image: good\_coconut.jpg | Page reloads to empty/default state | Image and results cleared | Pass |

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