Mangosteen Grading System

Phase 1: Planning & Workflow Design

Submitted By

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A Report Submitted in Partial Fulfillment of

the Requirements for

Senior Project 2025

Faculty of Information and Communication Technology

Semester 2/2024

Introduction

Mangosteen, often referred to as the "queen of fruits," is a tropical fruit known for its rich flavor and numerous health benefits. In the agricultural industry, accurate grading of mangosteens based on size is crucial for quality control, pricing, and market distribution. Traditionally, size measurement is performed manually using calipers, which is time-consuming and prone to human error. To address this issue, our project aims to develop an automated Mangosteen Grading System that utilizes deep learning and computer vision techniques to measure the fruit's diameter efficiently.

This project integrates YOLO v11 (Image Segmentation) to detect mangosteens and Hough Circle Transform to identify a reference object (a 1 cm red circle) for size calibration. The proposed system will process images of mangosteens placed on a white background, detect their boundaries, and calculate their diameter in real-world units. The implementation of this automated system can enhance efficiency, reduce human errors, and streamline the grading process in the fruit industry.

Project Phases

To ensure a systematic approach, our group has divided the project into the following phases:

- **Phase 1: Planning & Workflow Design**
  - Define project objectives and methodology.
  - Develop a detailed workflow for data collection, model training, and evaluation.
  - Identify the necessary tools and technologies.
  - Collect images and annotate them using polygon segmentation.
- **Phase 2: Implementation & Model Training**
  - Train the **YOLO v11** model for segmenting mangosteens.
  - Apply the **Hough Circle Transform** to detect and measure the reference circle.
  - Convert detected diameters from pixels to real-world units.
- **Phase 3: Testing & Performance Evaluation**
  - Test the trained model on unseen data for validation.
  - Compare the system's measurements with actual measurements.
  - Analyze key performance metrics, such as precision, recall, and mean absolute error (MAE).
- **Phase 4: Deployment & Optimization**
  - Develop a **user-friendly interface** for practical application.
  - Optimize model accuracy and processing efficiency.
  - Implement batch processing for grading multiple mangosteens in a single image.

By following these structured phases, we aim to develop a robust and efficient grading system that can be implemented in real-world agricultural settings. The next section outlines the detailed workflow of our proposed system.

Detailed Workflow

1. Data Preparation

Objective: Prepare high-quality training data for model learning.

1.1 Image Collection

- Capture high-resolution images of mangosteens on a white background with a 1 cm red reference circle.
- Maintain consistent lighting and standardized camera positions to minimize variations.
- Organize the dataset systematically for efficient retrieval.

1.2 Image Annotation (Labeling)

- Utilize offline annotation tools (e.g., LabelMe, CVAT).
- Apply polygon segmentation for more precise shape detection.
- Store labeled data in YOLO annotation format.

1.3 Dataset Splitting

- **Training Set (70%)** – Used for training the model.
- **Validation Set (15%)** – Used for fine-tuning model parameters.
- **Test Set (15%)** – Used to evaluate final model performance.

2. Model Training (YOLO v11)

Objective: Train the model to detect mangosteens accurately.

2.1 Model Setup

- Deploy **YOLO v11** for deep-learning-based image segmentation.
- Configure essential hyperparameters:
    - **Epochs** – Number of training iterations.
    - **Batch size** – Number of images processed per step.
    - **Learning rate** – Speed of model weight adjustments.

2.2 Training Process

- Load the labeled dataset into YOLO v11.
- Utilize GPU acceleration (Google Colab) for efficiency.

- Save the best model weights based on validation performance.

2.3 Model Validation

- Evaluate the model on the validation set.
- Fine-tune hyperparameters to improve detection accuracy.

3. Size Calibration (Using Hough Circle Transform)

Objective: Convert pixel measurements into real-world units (cm).

3.1 Detecting the Reference Circle

- Convert images to HSV color space to isolate the red reference circle.
- Apply thresholding and morphological operations to refine the mask.
- Detect the red reference circle using the Hough Circle Transform.

3.2 Calculating the Scale Factor

- Measure the diameter of the detected reference circle (in pixels).
- Compute the Scale Factor using:

$$Scale = \frac{1\ cm\ (Actual\ Diameter)}{Detected\ Diameter\ (Pixels)}$$

3.3 Measuring Mangosteen Diameter

- Use YOLO v11 to detect the mangosteen boundary.
- Compute the mangosteen's diameter in pixels.
- Convert it to centimeters using:

$$Mangosteen\ Diameter\ (cm) = Detected\ Diameter\ (Pixels) \times Scale\ Factor$$

4. Testing & Evaluation

Objective: Validate system performance and accuracy.

4.1 Testing with Unseen Data

- Test the model on new images outside the training dataset.
- Assess detection consistency across different environments.

4.2 Performance Metrics

- **Precision** – Measures how many detected objects are actually mangosteens.
- **Recall** – Measures how many mangosteens were correctly detected.
- **Mean Absolute Error (MAE)** – Measures the deviation from actual diameter measurements.
- Compare model measurements with ground truth.

5. Deployment & Application

Objective: Implement the system in a real-world environment.

5.1 Developing a User Interface

- Create a GUI or web-based application for user-friendly interaction.
- Allow image uploads and display results with visual overlays.

5.2 Real-World Testing & Optimization

- Test on new images under different conditions.
- Implement batch processing for detecting multiple mangosteens in a single image.
- Retrain the model if significant errors are identified.

Summary of Workflow

1. **Data Preparation**: Image collection, annotation, dataset splitting.
2. **Model Training**: Training YOLO v11 for segmentation.
3. **Size Calibration**: Applying Hough Circle Transform for measurement.
4. **Testing & Evaluation**: Verifying accuracy with real-world measurements.
5. **Deployment**: Implementing a scalable solution for automatic grading.

Flowchart Representation