ABSTRACT

Cashew kernel grading determines the commercial value of nuts based on shape, size, and surface quality.Traditional manual grading is slow and inconsistent due to human error, fatigue, and lighting variations, affecting both product quality and pricing.This project proposes a real-time automated grading system using Computer Vision (CV), embedded hardware, and Artificial Intelligence (AI)-based You Only Look Once — a one-stage object detection framework for real-time applications (YOLO) classification to improve accuracy, speed, and reliability.

The proposed work focuses on developing and implementing an intelligent cashew kernel classification system capable of operating in real time. A Deep Learning (DL) strategy was employed, utilizing a custom dataset recorded with a high-definition webcam under various lighting conditions to represent three commercial kernel grades: W180, W300, and W500. Labeling and data augmentation were performed using Roboflow, and the YOLOv5s model was trained for detection and classification. The model was trained to produce bounding boxes $\mathbf{B}$ and class predictions with good Mean Average Precision (mAP), by optimizing loss functions that include IoU, precision (P), and recall (R).

The trained YOLO model was run on a A compact ARM-based single-board computer used for real-time edge inference and control (Raspberry Pi) for real-time inference at 5 FPS. Video frames from a top-mounted webcam over a conveyor system were processed, and detected classes were sent to an Arduino Uno over Universal Asynchronous Receiver Transmitter (UART). Arduino drove stepper motors and mechanical flaps using L298N drivers to physically sort kernels into bins. The system obtained more than 93% accuracy in classification and doubled the throughput compared to hand grading. Hardware-software co-design guarantees strong edge inference and real-time physical sorting.

Hardware implementation confirmed the simulated results. Real-time inference on Raspberry Pi, complemented by UART-based communication to the Arduino-driven flap system, demonstrated physical sorting accuracy of 94–96% for all three classes—W180 (96%), W300 (94%), and W500 (94%). The combination of AI-based detection with low-cost embedded modules is found to be cost-effective and scalable and provides more than 87% classification accuracy and greatly minimizes operational cost and labor dependency in industrial applications.