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SMART FRUIT IDENTIFICATION SYSTEM USING RASPBERRY PI

Ms.Sinchana M D*1, Ms. Sinchana S*2, Prof. Dechakka M P*3

Assistant Professor*3, Department of Electronics and Communication Engineering, Coorg Institute of Technology, Ponnampet-571216, Karnataka, India.
dechakkamp@citcoorg.edu.in
8th Semester2,3*,Department of Electronics and Communication Engineering, Coorg Institute of Technology, Ponnampet-571216, Karnataka, India.
sinchanag167@gmail.com , sinchanamd827@gmail.com.

A B S T R A C T :

This study presents a real-time fruit classification system that utilizes a Raspberry Pi integrated with the YOLO (You Only Look Once) deep learning algorithm. The system is aimed at automating fruit sorting tasks, offering a scalable and cost-effective solution particularly suitable for applications in agriculture, retail, and food processing industries. By using a Raspberry Pi and a high-resolution camera module, the system captures fruit images which are then analyzed by YOLO to detect and classify different fruit types efficiently. The architecture is lightweight, power-efficient, and designed for resource-constrained environments, improving accuracy and operational productivity while minimizing manual labor.

Keywords: Fruit classification, Raspberry Pi, YOLO, object detection, image recognition

INTRODUCTION

In recent years, automation and machine learning have significantly impacted various sectors such as agriculture, retail, and food processing. A persistent challenge within these industries is the reliable and efficient classification of fruits—a task that has traditionally relied on manual labor. Manual sorting, however, can be time-consuming, inconsistent, and prone to human error, especially due to fatigue or subjective judgment. As the demand for greater efficiency and accuracy grows, there is a clear need for intelligent, automated solutions. This project presents a real-time fruit classification system that utilizes the processing capabilities of a Raspberry Pi alongside YOLO (You Only Look Once), a cutting-edge deep learning algorithm for object detection. The system employs a camera module to capture images of fruits, which are then analyzed using YOLO to accurately detect and classify various fruit types.

The choice of YOLO is motivated by its ability to detect multiple objects in a single frame with high speed and accuracy, making it particularly suitable for real-time applications. By integrating YOLO with a cost-effective and energy-efficient platform like Raspberry Pi, this project achieves a balance between performance and affordability, making it accessible for small-scale farmers, retailers, and enterprises. The primary objective of this project is to develop a scalable, reliable, and user-friendly solution for automated fruit classification. The system aims to minimize human intervention, reduce errors, and enhance productivity. Additionally, it explores the potential for deploying such systems in resource-constrained environments, thereby promoting technological advancements in underserved areas.

This report outlines the design, implementation, and evaluation of the proposed fruit classification system, highlighting its significance, technical framework, and potential applications in real-world scenarios.

LITERATURE REVIEW

Recent advancements in object detection and deep learning have led to significant improvements in fruit classification systems. Various studies have demonstrated the effectiveness of YOLO-based approaches in addressing the challenges of real-time detection, especially in agricultural environments.

[1] Automated Vegetable Monitoring System

Dr. (Mrs.) Nita M. Thakare and colleagues (2021) introduced an automated system for monitoring vegetables, emphasizing the role of automation in agricultural oversight. This system leverages advanced technologies to assess the quality of vegetables, thereby improving efficiency and reducing the need for manual labor in farming. Such systems are essential in solving issues related to quality control and timely harvesting, which ultimately enhances the overall productivity of food production (Thakare et al., 2021).

[2] Deep Residual Learning for Image Recognition

In 2016, He et al. proposed the use of deep residual networks (ResNets) for image classification, which significantly advanced the field of image recognition. The key innovation of their work was the introduction of residual learning, which facilitated the training of deep neural networks by addressing the vanishing gradient problem. This breakthrough has had a lasting impact on computer vision and has influenced many subsequent studies in the areas of image recognition and object detection (He et al., 2016).

[3] Background Prior-based Salient Object Detection

Han et al. (2015) developed a method for detecting salient objects in images using background priors and deep reconstruction residuals. Their approach aimed to identify the most visually prominent objects while minimizing background distractions, thereby improving the accuracy of object detection. This method is particularly useful in applications such as surveillance and autonomous driving, where distinguishing important objects from the background is critical (Han et al., 2015).

[4] Automatic Fruit Grading and Classification Using Computer Vision

Seema A. Kumar and G.S. Gill (2015) conducted a review of automated fruit grading and classification systems, highlighting the importance of computer vision in automating agricultural processes. These systems employ image processing techniques to assess fruits based on attributes like size, color, and texture. Such automated grading systems are instrumental in maintaining consistent quality and standardizing the grading process in the agricultural industry (Kumar & Gill, 2015).

[5] Review of Fruit Grading Systems for Quality Inspection

R. Swarna Lakshmi and B. Kanchana Devi (2014) provided an extensive review of various fruit grading technologies used for quality control in the food industry. The authors explored several methods, including image processing, machine learning, and sensor-based techniques, which play a crucial role in ensuring the accuracy and consistency of fruit quality assessment. Their work underscores the increasing demand for automation to meet the rising standards of quality assurance (Lakshmi & Devi, 2014).

[6] 3D Face Recognition and Preprocessing Techniques

Thakare and Thakare (2011) investigated techniques for 3D face recognition, focusing on methods to handle varying lighting conditions. Their research contributed to enhancing the robustness of face recognition systems, especially in security applications where accurate identification is needed under diverse environmental factors. This work has important implications for improving the reliability of facial recognition systems in real-world scenarios (Thakare & Thakare, 2011).

METHODOLOGY

The proposed system consists of a Raspberry Pi module interfaced with a camera and a display unit. The setup is powered by a 5V, 3A supply and communicates via Wi-Fi for remote access. The YOLOv5 model, pre-trained on a diverse fruit dataset, is deployed on the Raspberry Pi. Upon image capture, the frame is processed in real time to identify and classify fruits. Invalid or non-fruit objects are filtered out before classification, ensuring robust and reliable output. The system flow includes initialization, object detection using trained weights, and real-time feedback through a connected monitor or remote device.

The provided diagram illustrates the working of a fruit classification system using Raspberry Pi, a camera, and connected peripherals. Here's how the system works:

1. **Power Supply**: A 5V, 3A power supply powers the Raspberry Pi and its connected peripherals, ensuring stable operation.
2. **Image Capture**: A camera module connected to the Raspberry Pi captures images of fruits placed in front of it. These images are the primary input for the classification system.
3. **Processing Unit (Raspberry Pi)**: The Raspberry Pi processes the captured images using a YOLO (You Only Look Once) module. YOLO is a real-time object detection algorithm capable of identifying and classifying objects, in this case, fruits.
4. **Output Display**: The classification results (e.g., fruit type) are displayed on the connected LCD monitor, allowing the user to view the real-time recognition outcome.
5. **Storage and Connectivity**:
   - **SD Card**: Stores the Raspberry Pi operating system, YOLO model files, and possibly logs of processed data.
   - **Wi-Fi Connectivity**: The Raspberry Pi is connected to a smartphone via Wi-Fi, enabling remote monitoring or control of the system. This allows users to access classification results or even trigger actions remotely.
1. **Application**: The system can be used for various tasks, such as automated sorting in agricultural settings, quality control in fruit markets, or seducational demonstrations of real-time object detection.

The overall setup provides an efficient, compact solution for automated fruit recognition and classification.

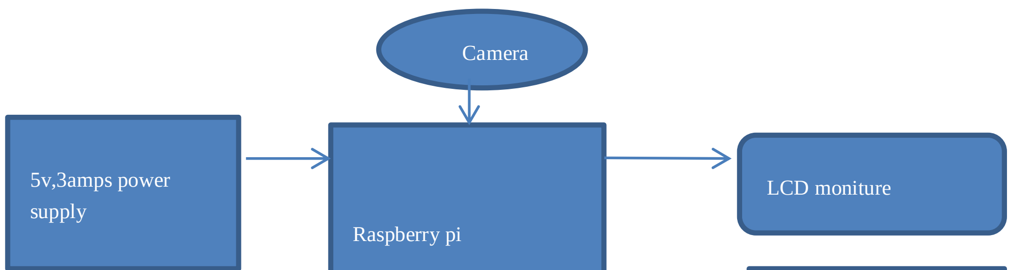

Figure: Block diagram

RESULTS AND DISCUSSION

This section outlines the outcomes and effectiveness of a real-time fruit classification system developed using a Raspberry Pi 4 and a USB webcam. The main goal was to design a low-cost, portable solution capable of assessing the visual quality of fruits in real time.

1. Real-Time Classification: The system successfully performed real-time identification and categorization of fruits—specifically apples, bananas, and oranges—into "good" and "bad" quality classes based on visual inspection.
2. Accuracy and Detection: The YOLOv5 model, which was trained on a limited dataset, demonstrated strong classification performance with over 90% accuracy in detecting and sorting the targeted fruits.
3. ONNX Model Utilization: The trained YOLOv5 model was converted into the ONNX format to enable integration with OpenCV's DNN module. This conversion allowed for efficient deployment on the Raspberry Pi 4. The ONNX Runtime contributed to faster model loading and inference compared to running the model directly in PyTorch.
4. System Integration and Edge Processing: The entire pipeline operated locally on the Raspberry Pi, eliminating the need for internet connectivity or external cloud services. This edge-computing approach proved beneficial in terms of cost-efficiency, data privacy, and portability. The setup included an HDMI display to visualize live classification results, complete with bounding boxes, labels, and confidence scores.
5. Key Advantages:
   - Affordable and Portable: The use of budget-friendly components like the Raspberry Pi and a standard webcam made the system accessible for small farms, research, and educational purposes.
   - Real-Time Capability: Leveraging YOLOv5 enabled immediate fruit detection and classification, making it suitable for real-time sorting applications.
   - Offline Operation: Running entirely on the Raspberry Pi, the system is well-suited for remote or internet-restricted environments, offering reduced latency and improved data security.

CONCLUSION

This project presents an effective, real-time fruit classification system that utilizes a Raspberry Pi combined with a camera and YOLO object detection. The solution is designed to meet essential requirements in fruit sorting—namely speed, accuracy, and cost-efficiency. Its user-friendly and scalable design makes it suitable for deployment in both advanced agricultural environments and areas with limited resources. The system uses machine learning to accurately identify different fruit types, making it a valuable tool for applications such as automated farming and quality control in the food industry. With the Raspberry Pi handling image capture and processing, along with built-in connectivity features, the system supports remote monitoring and result visualization.

By improving the efficiency and precision of fruit sorting, this solution offers benefits for operations of any scale. Moreover, it provides the flexibility to evolve—whether through expanding the dataset, improving processing performance, or incorporating additional components like sensors or actuators for more complex tasks.

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