

# A Novel Approach for Detecting Diseased Apple in Real Time

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**Abstract—** *This paper presents a comprehensive, real-time apple disease detection and sorting system that leverages modern artificial intelligence and embedded automation technologies. Utilizing a YOLOv5 deep learning model for object detection, Python for image processing, and an Arduino Nano for servo motor control, the system accurately classifies apples into fresh or rotten categories. A robotic arm powered by MG995R servo motors performs the actual sorting operation, ensuring precise and damage-free handling. The entire process is synchronized through efficient serial communication between Python and the microcontroller. This integrated solution not only improves produce quality assurance but also significantly reduces labor dependency, processing time, and operational errors in agricultural and food packaging sectors.*

**Index Terms—**YOLOv5, Apple Sorting, Real-Time Detection, Computer Vision, Embedded Systems, Automation

## I. INTRODUCTION

The demand for high-quality agricultural produce has surged dramatically in recent years, driven by a combination of factors including rapid global population growth, heightened consumer awareness of health and food safety, and the increasing role of exports in agricultural economies. Among the wide range of fruits cultivated worldwide, apples stand out due to their high nutritional value, long shelf life, and significant economic impact. However, ensuring the consistent quality of apples from harvest to market remains a persistent challenge, particularly in the context of large-scale production.

Traditional apple sorting and grading methods are predominantly manual and rely heavily on human visual inspection. While manual inspection is viable for small-scale operations, it is inherently limited by factors such as inspector fatigue, variability in human judgment, slow processing speed, and the inability to detect subtle or internal defects. These limitations result in inconsistencies in product quality, increased labor costs, and reduced throughput.

In addition, human inspection is not scalable or sustainable for high-volume processing facilities, particularly those aimed at export standards or automation-driven packaging lines.

To overcome these limitations, automation technologies have increasingly been explored in agriculture and food processing. Computer vision, in particular, has emerged as a promising solution due to its ability to replicate human perception while offering greater speed, consistency, and scalability. The convergence of deep learning techniques with real-time imaging systems and embedded control hardware has paved the way for advanced, intelligent sorting mechanisms capable of enhancing food quality and safety across the supply chain.

In this paper, we present a real-time apple disease detection and sorting system that integrates artificial intelligence and robotic automation. The system is designed to detect surface-level apple defects using a YOLOv5 deep learning model and Python-based computer vision. The detected results are communicated to an Arduino Nano microcontroller, which controls a servo-actuated robotic arm to sort the apples based on their classification (fresh or rotten). By automating the detection and sorting process, the proposed system significantly reduces the reliance on manual labor, enhances accuracy, and increases operational efficiency. The system is cost-effective, modular, and scalable, making it suitable for implementation in small- to medium-scale agricultural and food packaging facilities.

This work demonstrates the potential of intelligent automation in addressing real-world challenges in post-harvest fruit handling. It not only improves the quality control process but also contributes to minimizing food waste and maximizing productivity, thereby supporting broader goals of sustainable agriculture and smart farming.

## II LITERATURE SURVEY

Recent advancements in artificial intelligence, computer vision, and embedded systems have enabled significant progress in the automation of agricultural processes, particularly in the classification, disease detection, and quality prediction of fruits and vegetables.

Paper [1] E. Shanthini et al. (2024) proposed a CNN-based system for fruit disease detection, emphasizing the importance of identifying contaminated produce during packaging. While their model successfully classified diseased fruits, it lacked automated segregation, limiting its use in real-time sorting applications.

Paper [2] Akash A. M. et al. (2023) developed an IoT-based system using Raspberry Pi, DHT11 sensors, and CNNs to monitor storage conditions and detect spoilage. Though effective for shelf-life prediction and remote monitoring, it did not incorporate mechanical sorting components.

Paper [3] Shivani R and Tanushri (2022) implemented deep learning models, including Inception V3, for fruit classification and quality prediction. Their system achieved high accuracy using image datasets but was limited to software-based analysis without hardware integration.

These studies provide strong foundations in fruit classification and disease detection, but most lack real-time sorting. The present work addresses this gap by integrating deep learning with robotic actuation for complete automation.

## III PROPOSED SYSTEM

The proposed system offers an intelligent, real-time apple disease detection and sorting solution that integrates computer vision, deep learning, and embedded control hardware. It is specifically designed to overcome the limitations of manual and semi-automated systems by providing an end-to-end automated approach to fruit classification and handling.

At the core of the system is a USB camera that continuously captures high-resolution images of apples as they are manually placed in the inspection area. These images are processed in real time using

a Python-based script that implements a YOLOv5 deep learning model. The model is trained to recognize visual features indicative of rotten or fresh apples, such as discoloration, bruising, and fungal spots. Once detected, the model labels each apple accordingly.

The classification result is then communicated to an Arduino Nano microcontroller via USB serial communication. The Arduino acts as the main control unit, interpreting the result and driving two MG995R servo motors. These servos control the movement of a robotic arm and gripper mechanism, which sorts the apple by placing it into the appropriate bin based on its classification.

To support the electrical components, the system employs a power supply unit consisting of a 220V to 12V transformer and a buck converter, which step down and regulate the voltage for safe operation of the Arduino and servo motors. The control logic on the microcontroller is written in Embedded C, enabling precise timing and coordination of the sorting mechanism.

This system significantly enhances sorting accuracy and processing speed while reducing dependency on manual labor. It is modular, allowing for easy scalability, and cost-effective, making it suitable for small- to medium-scale agricultural and food packaging applications. The integration of artificial intelligence for detection and microcontroller-based actuation presents a robust and efficient approach to automated fruit sorting.

## IV DATA FLOW

The proposed system follows a well-defined data flow architecture that ensures seamless integration between image acquisition, processing, classification, decision-making, and mechanical actuation. This structured flow allows the system to perform real-time apple disease detection and automated sorting with high accuracy and speed.

The process begins with image acquisition, where a USB camera continuously captures real-time images of apples placed manually in the inspection zone. The camera is interfaced with a Python-based computer vision module using OpenCV, which fetches video frames for processing.

Next, in the image preprocessing stage, each captured frame undergoes enhancement operations such as resizing, noise reduction, and color adjustment. These operations are essential for improving the quality and consistency of the input data, ensuring robustness in varying lighting conditions.

The pre-processed image is then passed into the YOLOv5 deep learning model for object detection and classification. The model detects apples within the frame and classifies them as either fresh or rotten based on features such as texture, surface defects, and color. Detected apples are highlighted with bounding boxes and corresponding labels for visual confirmation.

To ensure classification reliability, the system incorporates a stabilized decision-making mechanism. Instead of acting on a single frame, it uses a counter-based method to track consistent classification results across multiple consecutive frames. This step minimizes false detections caused by noise or transient changes in appearance.

Upon reaching a stable classification decision, the system transitions to the signal transmission phase. The Python script sends a corresponding character ('G' for fresh, 'R' for rotten) to the Arduino Nano through USB serial communication.

Finally, in the sorting execution phase, the Arduino interprets the received signal and activates two MG995R servo motors connected to a robotic arm and gripper. The arm moves accordingly to place the apple into its designated bin fresh or rotten. After completing the operation, the arm resets to its neutral position, ready for the next apple.

This entire data flow from image capture to physical sorting is cyclic and continuous, enabling the system to process apples in real time with high accuracy, minimal human intervention, and consistent performance under varied environmental conditions.

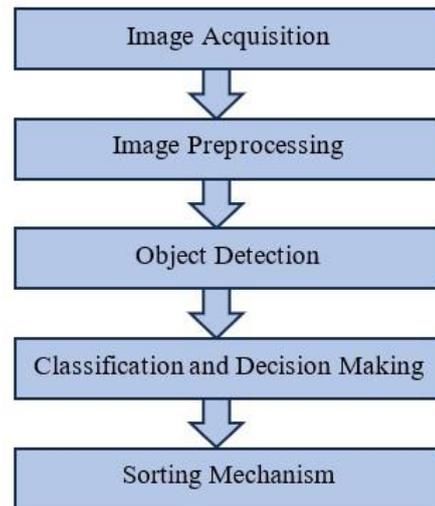


Figure 1: Data Flow Diagram

## V SYSTEM ARCHITECTURE

The architecture of the proposed apple disease detection and sorting system is designed for modularity, low-cost deployment, and real-time performance. It consists of integrated hardware and software modules that work in synchronization to detect and sort apples based on their surface conditions.

The hardware subsystem includes a USB camera, Arduino Nano, MG995R servo motors, a gripper mechanism, and a power supply unit comprising a 220V to 12V transformer and a buck converter. The USB camera acts as the image acquisition device and is directly connected to a computer running Python scripts. It captures real-time video frames of apples manually placed in front of the system.

The software subsystem is responsible for image processing and classification. The images captured by the camera are processed using OpenCV in Python. A pre-trained YOLOv5 object detection model identifies apples and classifies them as either fresh or rotten. The classification is based on visual characteristics such as discoloration, fungal growth, and bruises. Detected apples are highlighted with bounding boxes and labeled with either 'G' (Good) or 'R' (Rotten).

Once classification is complete, the result is sent to the Arduino Nano via serial communication using the PySerial library. The Arduino is programmed using

Embedded C and serves as the central control unit for mechanical actuation. Based on the signal received ('G' or 'R'), it controls two servo motors: one for the horizontal positioning of the robotic arm and the other for the vertical motion of the gripper. The gripper picks up the apple and places it in the respective bin (fresh or rotten).

The power supply module ensures the stable operation of the electronic components. The transformer steps down the voltage from 220V AC to 12V DC, which is further regulated by a buck converter to provide appropriate voltage levels (typically 5V for Arduino and 6V for servo motors). This architecture enables the system to perform real-time classification and sorting in a continuous loop, with high precision and minimal human involvement. Its scalability and affordability make it suitable for small- and medium-scale agricultural operations.

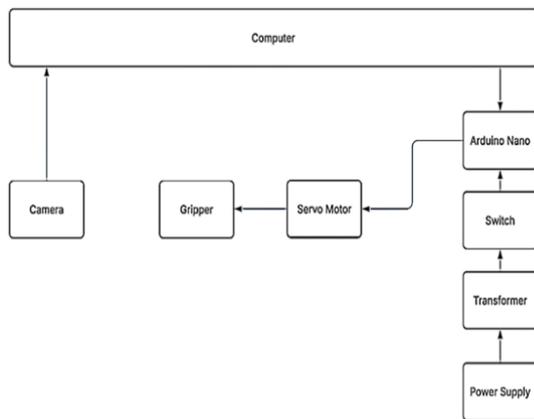


Figure 2: System Architecture

## VI IMPLEMENTATION

The implementation of the proposed apple disease detection and sorting system is divided into two main components: the software implementation for image processing and classification, and the hardware implementation for actuation and sorting.

### A. Software Implementation

The software side is responsible for capturing images, processing them, and classifying the apples in real time. A Python-based program is used, which leverages the OpenCV library to interface with a USB camera. The camera continuously captures live frames of apples as they are manually placed within its field of view.

Each frame is first preprocessed by resizing and noise filtering to enhance clarity and detection

performance. The processed frame is then passed into a YOLOv5 deep learning model (specifically trained on 358 labeled images of fresh and rotten apples) to detect and classify apples. YOLOv5 is selected for its speed and accuracy in object detection, making it suitable for real-time applications.

To improve classification reliability, the software incorporates a frame-based decision mechanism. Instead of reacting to a single frame's prediction, the system maintains counters that track the number of consecutive frames predicting the same label. Once a stable decision (either 'G' for fresh or 'R' for rotten) is confirmed, it is transmitted via USB serial communication using the PySerial library to the Arduino Nano.

### B. Hardware Implementation

The Arduino Nano acts as the core hardware controller, receiving classification signals from the software via the USB serial port. The microcontroller is programmed in Embedded C and responds to the input signals by driving two MG995R servo motors.

One servo motor controls the horizontal movement of the robotic arm to either side fresh or rotten while the other controls the vertical motion of the gripper mechanism, which picks up and releases apples into their respective bins. This actuation system is synchronized to perform the sorting task immediately upon receiving a classification.

To ensure stable power supply, a 220V to 12V transformer is used to convert mains AC voltage to 12V DC. This output is then regulated using a buck converter, providing 5V and 6V outputs for powering Arduino and servo motors respectively.

The entire system is mounted on a custom-built platform made from acrylic sheets, providing mechanical stability, visibility, and easy access for demonstration or field deployment. The prototype includes a side-mounted camera, a front-facing robotic arm, sorting bins, and protected housing for electronics.

This implementation showcases the seamless integration of artificial intelligence and embedded systems to deliver an automated, intelligent, and cost-effective solution for fruit classification and handling.

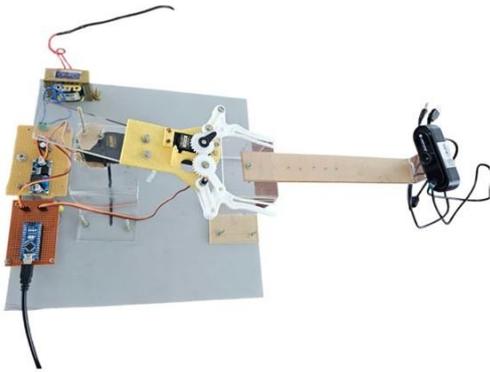


Figure 3: Top view of Prototype



Figure 4: Covered Top view of Prototype

### VII RESULT

To evaluate the effectiveness of the proposed apple disease detection and sorting system, a fully functional prototype was developed and tested under real-world conditions. The system was assessed based on classification accuracy, sorting reliability, responsiveness, and stability across different lighting environments.

The YOLOv5 model used for classification was trained on a dataset of labelled apple images, including both fresh and rotten samples. After training, the system was tested on 100 apple samples, comprising 60 fresh apples and 40 rotten apples. The classification outcome was compared against manually labeled ground truth data to calculate accuracy.

The results demonstrated a high classification accuracy:

- Fresh Apple Accuracy: 98.33% (59 out of 60 correctly classified)
- Rotten Apple Accuracy: 97.5% (39 out of 40 correctly classified)
- Overall System Accuracy: 98%

These results are summarized in Figure 4.

Classification	Actual Apples	Correctly Classified	Accuracy (%)
Fresh Apples	60	59	98.33%
Rotten Apples	40	39	97.5%
<b>Overall Accuracy</b>	<b>100</b>	<b>98</b>	<b>98%</b>

Figure 5: Result on Test Data (100 Apples)

Visual confirmation of classification was achieved through bounding boxes rendered in the live video feed green boxes for fresh apples and red boxes for rotten ones. This added layer of transparency helped monitor model performance during operation.

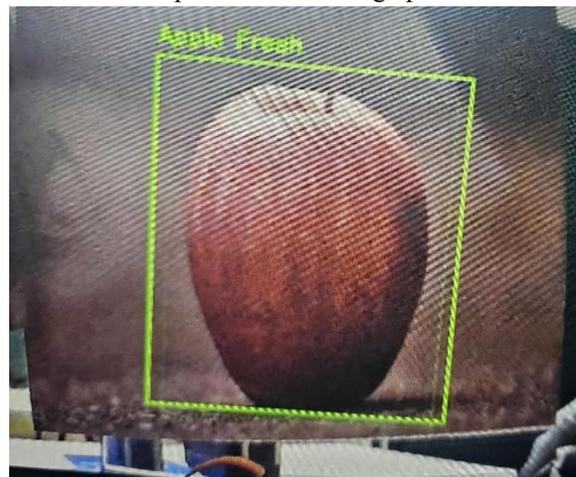


Figure 6: Fresh Apple Sample

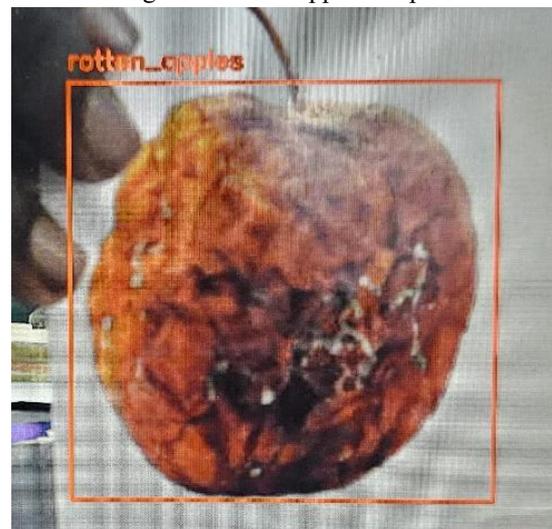


Figure 7: Rotten Apple Sample

In terms of sorting execution, the Arduino-controlled robotic arm successfully responded to classification signals with minimal delay, placing apples into the correct bins without collision or misplacement. The MG995R servo motors provided fast and precise

movements, and the gripper securely handled apples of various sizes without causing damage.

Furthermore, the system demonstrated robust operation under varied lighting conditions and sustained performance during extended use without mechanical or electrical failure. This confirms the reliability of the system for continuous use in small- to medium-scale agricultural environments.

#### VIII CONCLUSION

This paper presents a novel, real-time apple disease detection and sorting system that combines deep learning-based image classification with embedded automation. The integration of a YOLOv5 model with Python and OpenCV enabled accurate identification of surface-level defects in apples, while an Arduino Nano-based robotic arm executed precise sorting actions based on classification results. The system achieved an overall classification accuracy of 98% during real-world testing, demonstrating both its reliability and practical applicability.

The design is modular, low-cost, and scalable, making it suitable for deployment in small- to medium-scale agricultural and food packaging environments. By automating the traditionally manual process of fruit inspection and sorting, the proposed solution significantly reduces labor dependency, enhances consistency in quality control, and supports faster processing.

The successful implementation and testing of this system highlight the potential of combining artificial intelligence with embedded systems for smart agricultural applications. The project contributes meaningfully toward the advancement of automated, intelligent, and efficient post-harvest processing technologies, aligned with the growing needs of modern agriculture.

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