© April 2025 | IJIRT | Volume 11 Issue 11 | ISSN: 2349-6002

Design and Development of Color Sorting Mechanism of Fruits and Vegetables for Food Industry

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***Abstract*—This project's goal is to use an Arduino Uno microcontroller with an ESP 32 CAM object detecting module to construct a color sorting mechanism in the food business. Sorting fruits and vegetables according to their color and texture throughout production is crucial since the outcome has a direct impact on the company's reputation and the calibre of the final product that customers purchase. By substituting machine labor for manual labor, the paper seeks to remove errors that arise during the color sorting process. With the aid of the ESP 32 CAM module and the Edge Impulse software, it is capable of color and shape detection. We can quickly decrease labour-intensive tasks and boost efficiency by putting in place a color sorting system.**

***Index Terms*—Arduino uno, Conveyor, Edge impulse, ESP-32 CAM, Sorting.**

I. INTRODUCTION

In the manual color sorting of fruit and vegetables, a person visually inspects the products and separates them according to their color. This process is labor-intensive, subjective and prone to human error. Manual color sorting is done in numerous steps, which costs a lot of time and money, leads to poor hygiene and encourages human error. This is not good for the food and frozen food industries that use the sorting technique. By implementing a color sorting mechanism, we can reduce human errors and costs, save time and maintain quality and hygiene, which helps the industry maintain its reputation and gain customer trust. This paper is about the design and development of a fruit and vegetable color sorting mechanism using Esp32 CAM for color and object recognition. In this paper, a conveyor belt is used as a transportation medium for fruits and vegetables, which helps us to increase the production speed and save time. The conveyor belt consists of a drive roller connected to a shaft, a driven roller also connected to a shaft, a belt, a frame, a motor (which provides the rotation), fasteners, support screws and bearings. The ESP32 CAM is a versatile and widely used module with Wi-Fi/Bluetooth system on a chip manufactured by Espressif Systems. The ESP32 CAM is used to capture images of objects being sorted on the conveyor belt. To perform object recognition with an ESP32 CAM on Edge impulse, we first need to collect several images of fruits or vegetables and then label them. After that, we need to train a model and then export it to an Arduino library to use it on the ESP32 CAM. For sorting, we use a servo motor to help us push or pull the sorted vegetables to the corner. An infrared sensor is used to detect the presence of fruit and vegetables on the conveyor belt and also helps in timing the sorting mechanism (such as an actuator or servo motor).

II. LITERATURE SURVEY

Discussion about the existing color sorting mechanism of fruits and vegetables along with their color detecting sensor, micro-controller, and their limitation is done in this section.
[1] Kunhimohammed C. K, Muhammed Saifudeen K. K, Sahna S, Gokul M. S and Shaeez Usman Abdulla, et al – This research paper presents a prototype of an automatic color sorting machine designed for industrial applications. The main goal is to automate the sorting of object by their color using a TCS230 color sensor and a PCL16F628A microcontroller.
Limitations- The system can only sort 3 color (Red, Green, Blue), which make unsuitable for sorting multiple color object and the prototype was tested only with small object like soda plastic bottle caps making less adaptable for irregularly shaped items.[2] Indah Sulistiyowati, Hafidz Maulana Ichsan, Izza

Anshory, et al - This research presents a color-based object sorting system using an ESP-32 camera integrated with OpenCV in Python. The setup includes a conveyor belt controlled by an Arduino Uno R3 microcontroller, an ESP-32 camera for color detection, and servo motors for sorting objects into different categories. The system successfully sorts objects based on color with reasonable accuracy (Red: 80%, Green: 100%, Blue: 80%). Future improvements could include additional sensors, better lighting conditions, and advanced image processing techniques to enhance sorting accuracy and efficiency. Limitations-The ESP-32 camera is highly affected by ambient light, leading to inaccurate color detection due to noise and the ESP-32 camera tends to overheat, which may cause delays in processing.[3] M. Khojastehnazhand, M. Omid and A. Tabatabaeefar, et al - This work presents an automated grading system for lemons that uses machine vision to evaluate two key external quality attributes—color and size. The system employs a dual-camera configuration with two CCD cameras mounted approximately 25 cm above the conveyor belt. These cameras capture images of lemons against a white background under uniform illumination provided by four fluorescent tubes. Limitations-Despite a controlled lighting setup, slight variations in illumination can affect the accuracy of color detection and being PC-based, the system might not achieve the same level of real-time performance as solutions using dedicated microcontrollers or embedded systems.[4] Deepak Devasagayam, Ajinkya Shende, Aldrick Gonsalves, Kaustubh Padalkar, Vinit Rodrigues, et al- This paper presents the conceptual design and development of an automated fruit sorting and packaging machine. Detailed design calculations are provided for critical components such as the hopper and chain drive mechanism. Finally, the paper discusses limitations and areas for further improvement. An ESP32-CAM with OV2640 sensor is used to capture images for fruit recognition. This module is interfaced via an FTDI programmer. An Arduino UNO board is selected to process the input from the camera module and to control the sorting mechanism (actuated via servo motors). Limitations- Integrating multiple subsystems (sorting, packaging, weighing, and labelling) into a single unit increases overall system complexity and potential points of failure. Regular calibration is needed for the hopper and image processing unit to maintain sorting accuracy over time and the design presented is conceptual. Actual fabrication may reveal unforeseen mechanical tolerances or integration challenges.

Summary- The reviewed studies focus on automated color-based sorting system using different technologies. [1] By using TCS230 color sensor with microcontroller [2] Using ESP-32 CAM with OpenCV, [3] A machine vision-based lemon grading using dual camera system and [4] Design calculation of hopper and chain drive using ESP-32 CAM with Arduino Uno micro-controller. Each study highlights advancements in automated sorting system.

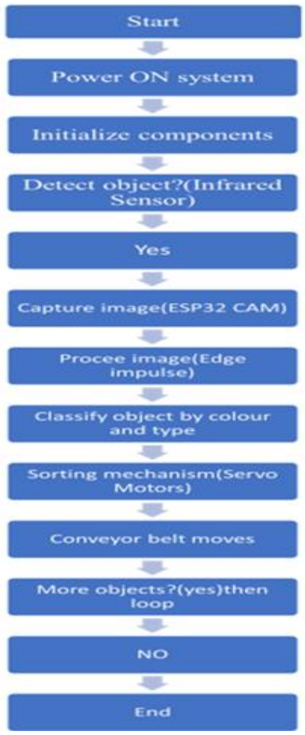
III. PROBLEM STATEMENT AND DESCRIPTION

Problem statement- 'Design and Development of Color Sorting Mechanism of Fruits and Vegetables for Food Industry'. Color sorting mechanisms are crucial in the food industry to ensure quality, safety, and efficiency by removing defective or contaminated products, improving efficiency, and reducing labor costs.

Figure 01 Manual chili sorting

Problem Description-Manual color sorting of fruit, vegetables and seeds is common in the agricultural, food and frozen food industries. In manual color sorting, trained employees visually inspect and separate food products (such as grains, fruits or nuts) by color, size, shape and presence of defects to ensure quality and uniformity. This is a good process, but it is also expensive, time-consuming and requires more labor. By replacing manual color sorting with a color sorting mechanism, we can easily increase industry productivity by saving time and money, reducing errors, maintaining the hygiene and quality of the product and reducing the number of workers.

IV. METHODOLOGY



V. LIST OF COMPONENTS

1) Conveyor Belt (conveyor rollers, shafts and belt)
2) ESP32 CAM
3) Infrared Sensor
4) Servo motor
5) Arduino Uno
6) DC Motor
7) Pulley System.

Figure 02 ESP32 Cam and IR Sensor

VI. PROTOTYPE DESIGN AND MANUFACTURING

Design of conveyor belt-$L = 2C + \pi/2(D + d) + (D - d)2/4C$
L = Total belt length
C = Centre-to-centre distance between pulleys (mm)
D= Diameter of the larger pulley (mm)
d = Diameter of the smaller pulley (mm)
In my case, we already have a conveyor belt, size (L=470mm, W=165mm, T=5mm).

Design of conveyor roller & shaft- The roller length should match or slightly exceed the conveyor belt width (W).
$Lr = W + clearance$, Lr=165+5=170 mm (assuming 5mm clearance) So, my final roller length is 175mm and diameter is 50mm.
The total shaft length (L) is=175+(2×30) +(2×25), L=175+60+50, L=285 mm (For this prototype 475mm length for driver shaft and 375mm for driven shaft is sufficient).

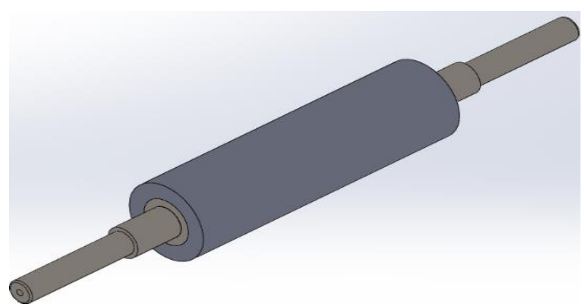


Figure 03 Conveyor roller shaft (Cad Model)

We have chosen 15 mm diameter for the shafts, but let's verify if it is safe.
By applying torsion equation, we get conclusion: A 15 mm diameter shaft is strong and safe for this application.
For material mild steel is suitable.

Design of conveyor frame- When designing a conveyor frame body consider factors like material properties, load capacity, safety regulations and environmental considerations.
Conveyor Frame Length: $L = Roller\ Distance + End\ Clearance$
Roller Distance: Distance between the two end rollers.

End Clearance: Space left for mounting the rollers.
Conveyor Frame Width (W): $W = Belt\ Width + 2 \times Side\ Clearance$
Belt Width: Typically, 165 mm (from your project).
Side Clearance: Space left for side guides and structure (5-10 mm on each side).

Figure 04 Conveyor belt prototype

Conveyor Frame Height (H):$H = Leg\ Height + Frame\ Depth$

Color and Object Identification-For color and object identification, we use ESP32 CAM. Software's like Edge Impulse is used for image processing and Arduino Ide is used for inserting programs. To perform color detection with an ESP32-CAM and Edge Impulse, steps are to be follow-

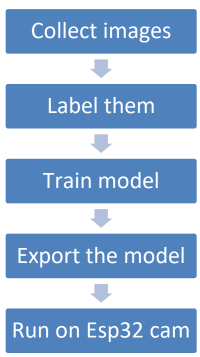


Figure 05 Steps for image processing

VII. STEPS TO ASSEMBLY OF PROTOTYPE

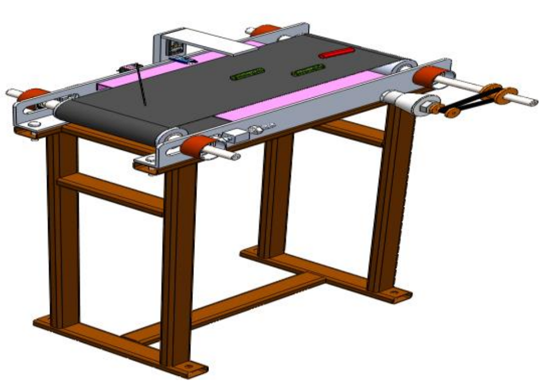


Figure 06 CAD Model for Prototype

1. First, we insert the conveyor roller and the shaft into the conveyor frame.
2. Then adjust the belt on the conveyor rollers using the belt tensioning mechanism.
3. After mounting the belt, we install the pulley system in the driver shaft and the DC motor.
4. Then we set the position of the Esp32 camera from where it can capture the object.
5. Then we install an infrared sensor near the Esp32 cam to detect the position of the objects.
6. Finally, we use a servo motor to sort different colored objects onto the conveyor.
7.After we have installed all the components, we connect the DC motor, servo motor and infrared sensor to the Arduino Uno using jumper cables.

VIII. RESULT & DISCUSSION

The developed color sorting mechanism successfully identified and sorted vegetable by using the ESP32-CAM and Edge Impulse. The system achieved an accuracy of 90%, with occasional misclassifications due to lighting variations. The conveyor worked efficiently, reducing manual labor and increasing sorting speed. Challenges included overheating of the ESP32-CAM, lighting inconsistencies and synchronization of the servo motors. Compared to manual sorting, the system improved accuracy, hygiene and efficiency. Future improvements include better lighting control, advanced cameras and multi-color sorting capabilities.

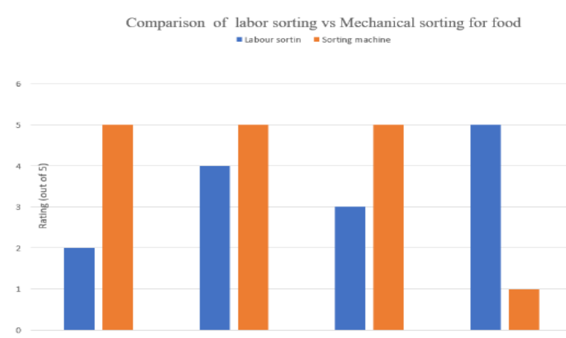


Figure 06 Bar chart

Factors-Speed, Accuracy, Consistency, Human dependency.
Blue bar indicates labor sorting and orange bar indicate machine sorting.

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