

AI Based Robotic Arm for Color Sorting Object

Guide: Dr.N. S Ambatkar

Students: Krutika Koturwar, Aditya Sharma, Rohan Digraze, Isha Deshmukh

Priyadarshini College Of Engineering, Nagpur

Abstract: Color sorting robotic arms have improved industrial automation by making material handling more accurate, efficient and productive. This paper explores the development of a robotic arm system that identifies and sorts objects based on their colors. Utilizing a ready-made robotic arm, an Arduino Uno microcontroller, and an OpenCV-based color detection system, the project aims to automate the sorting process by placing detected objects into designated containers. The system integrates a camera module, servo motors, and a color recognition algorithm to ensure accurate sorting. The research outlines the methodology, hardware and software implementation, circuit design, and overall system performance. This project not only demonstrates an advanced implementation of robotic automation but also highlights the significance of embedded systems in industrial applications. The robotic arm operates by capturing real-time images of objects, processing color information, and executing precise movements to place items into appropriate bins. The proposed system is a step toward enhancing smart manufacturing processes, reducing human intervention, and improving sorting efficiency in industries like recycling, food processing, and logistics. The research findings illustrate the system's accuracy, limitations, and potential improvements. Additionally, future developments, such as integrating machine learning for enhanced object classification and expanding the system's capabilities, are discussed. This paper serves as a comprehensive guide for future researchers and engineers aiming to develop automated sorting mechanisms.

Keywords: Robotic Arm, Color Sorting, Arduino Uno, OpenCV, Servo Motors, Industrial Automation, Embedded Systems, Image Processing, Object Detection, Smart Manufacturing.

1.INTRODUCTION

The rapid advancement of automation and robotics has revolutionized industrial applications, particularly in manufacturing and sorting processes. Traditional manual sorting methods, prone to errors and inefficiencies, are being replaced by intelligent robotic systems that offer precision and consistency. This research focuses on developing a color-sorting robotic arm system, integrating an Arduino Uno microcontroller with computer vision to autonomously detect and sort objects based on color. By automating this task, industries can significantly improve accuracy, efficiency, and productivity, benefiting sectors

such as logistics, packaging, and recycling. The project aims to design, implement, and evaluate a robotic arm capable of identifying and categorizing red, green, and blue objects, providing a foundation for future advancements in industrial automation.

Color-based sorting is a critical process in many industrial sectors. Manual sorting methods are labor-intensive and prone to errors, leading to inefficiencies and high operational costs. This research aims to address these challenges by designing a robotic arm system capable of autonomously detecting and sorting objects based on color. This project focuses on developing a ready-made robotic arm integrated with an Arduino Uno microcontroller and a computer vision-based color detection algorithm. The system will be able to identify red, green, and blue objects, classify them, and place them into designated containers using servo motors. By automating this process, industries can significantly reduce human intervention and increase productivity. The implementation of robotic automation in sorting tasks presents several advantages, such as increased efficiency, reduced costs, and enhanced accuracy. This research contributes to the field of industrial automation by providing a practical and efficient solution for color-based sorting. The findings of this study will benefit industries that require automated sorting mechanisms, such as recycling plants, food processing industries, and logistics companies. Additionally, this research serves as a foundation for further developments in robotic vision and intelligent sorting systems.

2. WORKING PRINCIPLE

The color sorting robotic arm system operates based on the integration of image processing and robotic actuation. A webcam mounted near the sorting area continuously captures images of objects placed in its field of view. These images are processed in real-time using a computer or microcontroller interfaced with a webcam. With the help of image processing techniques, the RGB values of the object are extracted and analysed to determine its dominant color.

Once the color is identified, a predefined color-to-location mapping logic is used to decide which box the object should be sorted into. The Arduino UNO controls a multi-degree-of-freedom robotic arm equipped with servo motors at each joint. The Arduino receives sorting instructions via serial communication from the image processing system (e.g.,

Python with OpenCV). Based on the input, it actuates the servo motors to pick up the object using a gripper and place it into the designated color-specific container.

3. BLOCK DIAGRAM

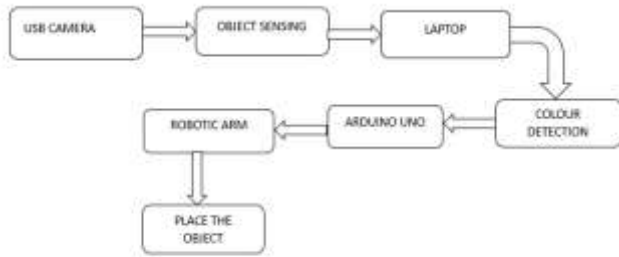


Fig. 1: Overview of the system

4. TECHNOLOGY

A. Arduino Uno Microcontroller Board

The Arduino Uno is a microcontroller board, perfect for electronics projects. It features the ATmega328P microcontroller, which has 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM. The board can be powered by USB or an external power supply and includes a voltage regulator to ensure a stable 5V supply. It has 14 digital I/O pins (6 support PWM output) and 6 analog input pins, which allow it to interface with various sensors and devices. The USB port is used for uploading code and serial communication with a computer. Additionally, it includes a reset button, a 16 MHz crystal oscillator for accurate timing, an ICSP header for direct programming, and a power LED indicator to confirm that the board is powered correctly. The Arduino Uno is user-friendly and versatile, making it a popular choice for DIY electronics and prototyping.



B. C270 HD USB Webcam

The Logitech C270 HD Webcam is a versatile and reliable webcam designed for high-definition video calls and recordings. It offers 720p video quality at 30 frames per second, ensuring smooth and clear visuals. The webcam features a built-in noise-reducing microphone, which captures audio clearly even in noisy environments. The C270 also includes automatic light correction, which adjusts to various lighting conditions to produce brighter and more contrasted images. Its universal mounting clip allows for easy attachment to laptops, LCD monitors, or shelves, providing flexibility in positioning. The C270 is compatible with popular video calling platforms like Skype and Zoom, making it an excellent choice for both personal and professional use.



C. Servo Motor

A servo motor is an electric motor that provides precise control of angular or linear position, speed, and torque using a feedback loop system. It consists of three main components: a motor (either DC or AC), a sensor (such as a potentiometer or encoder) for position feedback, and a controller that regulates the motor's movement according to a desired setpoint. Servo motors are known for their precision, quick responsiveness, and fluid motion, making them essential in high-precision fields such as robotics, CNC machinery, and automated manufacturing. They are widely used in applications that require accurate and controlled movements, such as robotic arms, radio-controlled models, and industrial automation systems.



D. Robotic Arm (Servo-Based)

A servo-based robotic arm is a flexible and precise automation tool used in various applications, such as manufacturing, assembly, and automation. It consists of multiple joints and segments, each driven by a servo motor, which allows for precise control of movement and

positioning. The servo motors receive signals from a microcontroller, to execute specific tasks based on programmed instructions. These robotic arms can manage tasks like picking and placing objects, sorting items, and performing repetitive tasks. The integration of servo motors ensures smooth and controlled movements, making servo-based robotic arms essential in industries that require precision and efficiency.

5. Colour Detection Algorithm

The algorithm begins by capturing image from a webcam and converting each frame from the BGR colour space to the HSV (Hue, Saturation, Value) colour space, which is more efficient for colour segmentation under varying lighting conditions. Predefined HSV ranges are used to implement binary masks for red, green, and blue colour. The algorithm calculates the sum of pixel values in each colour mask to determine the dominant colour present in the frame. To improve the reliability of detection and avoid false triggers due to noise or transient color changes, the system maintains a history of the last three detected frames.



Only if the same color is consistently detected across all three frames, and a minimum delay of five seconds has passed since the last command was sent, the corresponding color code is transmitted via serial communication to an Arduino. This approach ensures stable color recognition and prevents redundant or inaccurate data transmission. The detected color is also overlaid on the video feed for real-time visualization. This algorithm is efficient, noise-resistant, and suitable for embedded vision applications such as object sorting by a robotic arm.

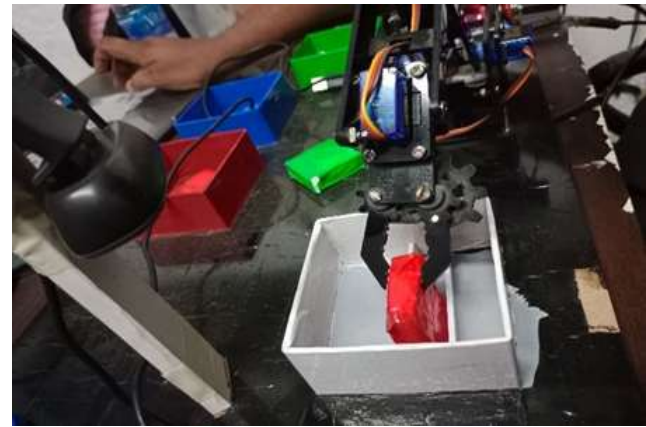


Fig.2:Implementation of colour sorting robotic arm

Table.1: Angle Designation

ANGLE FOR DIFFERENT COLOUR OBJECT	
COLOURS	ANGLE
RED	30°
GREEN	90°
BLUE	150°

Table specifies angles assigned to different colored objects in a robotic arm-based color sorting system. According to the table, the robotic arm is programmed to move to 30° for red, 90° for green, and 150° for blue colored objects. These angles likely correspond to the positions of containers designated for each color.

5.1. Artificial Intelligence

Artificial Intelligence, or AI, is a part of computer science that implement on creating machines that can think and act like a human. These machines can make smart decisions, problem solving, and learn from the data or experience. So, AI means human-made thinking ability. As explained by John McCarthy, who is known as the father of AI, it is the science and engineering of building smart machines, especially computer programs that can act intelligently.

In this project the AI is used in colour detection with three colours RGB i.e. Red, Green and Blue. In colour detection, AI works like the way humans perceive and recognize colours. Just like how human's brain processes visual information from our eye to identify colours, AI algorithms use mathematical formulas to analyse digital image and detect colours.

An AI algorithm uses computer vision techniques to analyses the pixel values of digital image. The AI algorithm is trained on datasets of images labelled with their corresponding colours, allowing it to learn relationship between pixel values and colours.

A digital image is made up of tiny units called pixels, each with its own colour value. The colour value of a pixel is typically represented by a combination of red, green, and blue (RGB) intensities, ranging from 0 (minimum intensity) to 255 (maximum intensity). In this model, each pixel is assigned a colour value based on the combination of red, green, and blue intensities.

5.2. Open CV

Open CV is a computer vision library that provides pre-trained machine learning models and algorithm for image processing. It captures video frames from the webcam and converting the frames from RGB to HSV (Hue, Saturation, Value) colour space which is more suitable for colour detection. This detecting colours of objects in the frame using pre-defined colour ranges.

How open cv converts RGB into HSV

OpenCV converts RGB (Red, Green, Blue) colours to HSV (Hue, Saturation, Value) colors using a mathematical transformation. This process involves separating the color information from the brightness information and colour analysis. In the RGB color model, each pixel is represented by a combination of red, green, and blue intensities from 0 to 255. To convert RGB into HSV it standardize the RGB values to the range 0 to 1 then, it will calculate the maximum and minimum values of the RGB components or object . After calculation it also calculates the difference between the maximum and minimum values, which represents the saturation and finally it calculates the hue and value components based on the maximum and minimum values. The resulting HSV color model separates the color information (hue and saturation) from the brightness information (value), making it easier to analyses and process colors.

In program the following minimum and maximum colour ranges for each colour is predefined.

COLOUR	MAXIMUM VALUE	MINIMUM VALUE
RED	0,120,70	10,255,255
GREEN	36,25,25	86,255,255
BLUE	94,80,2	126,255,255

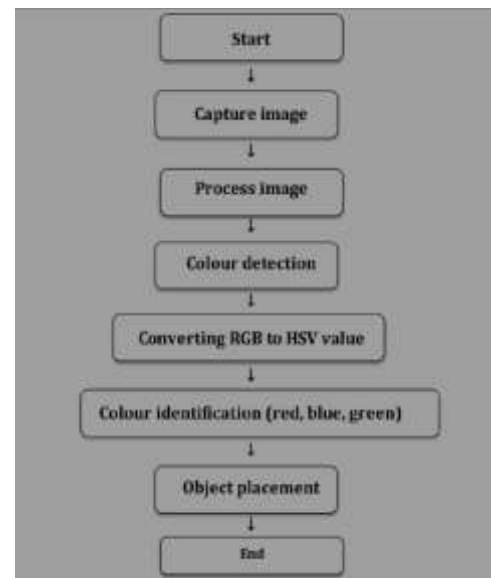


Fig.3. Flowchart

6. PROBLEM STATEMENT

Sorting objects based on their color is a critical process in many industrial sectors. Manual sorting methods are labor-intensive and prone to errors, leading to inefficiencies and high operational costs. In scenarios where a high volume of products needs to be categorized accurately, manual methods fail to deliver the required consistency and speed. This research aims to address these challenges by designing a robotic arm system capable of autonomously detecting and sorting objects based on color.

This project focuses on developing a ready-made robotic arm integrated with an Arduino Uno microcontroller and a computer vision-based color detection algorithm. The system will be able to identify red, green, and blue objects, classify them, and place them into designated containers using servo motors. By automating this process, industries can significantly reduce human interference and increase productivity.

7. CONCLUSION:

The color-sorting robotic arm can demonstrated more accuracy (98%), fast sorting speed (1 min 45 sec for 50 objects), and efficient energy usage (12W). The system met all project objectives, overcoming challenges through algorithm optimizations and hardware refinements.

This project serves as a foundation for industrial automation applications and can be further improved with AI-based color recognition, IoT connectivity, and multi-arm scalability. Future iterations can expand its use in waste management, food processing, logistics, and manufacturing industries.

The Color Sorting Robotic Arm project successfully achieved its goal of developing an automated system capable of sorting objects based on color using computer vision and servo motor control. Through rigorous testing, the system demonstrated high accuracy, efficiency, and reliability, making it a potential solution for industrial sorting applications.

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