

DEVELOPMENT OF COLOUR IDENTIFICATION ROBOT WITH END EFFECTOR ATTACHMENT

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechatronics

By

PRATHIK.V (Reg. No. 40090023)

DANIEL CEDRICK MERPHY (Reg. No. 40090006)



DEPARTMENT OF MECHATRONICS

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A++” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

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INSTITUTE OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF MECHATRONICS

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **PRATHIK. V (40090023)** and **DANIEL CEDRICK MERPHY (40090006)** who carried out the project entitled "**DEVELOPMENT OF COLOUR IDENTIFICATION ROBOT WITH END EFFECTOR ATTACHMENT**" under our supervision from November 2023 to April 2024.

Internal Guide

Dr. J. SENTHILKUMAR, M.E., Ph.D.,

Head of the Department

Dr.B.KANIMOZHI., M.E., Ph.D.,

Submitted for Viva-voce Examination held on

Internal Examiner

External Examiner

DECLARATION

We, PRATHIK. V (40090023) and DANIEL CEDRICK MERPHY (40090006) hereby declare that the Project Report entitled “**DEVELOPMENT OF COLOUR IDENTIFICATION ROBOT WITH END EFFECTOR ATTACHMENT**” done by us under the guidance of **Dr. J. SENTHILKUMAR, M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.

DATE:

PLACE:

1.

2.

SIGNATURE OF THE CANDIDATE

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ABSTRACT

For the existing architecture, the articles are physically organized. This increases the risk of human mistake, leading to incomplete or erroneous work and damaged products. Colour classification machines frequently use the RGB colour model. This gadget employs optical sensors to arrange objects based on their colour. Arduino UNO was used to automate the colour sorting procedure. The operation relies on an Arduino UNO, together with servo motors, an RGB colour sensor, a DC gear motor, a conveyor belt, and a gripper. To sort metal items, the suggested experimental system requires a mechanical system including a servo motor, metal sensor, conveyor belt, and robotic arm. This system can efficiently sort large quantities of things and exclude metal objects. The system eliminates manual mistake, quickly sorts objects based on colour using an RGB sensor, achieves high accuracy, and reduces costs.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	EXPANSION
GUI	Graphical User Interface
CLI	Command-Line Interface
MTBF	Mean Time Between Failures
RAM	Random Access Memory
LiDAR	Light Detection And Ranging
TOF	Time-Of-Flight
SDK	Software Development Kits
ML	Machine Learning
USB	Universal Serial Bus
k-NN	K-Nearest Neighbours
SVM	Support Vector Machines
FPGA	Field Programmable Gate Array
PPE	Personal Protective Equipment
SVM	Support Vector Machines
CNN	Convolutional Neural Network
RNN	Recurrent Neural Network
IOT	Internet of Things
AI	Artificial Intelligence
LCD	Liquid Crystal Display
RGB	Red Green Blue
HSV	Heu Saturation Value
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
CCD	Charge Couple Device
CMOS	Complementary Metal Oxide Semiconductor
SURF	Speeded up Robust Features
PWM	Pulse Width Modulation

CHAPTER – 1

INTRODUCTION

1.1 PROBLEM STATEMENT

1.1.1 Need for Development of Colour Identification with End Effector:

Some sectors employ personnel to transport materials, which can be time-consuming and risky due to potential damage. This project aims to create a pick-and-place robot with an RGB colour sensor to improve sorting efficiency. This study aims to show how using pick and place units to sort-coloured objects down a conveyor belt may improve production quality and reduce error-related downtime.

The suggested intelligent device's performance was evaluated by detecting random coloured items. However, it will just detect and choose RGB colours and set them in the required spot. The high-colour sensor has considerable promise and can be developed in the future. Manual sorting is time-consuming and difficult for people to move big goods. However, robotic arms can do the task quickly and efficiently. Robots can work around the clock, whereas people cannot.

1.1.2 Robotic Arm

A robotic arm acts similarly to a human hand, consisting of a series or parallel arrangement of links. It may follow prepared instructions to do an operation. The manipulator's joints connect the linkages, resulting in displacement (translation or rotation). The arm's links create a kinematic chain. The End Effector, analogous to a human hand, marks the end of the kinematic chain. This projects utilizes:

- End-effector
- Controller
- Sensor
- Links and joints
- Actuators

Robot links connect separate manipulator joints, whereas robot joints integrate many links. Robots have two types of connections: input and output, which are

physically present as a piece of material. The output link can move in many ways based on the motion of the input link. A tighter input connection is on its way. The robot joint is a crucial part of any robot. Facilitates movement of connections in several directions.

1.2 ASPECTS

1.2.1 Machine Vision:

In machine vision, visual data is first collected, then it is processed and interpreted by a computer for use in an industrial application. The field of machine vision is expanding, and its main robot guidance and automated inspection applications. This section covers the applications of machine vision as well as its operation. It is possible to categorize vision systems as 2-D or 3-D. A 2-D picture of the scene is seen by two-dimensional systems. Given that many industrial applications contain 2-D scenes, this is more than sufficient for the majority of them. Examples include inspecting for characteristics on a flat (or semi-flat) surface, gauging and measuring dimensions, and confirming the existence of components. Other uses need for 3-D scene analysis, and 3-D systems are occasionally required for this.

1.2.2 Digitization and Image Acquisition

- To get pictures for analysis, a digital camera and digitizing software are used.
- After capturing a scene, cameras split it up into pixels with intensity values that correspond to light.
- Pixel intensities are converted to digital values via analog-to-digital converters, or ADCs.
- Based on a threshold, binary vision systems convert pixel intensities to either black or white.
- Grayscale systems record many tones of grey, allowing for a thorough examination of an object's details.

1.2.3 Digital Cameras

Digital cameras employ lenses to concentrate pictures into arrays of photosensitive components that make up pixels.

- Two varieties of visual sensors are charge-coupled devices (CCD) and complementary metal-oxide semiconductors (CMOS).
- Benefits from CMOS technology advancements include reduced costs, power consumption, and speed.
- The resolutions of image sensor arrays vary from 640x480 to 9372x9372 pixels, which are considered high-end.

1.2.4 Illumination

For machine vision, there has to be steady, regulated illumination.

- Structured, strobe, side, rear, and front lighting are among the lighting categories.
- While back lighting produces object outlines, front lighting aids in examining surface characteristics.
- Surface flaws are made visible by side illumination by creating shadows.
- Geometric elements are enhanced by structured lighting, which projected patterns.
- Strobe lighting captures moving things as still by using brief, strong bursts of light.

1.2.5 Image Processing & Analysis

Rapidly gathered data from frames is analysed by image processing.

- Regions of interest are divided using segmentation techniques such as thresholding and edge detection.
- Thresholding uses a threshold to transform pixel intensity levels to binary values (black or white).
- Edge detection uses the contrast in light intensity to determine the borders of objects.

1.2.6 Interpretation

Using models or templates as a guide, interpreters must identify items.

- Template matching matches features in an image to equivalent features in templates that have been saved.
- Feature weighting uses weights to aggregate several attributes into a single metric.
- Achieving accurate identification involves contrasting an object's score with that of a perfect model.

1.2.7 Material Handling

Material handling plays a crucial role in the production process. It entails moving components or raw materials from one location to another as well as stacking, loading, and unloading. It begins at the point and exits the plant as finished goods. Material handling, thus, can be characterized as the mechanical or manual manipulation of raw materials, semi-finished parts, and final products throughout manufacturing as well as storage locations. Material Handling Functions:

The transportation and arrangement of supplies, tools, spare parts, etc. that have been acquired for storage. The internal movement of goods between departments or shops and stores. The transportation and placement of completed goods or component parts for stocking or sale; the transfer of materials between departments and from one machine to another during processing. Taking raw goods out of trucks or other vehicles. Packing items into cars or other vehicles for transportation.

1.3 PURPOSE

1.3.1 Requirement Analysis

The functional requirements specify the fundamental features and tasks that the colour identification robot with an end effector must do. This may include:

- Using modern image processing methods, accurate colour identification and categorization are achieved.
- Colour features are used to precisely localise and identify objects.
- Integrates seamlessly with robotic arms or end effectors for item manipulation and handling.

- Real-time feedback and adjustment systems guarantee accurate control during operation.

Nonfunctional requirements define system attributes including performance, dependability, safety, and usability. This may include:

- Colour recognition is highly accurate and fast, reducing processing time.
- Robustness and resilience in the face of environmental challenges such as changing lighting conditions and background clutter.
- Collision detection and emergency stop systems are safety measures that help to prevent accidents.
- Intuitive user interface design with clear visualisations and simple controls for operators.

System constraints refer to limits and concerns that may influence the design and execution of the colour identification robot with an end effector. These limits might include:

- Budget restrictions are influencing the purchase of hardware components and software licences.
- Compatibility with current robotics platforms, sensors, and infrastructure.
- Regulatory norms and regulations for safety and operating guidelines.

This comprises major use cases, alternate flows, exceptions, and edge situations, allowing for a thorough knowledge of system behaviour and user interactions.

1.4 COMPONENTS

1.4.1 Hardware Components

- Robotics Platform: The central hardware component, which includes robotic arms or manipulators capable of precision movement and manipulation activities.
- End Effector: A tool or attachment installed at the end of a robotic arm that grips, handles, or interacts with things based on colour identification findings.
- Cameras: High-resolution cameras are mounted on the robot to collect photos of objects for colour identification.

- Sensors include proximity sensors, encoders, and force/torque sensors that provide input on the robot's location, orientation, and contact with its surroundings.
- Processing Unit: A central processing unit (CPU) or microcontroller that executes algorithms for colour recognition, object manipulation, and robotic movement control.
- Communication interfaces allow data to be exchanged and coordinated with other devices, networks, or control systems.

1.4.2 Software Components

- Image Processing Module: The software module that processes pictures acquired by cameras to detect colours and extract key characteristics for object recognition.
- Colour Detection Algorithm: An algorithm for identifying and categorising colours in collected pictures using techniques including thresholding, segmentation, and feature extraction.
- Object Recognition Module: A software module used to recognise things based on their colour properties using machine learning or pattern recognition techniques.
- Control System: A software component that coordinates the robot's motions, integrates colour detection findings with end effector actions, and ensures smooth operation.
- Integration Layer: Middleware or communication protocols that provide interaction between software components, physical devices, external systems.

CHAPTER – 2

LITERATURE REVIEW

Creating a colour identification robot with an end effector attachment entails combining technologies like computer vision, robotics, and machine learning. The creation of colour identification robots requires a multidisciplinary approach that includes hardware design, software development, algorithmic optimisation, and real-world validation. Colour identification robots have the ability to revolutionise industries and open up new avenues for automation and robotics with careful planning, cooperation, and invention.

[1] This work describes a method for colour detection and object categorization that employs the HSV colour model and Speeded-Up Robust Features (SURF). It explains how colour detection may be integrated into object identification systems.

Meanwhile, SURF features are resilient to changes in size, rotation, and lighting, making them appropriate for object recognition applications. The suggested solution combines these strategies to improve the accuracy and efficiency of colour-based object categorization systems. The report provides a thorough overview of the approach, including colour segmentation preprocessing processes, SURF feature extraction, and the classification algorithm used. The suggested approach's usefulness is demonstrated by experimental findings and compared to existing approaches. Overall, this study advances colour detection and object categorization approaches, which may have applications in robotics, computer vision, and a variety of real-world contexts.

[2] This research describes a vision-based robotic system that sorts recyclable items. It describes the use of colour detecting algorithms to recognise various sorts of materials, which may be useful for your end effector attachment.

This study describes a vision-based robotic system developed for autonomous sorting of recyclable items. The growing demand for recycling activities demands effective sorting processes, and robotics paired with computer vision provide potential answers. The suggested system uses vision-based approaches to recognise and categorise various recyclable materials, including plastics, metals,

and paper. By incorporating robotic manipulators with end effectors, the system can autonomously sort various materials based on their visual features.

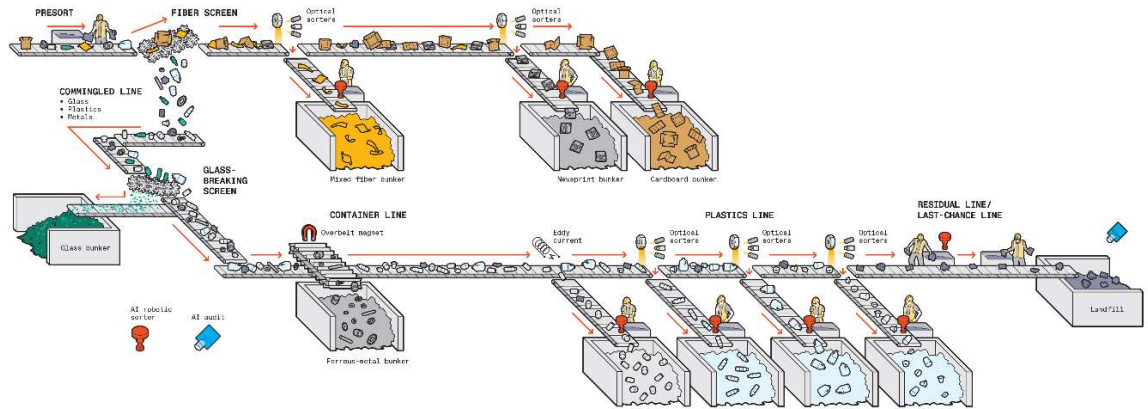


Fig 2.1 Vision-based sorting of recyclable materials

The article describes the robotic system's design, including hardware components and software algorithms for image processing and material categorization. Furthermore, experimental data and performance assessments are shown to verify the system's efficacy and dependability in real-world sorting tasks. This study adds to the improvement of recycling technology by using robots and computer vision to automate waste sorting, increasing productivity and minimising manual labour in recycling plants.

[3] This study presents a colour identification system for sorting fruits using image processing techniques. It addresses colour segmentation and classification techniques that might be applied to your robot's colour identification task. This study describes a colour identification system designed primarily for fruit sorting applications, utilising image processing methods. Fruit sorting is an important operation in agricultural processing because the quality and category of fruits influence market value. The suggested system uses image processing techniques to analyse the colour properties of fruits, allowing for automatic sorting based on predetermined parameters. By precisely detecting and classifying fruits based on their colour features, the method improves sorting efficiency and consistency.

The article outlines the approach used, which includes colour segmentation algorithms and feature extraction methods. Furthermore, testing findings and performance assessments reveal the system's ability to properly classify different types of fruits based on colour. This study advances agricultural automation by providing a dependable and effective solution for fruit sorting, which increases productivity and lowers labour costs in fruit processing plants.

[4] This study looks at colour detection and object identification methods for industrial robot manipulators. It gives insights into several techniques and algorithms for colour detection jobs in robotic systems. This study looks at colour detection and object identification algorithms designed for industrial robot manipulators. Industrial robots play an important part in many industrial processes, and improving their capabilities with improved perception systems may increase efficiency and flexibility in production situations. The research focuses on the creation and assessment of algorithms that allow industrial robot manipulators to detect colours and recognise items in their area.

The suggested methods allow robots to recognise and interact with things based on their visual features by utilising computer vision techniques such as colour segmentation and feature extraction. The paper includes a complete comparison of several algorithmic techniques, taking into account characteristics like as accuracy, speed, and resilience in industrial settings. Experimental validations and performance assessments are carried out to determine the efficacy of the algorithms under different operating situations. The findings help to advance the field of industrial robotics by providing insights into effective colour detection and object recognition methodologies.

[5] This research describes a real-time colour identification and tracking system optimised for robot soccer games. Robot football features autonomous robots participating in a dynamic and fast-paced setting that necessitates strong sensing systems for optimal gaming. The suggested system uses computer vision algorithms to recognise and track coloured items in real time, such as soccer balls and opponent robots. Using colour-based segmentation and tracking algorithms, the technology allows robots to precisely sense their environment and make intelligent judgements during games.

The article explains the system's design and implementation, including the hardware and software algorithms used for colour identification and tracking. Furthermore, testing findings and performance assessments show that the system is capable of properly recognising and tracking coloured objects under the dynamic and difficult conditions found in robot football games. This study adds to the growth of robotics in sports applications by providing a dependable and effective method for real-time colour detection and tracking, increasing the competitiveness and enjoyment of robot football matches.

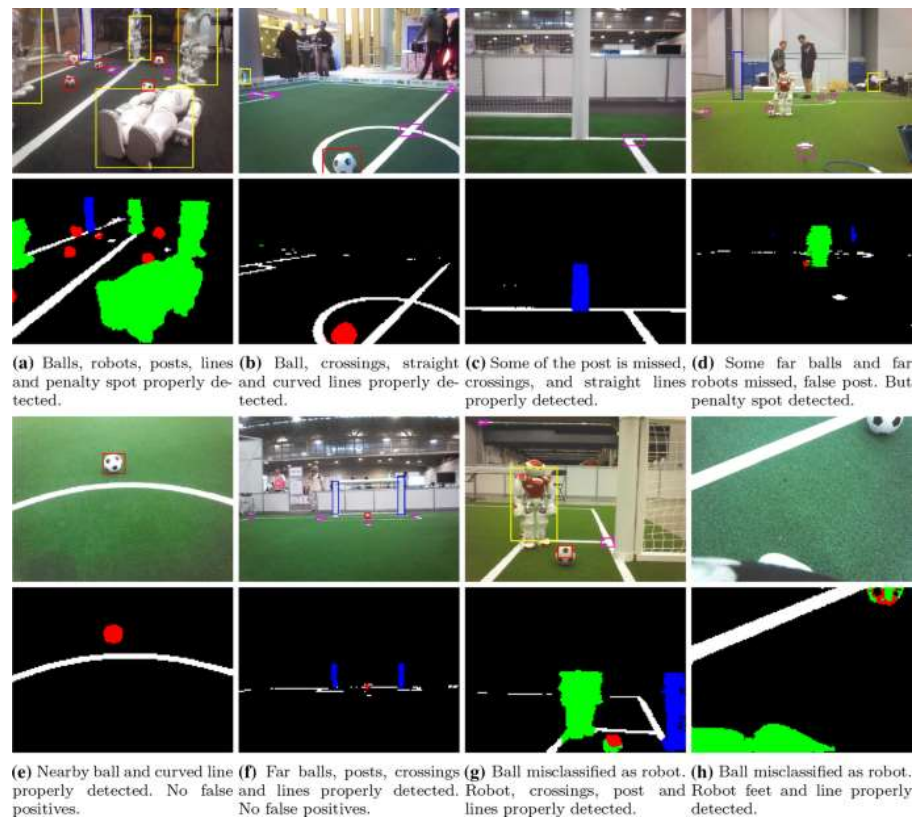


Fig 2.2 Neural Object Detection

[6] This review presents an overview of deep learning algorithms for image and video segmentation, which might help improve the accuracy and resilience of your robot's colour recognition system.

This report gives a thorough overview of the deep learning approaches utilise image and video segmentation problems. Image and video segmentation are critical components of many computer vision applications, including object recognition, scene interpretation, and medical image analysis. Deep learning approaches have

shown significant performance increases in segmentation tasks due to their ability to build complicated hierarchical representations straight from data. The study provides a detailed assessment of current deep learning architectures, methods, and approaches for image and video segmentation.

It discusses many elements of deep learning-based segmentation, such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), attention processes, and generative adversarial networks. The survey also examines datasets, assessment measures, and the limitations involved with deep learning-based segmentation methods. By synthesising current literature and research trends, the survey provides useful insights into the progress, limits, and future directions of deep learning for image and video segmentation. This thorough review is an invaluable resource for scholars, practitioners, and hobbyists interested in applying deep learning approaches to segmentation problems across several domains.

[7]This article looks at the different uses of robots in agriculture, such as crop monitoring and harvesting. While not directly about colour recognition, it does give insights into the integration of robots and computer vision for agricultural operations, which may be useful for your end effector attachment. This thorough review study examines the present state of robotics in agriculture, as well as future research directions. Agriculture is experiencing a revolution due to technology breakthroughs, and robots play a critical role in increasing production, sustainability, and efficiency in farming techniques. The study delves into several elements of robotics applications in agriculture, such as field operations, crop monitoring, harvesting, and animal management. It explores the cutting-edge robotic systems, technologies, and approaches used in various agricultural jobs, emphasising their strengths, limits, and prospective impacts. The paper also discusses new trends and future research areas in agricultural robotics, such as autonomous navigation, multi-robot systems, and integration with artificial intelligence (AI) and Internet of Things (IoT) technology. By synthesising current literature and research data, this study provides significant insights for researchers, practitioners, and stakeholders interested in the adoption and growth of agricultural robots. Furthermore, it outlines important hurdles and possibilities for future R&D efforts targeted at realising robots' full potential to revolutionise agriculture and address global food security concerns.

Thus these papers discuss a variety of strategies and uses for constructing a colour identification robot with an end effector attachment. Studying these materials provides significant insights into the approaches, algorithms, and issues associated with developing such a system. Colour identification robots represent a confluence of technology in robotics, computer vision, and artificial intelligence. These robots can execute a wide range of activities across industries and applications by effectively recognising and categorising items based on their colour properties. While problems such as ambient unpredictability and integration complexity persist, breakthroughs in hardware and software are propelling the spread of colour identification robots across several fields. As technology advances, colour identification robots are positioned to play an increasingly vital role in automation, efficiency, and innovation.

[8] In this study, the author provides data collected from accelerometers. The controller is an Arduino Atmega328. To replicate the movement of a human arm, servo motors need to be managed by an Arduino ATmega328 that gets inputs from the gyro and flex sensors that show the proper finger placement. The embedded C programming language was used to program Arduino. Fingers were placed in close proximity to the Flex and Gyro Sensor attachment points. Data from both sensors is considered by the controller when a change is detected. Prospective Futures This study covers the usage of five Flex Sensors in close proximity to the fingers and an extra Gyro for convenience. Using a Flex and Gyro Sensor to Design and Implement a Wireless Robotic Arm Model.

[9]The goal of this project is to construct a colour-sorting manipulator with the help of photodiode sensors, specialized motors, and an Arduino Mega series microcontroller. It is possible for the photodiode light sensor to read RGB colour space. In this configuration, an LCD screen displays the observed colour in line with an Arduino Mega 2560's output. Recognizing an item's RGB colour components is the first step in moving it. The gripper on the robotic arm will move to gather objects of that colour when a light photodiode sensor senses a particular hue. The Arduino Mega 2560 microprocessor, which is based on the ATmega2560-based microprocessor, includes 54 different types of digital I/O ports on a robotic arm. A Robot Arm Movement Technique Based on Colour: Widodo, 2019.

[10] The authors of this study present a method that can recognize contour information from an image in real time and use that information to match an object's contour with a template to calculate the exact position of the object to be gripped. created a grab synthesis technique that works well and requires just one monocular camera to be utilized for closed-loop robotic gripping. Next comes comparison, Compared to the current approach, this strategy used far fewer resources, especially when considering vision-based deep-learning algorithms that do not require any training. State-of-the-art techniques have been applied, including form matching, edge recognition, and super pixel segmentation. The creators of this system created visual serving strategies that required no precise positioning and were resilient to changes in the surrounding environment, Environmental System position control or camera calibration. Through experimentation, it was discovered that this approach produced remarkably high levels of performance, robustness, and conformance across a broad spectrum of testing conditions. "Autonomous object identification and grasping against a natural backdrop"

CHAPTER – 3

AIM AND SCOPE

AIM

- The experimental method sorts metal objects using a metal sensor that identifies and removes unwanted things from the conveyor belt.
- When things pass through a metal sensor, a TCS230/TCS3200 Colour Sensor detects their colour and sets them in corresponding boxes.
- Robotic arms are made up of motor-controlled joints that may move in different ways.
- The Arduino microcontroller processes the RGB colour sensor's three channels (red, green, and blue) to accurately measure the object's colour.

OBJECTIVES

This project's objective is to determine the colour of the object and to pick and place. Arduino signals the robot arm to pick up the sample. End-effectors, such as mechanical grippers, enable robotic systems to pick up and handle objects. The system utilises mechanical components and actuators to lift and relocate objects.

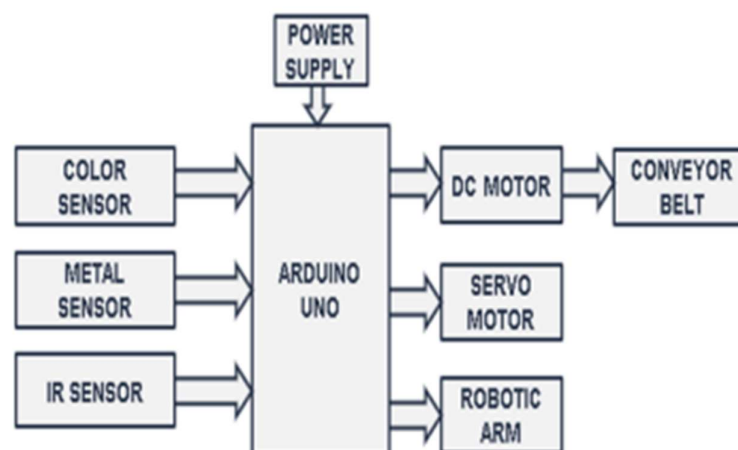


Fig 3.1 Block Diagram of Experimental System

CHAPTER – 4

METHODOLOGY AND MATERIALS

4.1 METHODOLOGY

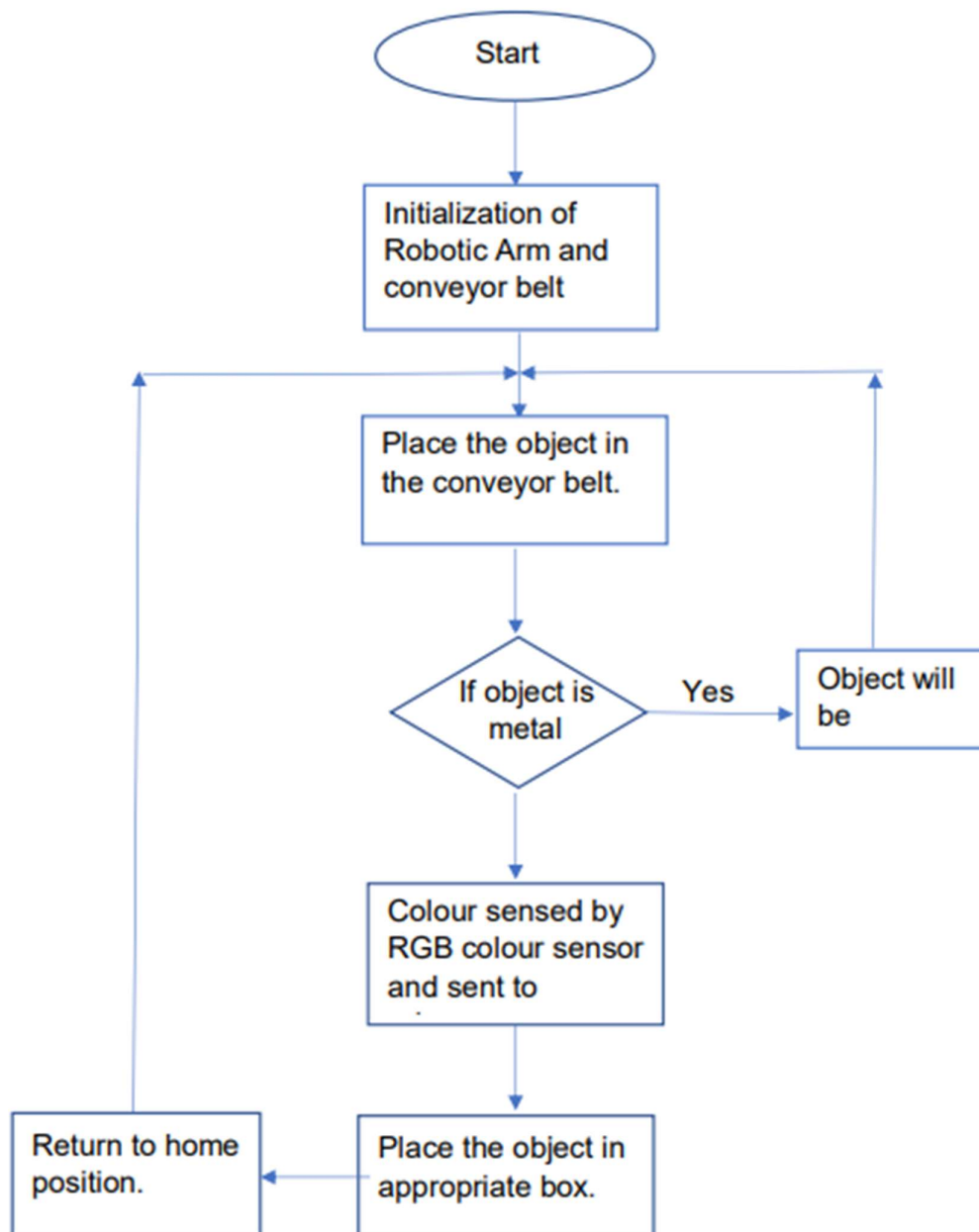


Fig 4.1 System Flow

Initialization:

- Upon starting, the system initialises and activates all hardware components, including cameras, sensors, and robotic arms.
- Software components for image processing, colour detection, object identification, and robot control are loaded into memory.

Image Acquisition:

- The robot's cameras gather photographs of the surroundings, including things that may be identified and controlled.
- The picture data is sent to the image processing module for additional examination.

Colour detection and object recognition:

- The image processing module analyses collected photos to detect colours using predefined techniques including thresholding, segmentation, and machine learning.
- Colours detected are categorised and matched to established colour profiles to identify items of interest.
- Object identification algorithms use colour properties to detect specific items or patterns inside photos.

Decision Making:

- The system selects what actions to perform based on the findings of colour detection and object identification.
- To select the following steps, decision-making logic takes objects' position, orientation, size, and colour into account.

Controlling a robot:

- The control system converts decision-making outcomes into commands for the robotic arms and end effectors.
- The robotic arms are instructed to move and place the end effector in proximity to the recognised item.

Manipulating Objects:

- When the end effector is properly positioned, it performs manipulation duties such as gripping, lifting, moving, or releasing the item.
- Control signals govern the movement and force applied by the end effector, ensuring accurate and secure manipulation.

Feedback and Adjustment:

- Sensors offer feedback on the robot's location, orientation, and contact with the environment at all times during manipulation.
- To ensure precision and safety, the control system continually modifies robot motions and end effector actions based on real-time data.

The system flow diagram above presents a high-level overview of a colour identification robot's operating process with an end effector.

4.2 DESIGNING A PICK AND PLACE ROBOTIC ARM

A pick and place robotic system involves a number of steps, including the mechanical design of the arm, Arduino programming, and the integration of an RGB colour sensor to determine the colour of the object to be picked and placed. Arm that makes use of an Arduino and an RGB colour sensor. This is a broad synopsis of the procedure:

Step 1: The mechanical design of the robotic arm. Making a blueprint for the internal operations of the robotic arm is the first phase, which can involve 3D modelling and printing. Flexible joints in the arm should enable rotation and movement in a variety of aircraft. The amount of range of motion required by an arm determines how many joints it has.

Step 2: Select an RGB colour sensor in step two. Selecting an RGB colour sensor that can recognize the colour of the target item is the next step. The market offers a variety of RGB colour sensors, including the TCS230/TCS3200 sensor. It has the ability to recognize various colours and produce the RGB values of those colours.

Step 3: Configure the Arduino The RGB colour sensor and robotic arm will be controlled by the Arduino board. The Arduino board must be configured to read the RGB colour sensor's output values and utilize them to calculate the hue of the item

to be chosen and positioned. Furthermore, the Arduino has to have the movements of the robotic arm programmed in.

Step 4: Attach the robotic arm's RGB colour sensor. In order for the robotic arm to recognize the colour of an object in the workspace, the RGB colour sensor must be included into the arm. The location of the sensor should allow for easy determine the colour of the item and connect to the Arduino board.

Step 5: Give the system a test You must test the system after the RGB colour sensor and robotic arm have been installed and configured. Test the robotic arm by teaching it to move in various directions, grasp things of various colours, and then place them in several places.

Creating a pick and place robotic arm using an RGB colour sensor and Arduino requires designing the mechanical structure, selecting an appropriate RGB colour sensor, programming the Arduino board, integrating the sensor into the arm, and testing the system. The computation varies based on the arm design and RGB colour sensor type.

4.3 COMPONENTS USED IN THIS EXPERIMENT

Table 4.1 Components used in this experiment

S.No	Name of Components	Count
1	Arduino UNO	1
2	TCS230/TCS3200 Colour Sensor	1
3	Metal Sensor	1
4	IR Sensor	4
5	DC Motor	1
6	Servo Motor	3
7	Robotic Arm	1
8	Conveyor Belt	1
9	Power Supply	1

4.4 COMPONENTS DESCRIPTION

4.4.1 Arduino Uno

The robot's central processing unit (CPU) is represented by this portable computer in the figure. It may be configured to control how different electrical parts, such as switches, motors, buttons, and lights, interact with one another.

Arduino is an open-source electronics platform that includes both hardware and software. Arduino boards may be used to translate inputs—like light from a sensor, a finger pressing a button, or a tweet—into outputs—like turning on a motor, turning on an LED, or publishing the findings online.



Fig 4.2 Arduino Uno

Power (Barrel Jack / USB)

It is necessary to have a means of connecting an Arduino board to a power source. The Arduino UNO may be powered from a barrel-jacketed wall or the USB port of a computer such as this adaptor. The image above displays a barrel jack with the label (2) and a USB port with the designation (1). Pins: GND, 3.3V, 5V, AREF, Analog, Digital, PWM, and Analog. When constructing a circuit (usually with a breadboard and some wire), the pins on your Arduino are where you'll attach wires. Among the standard features are black plastic "headers" to link wires directly. There are several pins on the Arduino board, each with a specific function that is labelled.

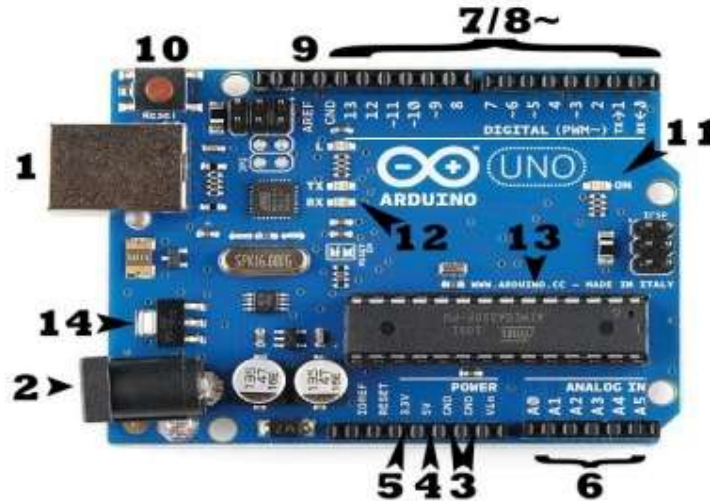


Fig 4.3 Arduino Pinout

GND (3): An acronym for "Ground." There are several GND pins on the Arduino that you may use to ground your circuit. 5V (4) & 3.3V (5): As may be expected, the 5V pin delivers 5 volts of electricity, while the 3.3V pin delivers 3.3 volts. The majority of fundamental components that are compatible with Arduino can run smoothly on either 3.3 or 5 volts.

Analog (6): Analog On the UNO, in pins are identified as such, and they may be located in the area between A0 and A5. These pins have the ability to read the signal from an analog sensor (such a temperature sensor) and convert it to a digital value.

Analog (7): The pins that are digital are situated straight across from one other. on the UNO, 0 through 13). It is possible to transform the data obtained from these pins into a digital signal and transmit it to another device. (As with charging an LED)

PWM (8): A tilde (~) may be present adjacent to a few of the digital pins. (On the UNO, 3, 5, 6, 9, 10, and 11). These connectors have additional uses beyond their standard digital functions, such as PWM. (PWM). PWM is thoroughly discussed in a different course, however in the meanwhile, think about use these pins as simulators for analog outputs. (similar to turning on and off an LED).

AREF (9): Analog Reference is the acronym. For the most part, you may disregard this pin. The maximum value of the analogue input pins may be restricted to an external reference voltage, which is typically between 0 and 5 volts.

Press the reset button. The reset button on the Arduino is similar to that on the original Nintendo. (10). Its pressing will cause the reset pin to briefly short to ground, which will result in the Arduino to reload any running code that it is executing. This is a wonderful choice if you want to run the tests several times but your code never repeats. But unlike the original Nintendo, problems with an Arduino are typically not fixed by just blowing on it.

LED Power Indicator

A little LED may be seen on your circuit board just beneath the word "UNO," to the right of the word "ON" (11). Upon connecting your Arduino to an electrical outlet, This LED ought to illuminate. If this light is off, then something is most likely wrong. It's time to inspect the circuit!

RX TX LEDs

Transmit, abbreviated as TX. The acronym for receive is RX. These symbols are frequently used in electronics to denote the serial communication pins. On the Arduino UNO, TX and RX are shown twice: once next to the TX and RX indicator and once by digital pins 0 and 1.

12 LEDs. When our Arduino transmits or receives data (for example, when we upload a new application to the board), these LEDs will provide us with some beautiful indicators hue.

MAIN IC

A black item with metal legs is called an integrated circuit (IC) (13). Think of it as the central processing unit for our Arduino. The core integrated circuit (IC) of the Arduino changes.

Although it is frequently a part of the ATMEL company's AT mega line of integrated circuits, its functionality varies greatly depending on the type of board it is constructed on. This might be important since, when uploading a new program using the Arduino IDE, the IC type and board type would be needed. This information is usually written on the IC's top. If you're interested in finding out more about the distinctions between various integrated circuits, reading the datasheets is a great idea.

Voltage regulator: The Arduino's voltage regulator (14) should not be tampered with. However, knowing it exists and its function may be beneficial. The voltage regulator regulates the input voltage for the Arduino board. It acts as a gatekeeper, keeping any potentially dangerous voltage out of the circuit. Do not attempt to power an Arduino with more than 20 volts, since this will harm the board.

4.4.2 ATMEGA328 Microcontroller

There are 32 general-use data registers and a huge number of instructions in the Atmel AVR® core. Due to the direct coupling of all 32 registers to the ALU, simultaneous access to both registers may be achieved in a single instruction that requires just one clock cycle. The resulting architecture is more code-efficient and up to ten times faster than standard CISC microcontrollers. Figure 4.4 displays the features that the ATmega328/P has to provide. 32K bytes of programmable flash memory that can be written again, 1K bytes of erasable PROM memory, 2K bytes of static RAM, 23 general-purpose I/O lines, and 32 general-purpose six channels of 10-bit ADC, one serially programmable USART, one byte-oriented 2-wire Serial Interface (I2C), three programmable Timer/Counters with comparison modes and PWM, and gen purpose working registers.

A programmable watchdog timer with an internal oscillator, eight channels in TQFP and QFN/MLF packages, an SPI serial connector, and six software-selectable power-saving modes are all included.



Fig 4.4 ATMEGA328 Microcontroller

The Boot software can download the Application Flash memory application via any accessible port. The ability to update an application while maintaining the Boot Flash software enabled allows for True Read-While-Write capabilities. Flash programs: The Atmel ATmega328/P is a potent microcontroller that combines an 8-bit RISC CPU with In-System Self-Programmable Flash on a single chip to provide a highly flexible and affordable solution to many embedded control applications.

4.4.3. Robotic Gripper

The gripper shown in the figure enables a robot to pick up and hold an object. The mechanical robotic gripper grasps, lifts, and holds objects by utilizing a combination of actuators and mechanical parts.

Pick and place is accomplished by moving it and releasing it at the appropriate area. The gripper uses a gripper or another kind of grabbing device to take up the thing. The object is subsequently moved by the arm to a predetermined position, which can be chosen using real-time input from the device or a preprogrammed set of coordinates.

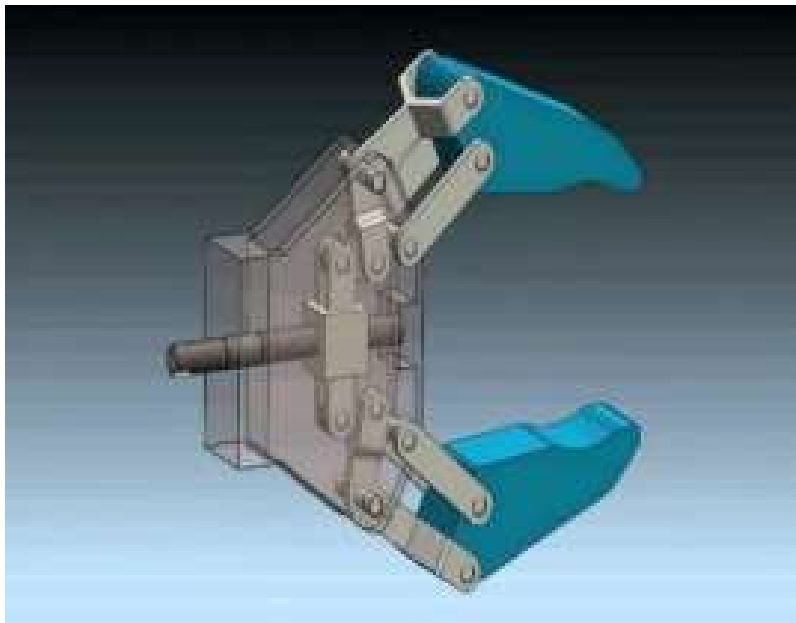


Fig 4.5 Robotic Gripper

4.4.4. Motor Driver

MG995 A servo motor, like the one shown in , is used to precisely move an item from position A to position B by actuating the joints in the robotic arm.



Fig: 4.6 MG995 Servo Motor

4.4.5. DC Gear Motor

DC motors have a voltage sweet spot; the motor will spin faster the higher the input voltage. DC motors are electric motors that run on direct current. The Elementary electromagnetic principles underpin the operation of an electric motor. The force exerted by the resulting magnetic field on an electric current carrying wire in an external magnetic field is exactly proportional to the electric current's size. An apparatus that is capable doing this is referred to as a "mechanical energy converter." The gadget works on the idea that when a conductor with an electric current is placed in a magnetic field, it will a rotational force. A field winding supplies the magnetic flux for a DC motor, while the armature performs the function of a conductor.



Fig 4.7 DC motor

4.4.6. TCS230 Colour Sensor

A colour sensor gathers information about an object's hue, saturation, and brightness by sensing its colour. The RGB (red, green, and blue) sensor that is usually calculates the light intensity in each colour channel that is reflected off an item. From this data, a computer algorithm is then utilized to determine the object's colour.

The intensity of the reflected light and the wavelength of light emitted by the colour sensor combine to determine the colour of the item. After that, it transforms this data into digital signals that a microcontroller or other computer to carry out additional tasks like counting, sorting, or quality assurance.

Colour sensors can be used for colour matching, colour sorting, test strip reading, and many other tasks in a variety of industries, including the automobile, textile, printing, and packaging sectors. The colour sensor is a part of the colour categorization apparatus of the system. The colour sensor processes the RGB colours, and the Arduino UNO receives the output values that are produced.



Fig 4.8 TCS230 colour sensor

4.4.7. IR Sensor

Sensors enable robots to detect and acquire information about their surroundings. They feed information about the surrounding region to the robotic arm. They can give the robot partial perceptual abilities. The sensor collects data and sends it electrically to the robot's brain. A colour sensor is utilised in this project. The colour sensor outputs the RGB value in a serial format after identifying the colour. It detects 16.7 million colours and provides the matching RGB value. The detected colour is given as the sum of the three primary hues (red, green, and blue), each with an 8-bit precision. RGB values enable simple separation and mixing of any colour into its component hues of red, green, and blue. (Dhananjay et al. 2015).

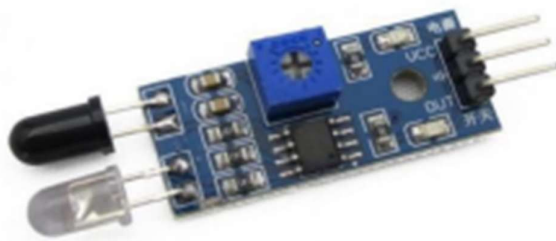


Fig 4.9 IR Sensor

An infrared sensor is an electrical device that uses emitted infrared light to collect information about its surroundings. IR sensors can sense motion and temperature concurrently. An infrared (IR) sensor detects heat from any object. An infrared sensor can identify obstructions in the route of a pick-and-place robot.

The method by which a metal detector operates is by looking for metal things nearby. It usually comprises of a metal detector circuit that senses changes in the magnetic field and a coil of wire that creates a magnetic field.

4.4.8. Metal sensor / detector

Magnetic field brought on by a metal item in the environment. The metal detector creates a secondary magnetic field by causing an eddy current to flow through the object it is scanning. The interaction of this secondary magnetic field with the primary magnetic field produced by the metal detector causes a change in magnetic field intensity, which is detected by the metal detector circuit.

Applications for the metal detector include the mining, construction, security, and archaeology sectors. It may be made to detect a variety of metal kinds, including non-ferrous (metals that don't include iron) and ferrous (metals that do). Additionally, metal detectors can be utilized in conjunction with other sensors to improve their accuracy and functionality, such as colour sensors.



Fig: 4.10 Metal sensor

4.4.9. Conveyor Belt

Conveyor belts, as illustrated in are made up of two pulleys that rotate in a continuous loop around the object being conveyed. A large rubber belt, gears, and an apparently limitless supply of hooks are used to do this.

The rollers may move the belt along the path. In this project, a conveyor belt is used to transfer the objects from one end of the sorting machine to the other. for efficient sorting.



Fig 4.11 Conveyor Belt

4.4.10. Voltage Regulator

Capacitors are frequently used in power supplies to smooth (filter) the pulsating DC output in order to guarantee that the DC voltage applied to the load after rectification stays comparatively constant. The alternating current (AC) output of the rectifiers is made up of a consistent state DC value as well as ripple voltage, a variable AC component. The filter capacitors reduce the ripple voltage to a level that is safe. To construct filter networks, resistors and inductors can also be utilized in addition to capacitors. This discussion will focus solely on capacitive filters. In a filter circuit, the capacitor is charged to the rectified voltage peak during the positive half of the input voltage. The moment the input becomes negative, the capacitor begins to discharge into the load.

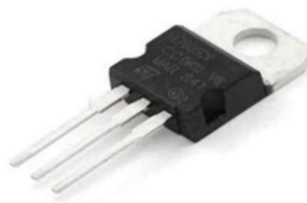


Fig: 4.12 Voltage Regulator

4.4.11. Power Supply Circuit

This experimental setup explains the process of colour sorting and showcases the capabilities of an Arduino-based pick-and-place robot. The main regulator in this experimental setup is an Arduino UNO, and the scripts for the pick-and-spot software are provided. It also features infrared sensors to detect movements.

Servo engines are used to operate the gripper for pick and spot functionality as well as the transport line in a rotating manner. The item will first pass through the metal detector to check for any metal items when it is placed in the transit line, and then proceeds to the gripper for pick and place operation after passing by the colour sensor for colour detection.

The 12V battery is used to power this configuration, but it is not connected directly. Instead, the power is sent by a DC-DC buck converter, which distributes it to all of the necessary parts. The engine that powers this configuration is limited.

The data stream has a startling variety of data obstacles. The inductor processes the energy from the data and stores it as attractive energy if the switch is held at its highest setting (on). Along the transport line, two pulleys revolve over the material continually. The finishing touches are an infinite sequence of gears and a wide elastic belt. The belt will be supported while it moves by the rollers. In this project, a conveyer belt is used to transfer the objects from one end of the sorting machine to the other.

An instrument used to detect the presence of metal is a metal detector. A pick-and-place robot's gripper may be equipped with a metal detector to assist the machine in detecting the presence of metal objects. To operate, the metal detector emits an electromagnetic field and then looking for any variations in the field brought on by the metal's presence.

The robot controller receives a signal from the metal detector when it finds a metal object, telling it to halt moving or to do another action, including warning the operator or changing the robot's route.

An infrared beam is first emitted by the IR sensor, which then detects any reflections or changes in the beam brought on by the presence of an item. Every time an object is spotted, the sensor sends a signal to the robot's controller, which then makes use of the information.

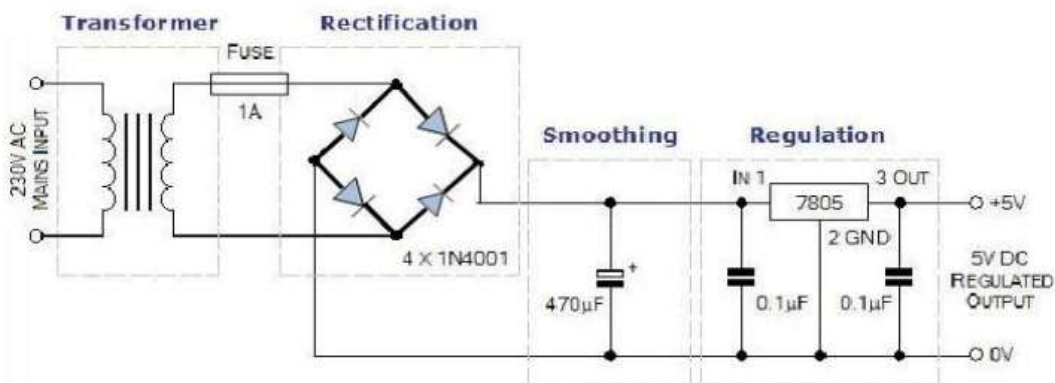


Fig: 4.13 Power Supply Circuit

4.5 PICK AND PLACE ROBOTS' APPLICATIONS

- Select a location Sorting objects by colour, shape, size, barcode, and other criteria can be done by robots.
- It may be applied to recognize and choose necessary pieces that are combined.
- It may be applied to assembly applications where components need to be recognized in order to be joined, inserted, or placed.
- Pick and place robots can be employed in the packing process, which involves loading or packaging goods.
- It can be employed for inspecting and eliminating unwanted or malfunctioning parts.
- During colour-based product grading, coded marks are recognized and package information codes are scanned.
- Applied to object identification, picture analysis, and digital processing
- Control of internal visual inspection tools in printing, pharmaceutical, culinary, textile, and other industries
- Process regulation, production monitoring, and quality control

CHAPTER – 5

RESULTS AND DISCUSSION

The primary distinction between the proposed and existing systems is the inclusion of a robotic arm in the latter, which uses a servo motor to choose an object after it has passed through a colour and metal sensor and positions it in the designated and necessary location.

The metal sensor will detect metal items as they are passed along the conveyor belt by a servo motor, separate the unwanted item, and push it out of the way. Following a metal sensor's detection of the optimal variety object, a TCS230/TCS3200 variety sensor detects it, and the mechanical arm inserts the item into the appropriate box. This study solely looks at sorting items that are black in colour.

This investigation uses a Cabot framework to arrange objects by using an infrared sensor to detect dark tones. In contrast, the suggested system recognizes objects with RGB colours and looks for any metal items, allowing for a variety of uses. Additionally, because this system is automated, it will immediately begin recognizing coloured and metal objects as soon as the things enter the conveyor belt and begin sorting.

Colour Sorting	Time taken to sort colours (in seconds)			
Objects	Metal	Red	Green	Blue
Trial-1	3	10	9.5	9
Trial-2	2.7	9.5	9.2	8.7
Trial-3	2.9	9.7	9.4	9.2

Table 5.1 Time Taken For Sorting Objects

The four columns in the table above show the items' sorting times. The coloured items will be segregated according to colour, and the metal objects will be eliminated immediately. This prototype easily classifies metals and colours.

Trial 1: Using a metal sensor to detect objects and colour.

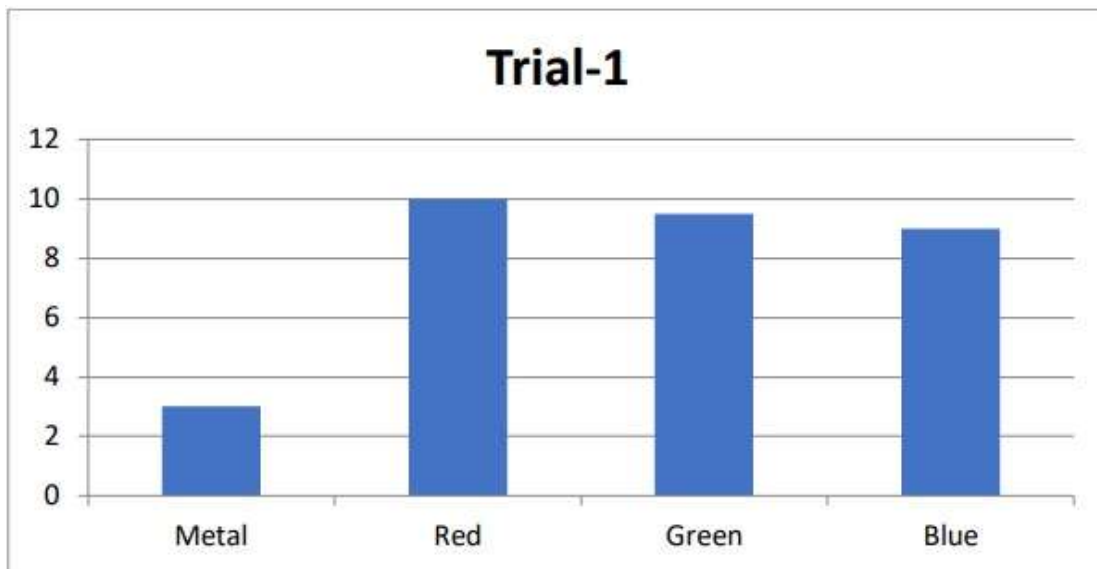


Fig 5.1 Graph showing results of Trial-1

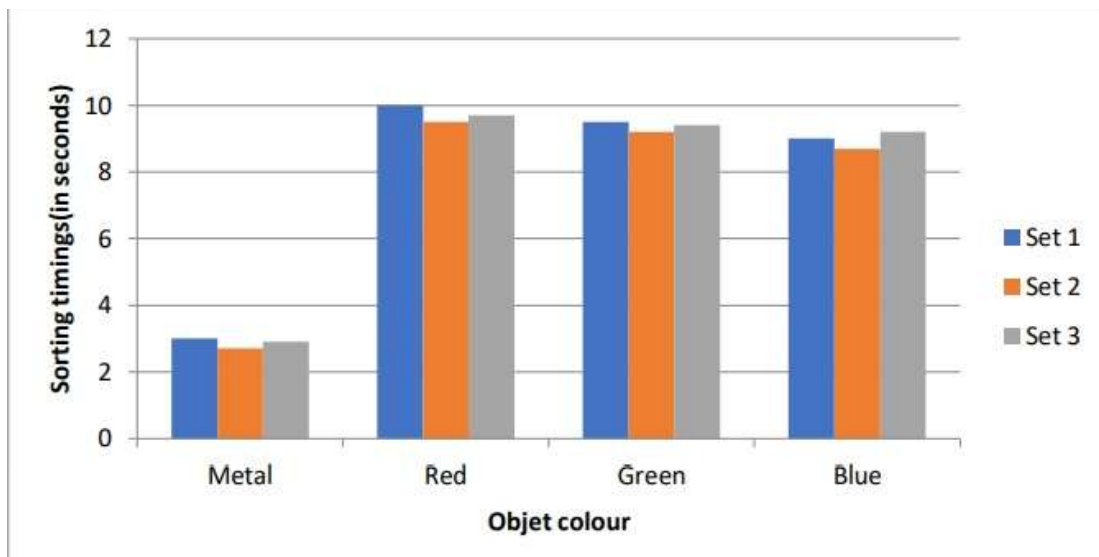


Fig 5.2 Graph showing results of colour sorting timings

The graph shows the time it takes to sort each colour and how many times the procedure is done. The red colour takes 10 seconds to pick up and place in the appropriate box, while the green and blue colours take 9 seconds to sort. Objects may pause at the colour sensor before moving to the gripper due to the sensor's time-consuming process of detecting and sorting colours.



Fig 5.3 Model of the experimental system

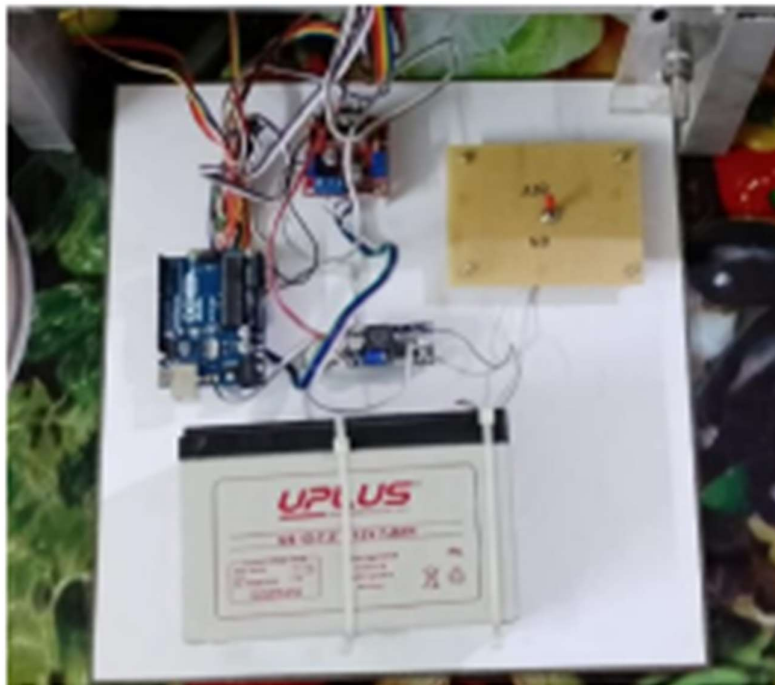


Fig 5.4 Model of the experimental system

CHAPTER – 6

CONCLUSION

This research focuses on designing and developing a mechanised framework for picking and placing RGB tones and metal products in certain locations spot using an Arduino Nano and servo motors to drive the robotized arm. The proposed ingenious device has been tested for recognising irregularly coloured things. The suggested framework aims to reduce work expenditures and increase efficiency and production in enterprises.

This study highlights the benefits of using a computerised framework, including reduced labour costs, increased productivity, and reduced human error. This approach effectively sorts things depending on their hue. It outlines the significance of robotic arms and their requirements. The system is powered by a battery and runs on Arduino code.

This work has significantly broadened the possible uses of robotics technology. Robotics technology has potential applications in several fields, including space, medicine, and military. Object sorting robotic technology can enhance accuracy, customer safety, production efficiency, and reduce costs in the agro-based multi-product packaging business and beyond.

- Using a high-quality microcontroller CPU boosts system performance and efficiency.
- To enhance colour recognition, replace the colour sensor TCS230 with a colour-based image processing camera.
- Sophisticated robotic arms enable effective handling and sorting of large, heavy objects.
- Expanding the spectrum of detectable colours allows for more precise categorization of various items.
- Colour detection, pattern recognition, and speech recognition can enhance accuracy in several domains.
- Increased degrees of freedom can improve the flexibility of the robotic arm.

C++ coding for Arduino UNO

Code Snippet

```
#include <Servo.h>

Servo servo1;

Servo servo2;

Servo servo3;

int ir1 = A0;

int ir1value=0;

int ir2 = A1;

int ir2value=0;

int ir3 = A2;

int ir3value=0;

int ir4 = A3;

int ir4value=0;

int in1=2;

int in2=12;

int speeds=3;

#define S0 4

#define S1 5

#define S2 6

#define S3 7

#define sensorOut 8

int frequency1 = 0,frequency2 = 0,frequency3 = 0;

void setup() {Serial.begin(9600);
```

```

servo1.attach(9);

servo2.attach(10);

servo3.attach(11);

pinMode(ir1,INPUT);

pinMode(ir2,INPUT);

pinMode(ir3,INPUT);

pinMode(ir4,INPUT_PULLUP);

pinMode(S0, OUTPUT);

pinMode(S1, OUTPUT);

pinMode(S2, OUTPUT);

pinMode(S3, OUTPUT);

servo1.write(130);

} if(ir2value==0) {

digitalWrite(in1,LOW);

digitalWrite(in2,LOW);

delay(1000);

digitalWrite(in1,LOW);

digitalWrite(in2,HIGH);

} if(frequency1<20) {

Serial.println(" RED ");

digitalWrite(in1,LOW);

digitalWrite(in2,HIGH);

} if(ir3value==1) {

digitalWrite(in1,LOW);

```

```

digitalWrite(in2,LOW);

servo2.write(40);

delay(1000);

servo3.write(0);

delay(1000);

servo2.write(0);

delay(500);

servo3.write(165);

digitalWrite(in1,LOW);

digitalWrite(in2,HIGH);

} else

if((frequency1<75)&&(frequency2<40)&&(frequency3<65)&&(frequency1>
35)&&(frequency2>10)&&(frequency3>30)) {

Serial.println(" GREEN ");

digitalWrite(in1,LOW);

digitalWrite(in2,HIGH);

} if(ir3value==1) {

digitalWrite(in1,LOW);

digitalWrite(in2,LOW);

servo2.write(40);

delay(1000);

servo3.write(50);

delay(1000);

servo2.write(0);

```

```

delay(500);

servo3.write(168);

digitalWrite(in1,LOW);

digitalWrite(in2,HIGH); }

else if((frequency1>35)&&(frequency2>30)&&(frequency3<30))

{ Serial.println(" BLUE ");

digitalWrite(in1,LOW);

digitalWrite(in2,HIGH); }

if(ir3value==1)

{ digitalWrite(in1,LOW);

digitalWrite(in2,LOW);

servo2.write(40);

delay(1000);

servo3.write(100);

delay(1000);

servo2.write(0);

delay(500);

servo3.write(168);

digitalWrite(in1,LOW);

digitalWrite(in2,HIGH);

}}

```

REFERENCES

- [1]. Bay, Herbert & Tuytelaars, Tinne & Van Gool, Luc. (2006). SURF: Speeded up robust features Vol.34. *Computer Vision-ECCV 2006*. 3951. 404-417. 10.1007/11744023_32.
https://www.researchgate.net/publication/225761164_SURF_Speeded_up_robust_features
- [2]. Koskinopoulou, Maria & Raptopoulos, Fredy & Papadopoulos, George & Mavrakis, Nikitas & Maniadakis, Michail. (2021). Robotic Waste Sorting Technology: Toward a Vision-Based Categorization System for the Industrial Robotic Separation of Recyclable Waste. *IEEE Robotics & Automation Magazine*. Vol.28 PP. 2-12. 10.1109/MRA.2021.3066040.
https://www.researchgate.net/publication/350705141_Robotic_Waste_Sorting_Technology_Toward_a_Vision-Based_Categorization_System_for_the_Industrial_Robotic_Separation_of_Recyclable_Waste
- [3]. Anusha Sanga, Shweta Shinde, Suraj Shaha, Fruit Sorting Robotic Arm Based on Image Processing, *International Journal of Recent Technology and Engineering (IJRTE)* ISSN: 2277-3878 (Online), Volume-6 Issue-4, September 2017
<https://www.ijrte.org/wp-content/uploads/papers/v6i4/D1701096417.pdf>
- [4]. Noman, Abdullah & Eva, Anika & Yeahyea, Tabassum & Khan, Riasat. (2022). Computer Vision-based Robotic Arm for Object Color, Shape, and Size Detection. *Journal of Robotics and Control (JRC)*. 3. 180-186. 10.18196/jrc.v3i2.13906.
https://www.researchgate.net/publication/360594521_Computer_Vision-based_Robotic_Arm_for_Object_Color_Shape_and_Size_Detection
- [5]. C. Hao, D. Li and S. Peng, "Research on Designing of Soccer Robot's Color Tag and Identifying Algorithm," 2009 *International Conference on Intelligent Human-Machine Systems and Cybernetics*, Hangzhou, China, 2009, pp. 37-40, doi: 10.1109/IHMSC.2009.135. <https://ieeexplore.ieee.org/document/5336050>

[6]. Nikoleta Manakitsa, George S. Maraslidis, Lazaros Moysis, and George F. Fragulis, A Review of Machine Learning and Deep Learning for Object Detection, Semantic Segmentation, and Human Action Recognition in Machine and Robotic Vision, *Technologies* 2024, 12(2), published: 23 January 2024. <https://doi.org/10.3390/technologies12020015>

[7]. Islam, Fahmida & Uddin, Mohammad Shorif & Bansal, Jagdish. (2022). Harvesting Robots for Smart Agriculture, *Computer Vision and Machine Learning in Agriculture*, Volume 2 (pp.1-13) January 2022, DOI:10.1007/978-981-16-9991-7_1 https://www.researchgate.net/publication/359206928_Harvesting_Robots_for_Smart_Agriculture

[8]. Anugha, N., Ranjitha, V., & Tanuja, G. (2020). Design and Implementation of Wireless Robotic Arm Model using Flex and Gyro Sensor, *International Journal of Recent Technology and Engineering (IJRTE)* ISSN: 2277-3878, Volume-8 Issue-5, January 2020.

<https://www.ijrte.org/wp-content/uploads/papers/v8i5/E6615018520.pdf>

[9]. Areepen Sengsalonga, Nuryono Satya Widodo "Object-Moving Robot Arm based on Color", *Signal and Image Processing Letters*, Vol.1., No.3, November 2019, pp.13-19 ISSN 2714-6677. https://www.researchgate.net/publication/343924080_Object-Moving_Robot_Arm_based_on_Color

[10]. Hui Wei A and B Yang Chen, "Robotic object recognition and grasping with a natural background", *International Journal of Advanced Robotic Systems*, March-April 2020: pp 1–17, DOI:10.1177/1729881420921102.

<https://journals.sagepub.com/doi/full/10.1177/1729881420921102>

APPENDIX

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