

# Pick and Place Robot for Color based Sorting

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**Abstract** - The use of robotics in industry is becoming more popular in recent years. The trend seems to continue as long as the robotics technology meets diverse and challenging needs of the producers. Rapid developments in digital computers and control systems technologies have significant impact in robotics like any other engineering fields [2]. By utilizing new hardware and software tools, design of these complex systems that need strong integration of distinct disciplines is no longer difficult compared to the past.

The purpose of this paper is to give a brief about design and implement a microcontroller based reliable and high-performance robotic pick and place robot system. The main intention of this paper is to show how pick and place units can be used for sorting colored objects in a conveyer line and thus improve overall quality of production and reduce downtime due to errors. To upgrade this process, images captured by the webcam can be processed with image processing techniques using MATLAB software [4]. This image processing technique and color detection techniques are applied for the taken image and the appropriate output is obtained in this project is presented in the paper. The servo motors used for the joints are controlled by Arduino microcontroller.

**Key Words:** MATLAB, Image Processing, GUI Design, Arduino, Colour Sorting, Robot.

## 1. INTRODUCTION

A robot can be defined as a programmable, self-controlled device consisting of electronic, electrical, or mechanical units. More generally, it is a machine that functions in place of a living agent. Robots are especially desirable for certain work functions because, unlike humans, they never get tired; they can work in physical conditions that are uncomfortable or even dangerous; they can operate in airless conditions; they do not get bored by repetition; and they cannot be distracted from the task at hand [4]. The robot is powerful, reliable and can be used in hot temperature area where a human after working for so long can become sick and exhausted. This project would also lead to a low-cost manufacturing food product as once the robot is implemented it can work repeatedly without any cost [1]. This project will introduce a new era in food industry to use automated machine and robot for more precise, cost effective and reliable work. This robot is able to work in industry for picking object and placing it on the table. The most apparent reasons that are associated in installing of robotic systems in food industry are saving of manpower, improved quality & efficiency, Ability to work in any hostile

environment, increased consistency & flexibility, increased yields and reduced wastage. The robot, which we have been able to make, is completely independent and intelligent [5]. In this robot we will use our own power supply which could be mobilized. The sole purpose of micro controller-based robot was to propose a design that introduces the idea of automation in food industries. The idea is to reduce manual-controlled system, which always needed a human interface. This Robotic system is feasible by small and local industries having small scale production [3].

This project presents the design of a Vision assisted pick and place robot. The main objective of the project is to pick and place an object from one place to other by 3 DOF robotic arm. USB camera is used as a vision sensor to measure the dimensions of the object to be picked. The USB camera collects the image of the object is transferred to the MATLAB API with image processing toolkits and modules to process the image. The processed dimension of the object is transmitted via serial communication to the microcontroller. The appropriate PWM signal is generated respectively to the servomotors. The robotic arm is designed with servomotors. Digital image processing algorithms are implemented to process the image captured by the USB camera to find the exact dimension of the object thereby to assist the robotic arm to finest.

## 2. SYSTEM DESIGN AND ANALYSIS

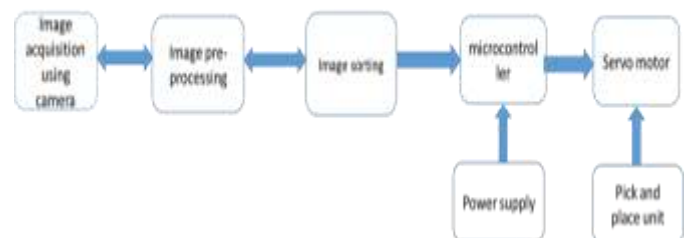


Figure-1: Block Diagram of Pick and Place Robot

### Elements of Block Diagram:

1. Image acquisition.
2. Image pre-processing.
3. Image sorting
4. Microcontroller

5. Servo Motors
6. Power supply

## 2.1 Block Diagram Explanation

### 1. Image Acquisition

To start with when the object on the conveyor is detected by the camera, image is captured by the camera and is sent to the MATLAB workspace. The input image obtained from the webcam cannot be directly given for processing. Pre-processing is done on the image such as thresholding. Then only object image is converted in binary format. This final threshold image of object is now ready for processing.

### 2. Camera

The camera used in this case will be overhead camera; it will take the snapshot of the object for colour sensing purpose. The image captured by the camera will be processed by image processing using MATLAB.

### 3. Image Processing

The objects are sorted on the basis of color and predetermined shape. To identify the color, firstly the image is converted into gray format and then thresholding is done. After thresholding color components are extracted and the image is converted into black and white format which is called as binary format. Find region properties & bounding box and the color are identified

### 4. Sorting Mechanism

The sorting mechanism consists of a linear actuator, servo motors and a conveyer assembly. After identifying the colour with predetermined size, command will be sent to direct the linear actuator through COM port of the computer via the development board. Conveyor assembly is in OFF state for this period. According to the size and colour the servo motors with help of linear actuator places the objects in their specified place.

### 5. MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming.

### 6. Microcontroller

The ATmega328 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the Atmega 328 achieves throughputs

approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed.

## 2.2 Steps in MATLAB Image Processing

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming.

MATLAB has special function which has very important role in various industrial applications which is a GUI design. GUI means Graphical User Interface it is the tool which helps the user to interact with the available machine.

So, in our project we have designed our own GUI for our image processing application which will help us in object sorting and this will make the project one of the best technologies for the pick and place robot to operate. GUI will be a one button start and it will execute the command which is entered by us in the GUI.

So, GUI designing is one of the similar types of Flowchart which consist of various steps to be performed [3].

Steps in Image processing:

#### 1. Starting camera

Starting a camera for the image processing in the MATLAB and taking the input from the camera attached to the system.

#### 2. Setting up port for the signal

After the camera is interfaced with the computer it is essential for the user to set up a port so that camera signal incoming can be received and it can be used for image processing steps in the program.

#### 3. Image capturing

After the Camera is setup with the computer and it is successfully running with the video being seen by the user it is necessary for the computer take the image and start the further process. And taking snapshot from the video, The image captured is stored as a snapshot in the GUI by the program and it is used for the further colour sorting. The snapshot function in the GUI design is put in while loop format so that it can limited but sufficient number of snapshot for the process[3].

#### 4. Applying Filter to the snapshot and clearing the pixel

After the snapshot the snapshot is cleared from the unwanted noise of the image and the image is made ready for the further image processing steps.

### 5. Subtracting the red green blue from the snapshot

The snapshot of the object is subtracted from Red Green Blue screen to extract the red part, green part, blue part from the object so that it is easy for the MATLAB to detect the colour of the object and the colour sorting part loops gets into execution.

### 6. Converting the RGB to black white and then grey scale

The red part of the image is taken by the MATLAB function but it is hard for the computer graphics to understand the RGB colour so it is converted to black and white first and then it is converted to grey scale so that further process is easier [3].

### 7. Blob analysis for length, centroids, Calculation of parameters

The MATLAB uses bounding box theory to calculate the parameters of the detected object the parameters include the Length, Width of the Box also it is capable of calculating the centroid of the object by the use of pixel theory. This step is very useful when you are going sort the object based on the length height of the object [3].

### 8. Comparison with the set value

The values obtained of the length and height is compared with the set values from the user so that Matlab can take decision about the Pick point and place point of the object.

### 9. Sending the signal to the port

After the decisions are taken it is sent to the microcontroller for further action to be taken on the hardware part of the pick and place robot.

### 2.2.1. Basic GUI Design for Image capturing, RGB to Grey scale

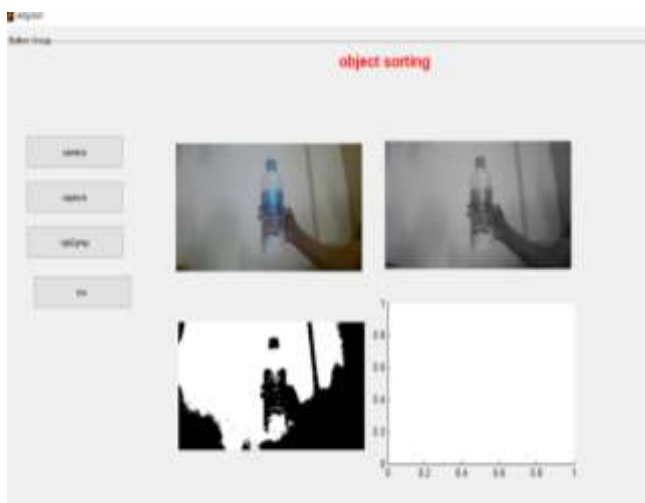


Figure-2: GUI for Basic Process

The basic steps in MATLAB Image Processing are capturing the image followed by conversion of RGB to grey where the image is converted into greyscale image and then finally the greyscale image is converted into black and white image.

After these steps the colour recognition is done for the process of colour sorting. The GUI for colour sorting is shown.

### 2.2.2. GUI for colour based sorting:



Figure-3: Red Colour Object Detection



Figure-4: Blue Colour Object Detection



Figure-5: Green Colour Object Detection

### 3. Mechanical Design

The figure no-6 depicts the mechanical design of the robotic arm. The robot arm has 3 degrees of freedom. 4 servo-motors are used for controlling motion of the robotic arm. The servo motor at base rotates the robotic arm about vertical axis. The motors at arm 1 and 2 are used for raising and lower of the robotic arm. The motor placed for actuation of gripper rotates the gear pair for opening and closing of the gripper.

The base is to be made of steel to absorb vibration and to support the robotic arm to prevent it from toppling. The arms are made of Mild Steel boxes as its strength is high and cost is less. Easy availability in different sizes is an added benefit. The gripper consists of two spur gear pair where one of the gear shafts is operate by a servo motor. The gripper is made of acrylic material due to its light weight and ease in manufacturing.

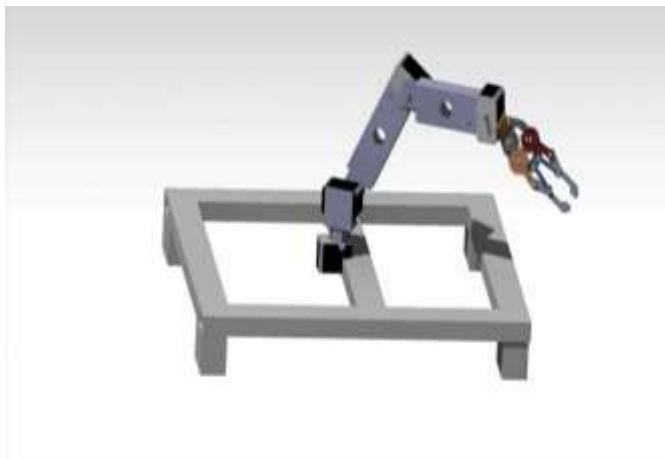


Figure-6: CAD Model

#### 3.1 Design Consideration

The following were put into consideration in the design process.

- Rectangular box pipes are chosen for the links because of their light weight and strength due to high section modulus and to reduce the weight of the arm.
- Materials used for the fabrication were locally sourced from available materials.
- The materials which will be used for the design will be light in weight so as to reduce the weight concentration on the base and the shoulder.
- Electrical actuators DC servos are chosen instead of hydraulic and pneumatic actuators because of the little power requirement and its light weight which is suitable for this design.

• Arduino Uno microcontroller is to be used for the purpose of controlling the servos and act as an interface between the computer and the pick and place unit.

• The torque is fully balanced by the inertia of the electric motors

#### 3.2 Material Selection

The most suitable material to fabricate the structure of the arm must be light and strong. Otherwise, the servo motor will not be able to pull up the arm and to perform the desired turning degree. Among the materials that can be considered to fabricate the structure are Mild steel, Aluminium, Perspex, plastic polymer and carbon fiber. In choosing the fabrication materials, the aspect of availability of the materials, the overall cost and the flexibility to be shaped, should also be taken into consideration. Thus, among the four materials considered, the Mild steel is the most ideal material to be chosen as fabrication material.

#### 3.3 Workspace Determination using Robo-Analyzer

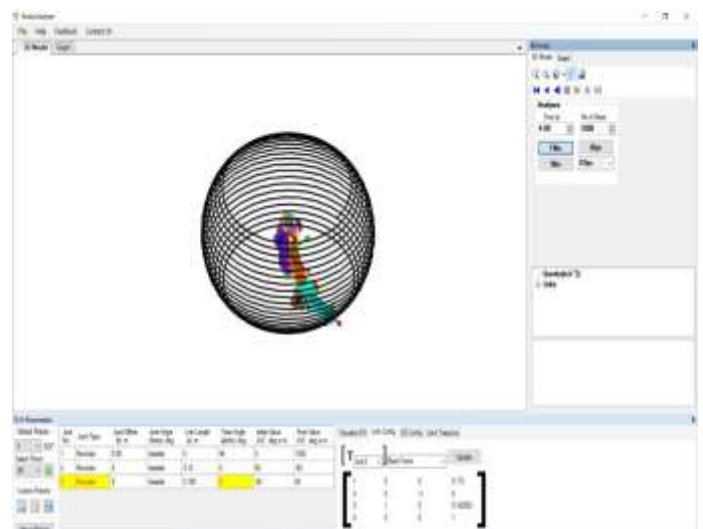


Figure-7: Workspace of Robotic Arm

A robot's workspace is the total volume swept out by the end effector as the manipulator executes all possible motions. The shape of the workspace dictates the application for which each design can be used. The workspace depends on the application for which the robot is to be used for. For industrial application robots having very large workspace called as LWR are generally used.

The workspace of the designed robotic arm is determined using Robo-Analyzer software. The Length of the arms and the number and orientation of the joints are the input parameter for the workspace determination of robotic arm. The initial and final position of the arm links have to be given and Forward Kinematics Analysis is done by the software in order to determine the workspace of the robot. The

workspace for the designed robot is called as articulated workspace which is shown as shown above.

For the given picking point, by direct kinematical analysis in Robo-Analyzer the arm length were determined to be 0.13m and 0.108m for the first arm and second arm respectively to achieve the required pick and place positions.

### 3.4 Finite Element Analysis of Components

The moment acting on the arm at the joint is calculated considering the weight of each part and the distance of the part from the joint as follows;

$M = \text{weight of object} \times \text{distance of object from joint} + \text{weight of gripper} \times \text{distance of CG of gripper from joint} + \text{weight of motor} \times \text{distance of CG of motor from joint} + \text{weight of arm} \times \text{CG of arm}$

$$M = (120+60) \times 10^{-3} \times 0.5 \times 9.81 + (120+50) \times 10^{-3} \times 0.05287 \times 9.81 + 120 \times 10^{-3} \times 0.05363 + 60 \times 10^{-3} \times 0.152$$

$$M = 0.9866 \text{ Nm} = 986.626 \text{ Nmm.}$$

The torque is applied at one joint and the other joint is fixed.

The maximum stress was determined to be 60.081 MPa.

The Yield tensile strength of material selected is 247 MPa.

Hence the design was found to be safe.

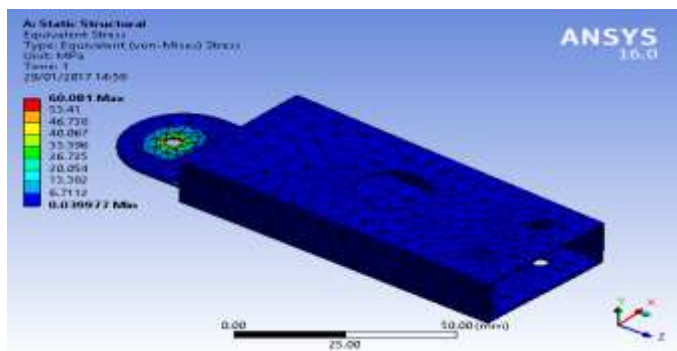


Figure-8: Stress Analysis of arm 2

The moment acting on the arm at the joint is calculated considering the weight of each part and the distance of the part from the joint as follows;

$M = \text{weight of arm 1} \times \text{distance of CG of arm from joint} + \text{weight of arm 2} \times \text{distance of CG of arm from joint} + \text{weight of motor} \times \text{distance of CG of motor from joint} + \text{weight of clamp} \times \text{distance of CG of clamp from joint} + \text{weight of gripper} \times \text{distance of CG of gripper from joint} + \text{weight of object} \times \text{distance of CG of gripper from joint}$

$$M = 75 \times 0.229 \times 9.81 + (150+60) \times 0.038 \times 9.81 + 150 \times 0.0536 \times 9.81 + (150 + 120) \times 0.05287 \times 9.81 + (150 + 120 + 50) \times 0.5 \times 9.81 + 0.5 \times 9.81 \times (150+120+60)$$

$$M = 3653.929 \text{ Nmm} = 3.6539 \text{ Nm.}$$

The torque is applied at one joint and other joint is fixed.

The maximum stress was determined to be 65.866 MPa.

The Yield tensile strength of material selected is 247 MPa.

Hence the design was found to be safe.

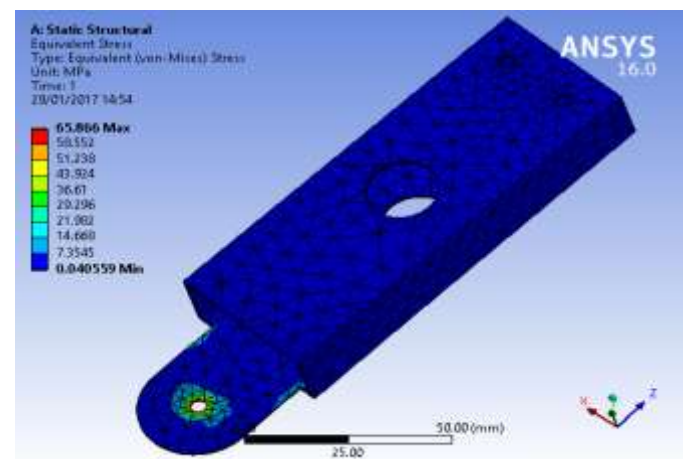


Figure-9: Stress Analysis of arm 1

### 3.5 Motor Selection for Pick and Place Robot

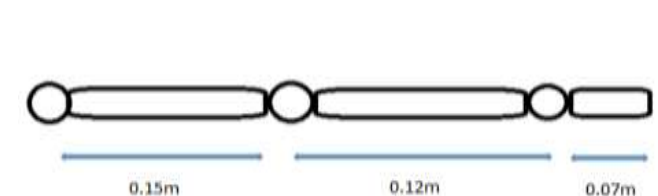


Figure-10: Torque Calculation

Moment = force x perpendicular distance.

$$W_0 = 55\text{g}, W_1 = 37\text{g}, W_2 = 500\text{g.}$$

$W_0 =$  Weight of motor at gripper

$W_1 =$  Weight of motor at second arm.

$W_2 =$  Weight of object.

$$\text{Moment sustained at the shoulder } M_1 (0.5 \times 34) + (0.037 \times 27) + (0.055 \times 15) = 5.49 \text{ [kg-cm]}$$

But actual torque of the shoulder motor = 12 [kg-cm]

Excess torque = Actual servo torque – Calculated torque.

Therefore, excess available torque at the shoulder = 12 - 5.49 = 6.51 [kg-cm]

Moment sustained at the elbow  $M_2 = (0.5 \times 19) + (0.037 \times 12) = 4.135$  [kg-cm]

But actual torque of the Arm motor = 10 [kg-cm]

Excess available torque at the shoulder = 10 - 4.135 [kg-cm] = 5.856

Torque required at gripper = Gripping force  $\times$  distance of object from motor in cm

$$= (0.5 \times 9.81) / (0.2 \times 4)$$

$$= 98.1 \text{ Ncm}$$

$$= 10 \text{ kg-cm}$$

Hence a 12 kg-cm servo motor is chosen for the gripper based on required gripping force. As the motor chosen provides the required torque, the motor is selected for application.

### 3.6 Angle Determination using Robo-Analyzer



**Figure-10:** Angle determination using Robo-Analyzer

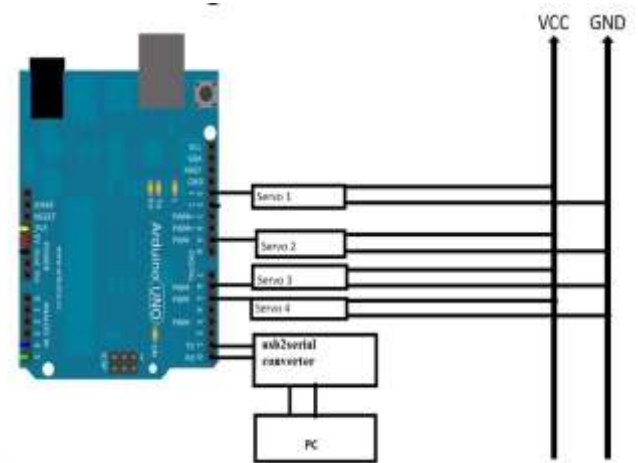
The angle that has to be maintained between the linkages in order to pick the object from a particular position was determined using Robo-Analyzer software.

Inverse kinematics feature of the Robo-Analyzer software was used to determine the angle between two linkages in order to pick an object at a distance of 0.35m from base.

The angle between horizontal and first arm was determined to be  $-27.4075^\circ$  and the angle between first arm and second arm required is  $57.9895^\circ$ .

Similarly, for different position of the object, the angle between the linkages can be determined using Robo-Analyzer software [4].

### 3.7 Hardware Implementation



**Figure-11:** Circuit Diagram

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm centre-positive plug into the board's power jack. Leads from a battery can be inserted in the G<sub>nd</sub> and V<sub>in</sub> pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts [2].

The microcontroller is connected to PC via USB2serial converter which is used for serial communication between the two systems. Based on the input from the PC from MATLAB the Arduino generates PWM signals which are used to control position of the servo motors connected to pin 3,5,6,9. The angles by which servo motors to be rotated are pre-determines and coded using the Arduino IDE.

### 3.8 Experimental Setup

After assembly of the manufactured parts of the robotic arm a complete model of the Pick and Place robot was ready for operation. There was a small platform built for picking the coloured boxes from the pick point. The Servomotor 1 which was the major motor for the complete rotation of the robotic arm from 0 to 180° angle. The Servomotor 2 for the first arm used to operate the angular motion of the first arm.

The Servomotor 3 was used to operate the angular motion of the second arm. After the second arm a Servomotor 4 was used to actuate the gripper of the robotic arm. The electrical supply for all servomotors was given a 5 Volt supply from a small breadboard and adapter was connected to the breadboard. The Supply Wire from all the servomotors were

connected to the Arduino Pulse Width Modulation port numbered as 3,5,6,9. The Arduino is given a 12 Volt supply from a separate adapter connected to it.

For the MATLAB and Arduino communication a USB to serial converter PLP 2P3P was used, the information from MATLAB which was digital format was converted into analog format with the help of this USB connector. The decision from the MATLAB was given to Arduino and the servomotors were actuated accordingly.



**Figure-12:** Experimental Setup of Pick and Place robot

### 3.9 Testing

An external webcam is used for the process of image recognition. The webcam records the image of the object and send the input in form of pictures to the MATLAB program.

The MATLAB program uses the image processing algorithm to convert the image into grey scale and then the grey scale image is converted into black and white image in the next step. The noise removal from black and white images is done to remove unclear pixels and a bounding box is formed around the geometry. Colour and size detection is done by the MATLAB and the signal is sent to the Arduino Uno Microcontroller.

Arduino IDE is used to program the servo motors. The servo motors are made to rotate to certain angles that the object is picked from a certain location and placed at the desired position on the basis of colour of the object. The servo motors are controlled by PWM signals from the Arduino Uno microcontroller. External 6V supply is given to the servo motors.

Repeatability of the project was tested by operating the pick and place robot for 60 objects of red, green and blue colour. The objects of different colours were placed at the picking point and the robot was used to sort the objects. 20 red, green and blue boxes were used.

Out of 20 red boxes all boxes were correctly sorted by the robot. In case of Green object, out of 20 objects all objects were sorted correctly. Similarly, all the blue objects were sorted correctly by the robot. Hence 60 out of 60 trials were found to be successful.

## 4. CONCLUSIONS

A robotic arm is designed and manufactured that can be used to pick and place the coloured boxes from the source to destination. The implemented robotic arm has 3 axis and 3 degrees of freedom. The design and manufacturing of the robotic arm was done for sorting the object on basis of its colour.

The features of the object were identified using image processing feature in MATLAB software to facilitate the sorting. The objects were sorted on basis of their colour by using the MATLAB algorithm and Arduino microcontroller was used to control the rotation of motor as per the signal obtained from MATLAB algorithm.

### 4.1 FUTURE SCOPE

- The MATLAB algorithm used was to sort the object b basis of 3 colors. Programs can be implemented to sort objects of multiple color and sizes using suitable programs.
- The arm manufactured was made of mild steel. Materials such as acrylic can be used for construction of arm for light weight and high rigidity the only drawback being the cost. This can significantly improve the load carrying capacity of the robotic arm.
- High definition cameras having high resolution power can be implemented into the project. They can be used to detect minor changes in color and shape of object. This can be implemented for multiple applications such as, the raw and ripe fruits can be segregated by robotic arm based on their color and the damaged ones can be removed from the lot. Edges of bottles used in packaging can be detected by such cameras and any defect in the shape of the bottle can be detected and the can be removed from the conveyer.
- Use of higher end motors can facilitate higher load carrying capacity and similarly use of stepper motor can provide better positional accuracy. This can improve the versatility of the manufactured robotic arm and it can be used for a variety of industrial applications where initially human labour had been used.

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