March - April 2020
ISSN: 0193-4120 Page No. 7190 - 7198

Design and Implementation of a Real-Time System for Sorting andPick and Place of Objects Depending on Color and Geometry

Tahseen Fadhil Abaas[a], Ali Abbar Khleif[b],Mohanad Qusay Abbood[c]

[a, b, c] *Department of Production Engineering and Metallurgy, University of Technology, Baghdad, Iraq*

[a] ***Email:***70047@uotechnology.edu.iq

[b] ***Email:***70080@uotechnology.edu.iq

[c] ***Email:***70209@uotechnology.edu.iq

Article Info
Volume 83
Page Number: 7190 - 7198
Publication Issue:
March - April 2020

Abstract
Pick and Place and sorting processes are tedious industrial processes that are usually carried out manually or semi-automatically, making them error-prone, time-consuming processes with varying productivity. Recently,there is a demand for many of these applications to become automated, including loading and unloading of CNC machines, assembly, and sorting.This paper presents an intelligent, developed and fully automated real-time system for pick and place parts based on the part's geometry, as well as the sorting of these parts depending on their color property.The system consists of a 5 DOF articulated robotic arm and a conveyor; they controlled using an Arduino Mega microcontroller equipped with an IR sensor to control the movement of the belt.Also, a PC based digital camera used to perform image processing and work as feedback to the Arduino microcontroller. C++ and C# used as programming languages. The C++ used to program the microcontroller, whereas the C# used to analyze to acquired image with the help of the EmguCV library.The intelligent system has been tested to pick and place several parts with two different geometric shapes (cylindrical and cubic) and three different colors (red, green, and blue) from a conveyor to the discharge station.The developed system has proved successful performance at all stages of the work during the test.

Article History
Article Received: *24 July 2019*
Revised: *12 September 2019*
Accepted: *15 February 2020*
Publication: *06 April 2020*

Keywords: Pick and place;Sorting process; Robotic system;Microcontroller;Image processing.

1. Introduction

The use of control systems in industrial applications instead of a human is called automation. Complex algorithms utilized in automated systems that lead to an increasein design costbut reducing time and human effort. Also, the use of automation will reduce the risks to humans associated with hazardous working environments [1, 2].

The use of robotics in automated industrial applications is growing rapidly, but without using the sensors, the robots will be unable to execute the tasks. A vision sensor is one type of sensor used in image sensor applications because of the low cost

TEST Engineering & Management
March - April 2020
ISSN: 0193-4120 Page No. 7190 - 7198

of a camera and the ability to extract large volumes of information from an image using image processing [3]. Image processing is applied to improve and enhance the images taken by a camera that works as a vision sensor. A microcontroller is a significant component in an automated system that works to control the components of systems such as sensors, motors, and drivers [4].

2. Literature Review

H. R. Ramesh and Pooja [5]investigated the robotic arm with three degrees of freedom, equipped with a USB camera, which was used to determine the color of an object using an image processing to carry out the work, usingLabVIEW software for image processing.

Madhav D. Patil [6] proposed an algorithm for calculating the inverse kinematic solution and trajectory planning for an industrial robot manipulator with 5 degrees of freedom (DOF). A VGA camera and MATLAB software were used to perform image processing. The proposed combination algorithm reduces the computation time and positioning error for finding the target in real-time.

Priyadharshini V. and et al. [7] developed an implementation of an automatic robotic pick & place operation. The offline surface clustering algorithm was presented to overcome the difficulties that occur in the linemod approach. MATLAB software was used to perform object detection by using an image processing algorithm. Objectdetection is transmitted to the microcontroller unit to accomplish a robotic arm pick & place process.

Yayati Dandekar and et al. [8] presented a system of a robotic arm with an emphasis on automating the assembly using object and color detection, using a robotic arm with four degrees of freedom. The C# with OpenCV library is used to process an image captured by a webcam and the Arduino microcontroller used to control the system.

Md. Hazrat Ali and et al. [9]presented a vision system integrated with a robot (Scorbot ER 9) to sort the objects according to color and geometry. A camera was fixed on the gripper, and the imageprocessing was performed using MATLAB software.

3. The Proposed System

The proposed system is a low-cost system for automation of the sorting process, according to the object's color and geometry. This system consists of a mechanical, electronic subsystem and software.

3.1 Mechanical subsystem

The mechanical subsystem consists of a 5 DOF robotic arm, a work surface, a conveyor, and containers (discharge stations), as shown in Figure 1. These components and specifications are depicted in the following sections.

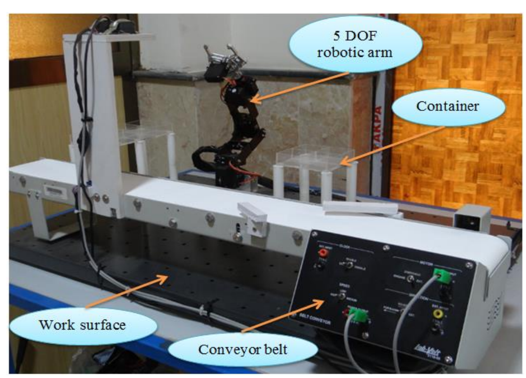

Figure 1: Mechanical components.

3.1.1 Robotic Arm

A robotic arm consists of links and joints in a chain form which have one fixed end and another free end. The 5 DOF robotic arm driven by servo motors as shown in Figure 2, the robot links made of aluminum to reduce their weights. The specification and Denavit-Hartenberg (DH): parameters of the robotic arm are illustrated in Table 1 and Table 2, respectively.

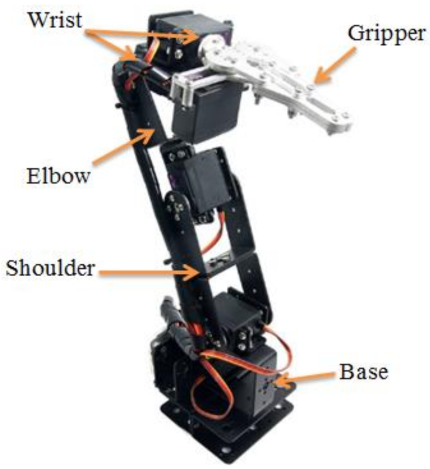

Figure 2: 5 DOF robotic arm.

Table 1: The specification of the robotic arm

Rotation angle	180 degree
Radius of gyration	355 mm
Height	460 mm
Maximum gripper opening	55 mm
Motors	Two (MG996R with torque 15 kg-cm) servo motors for (wrist, and gripper). Four (S2000MD with torque 21.5 kg-cm) servo motors for (base, shoulder, elbow, and wrist).

Table 2: DH parameters of the robotic arm

Link	a_i (mm)	α_i (degree)	d_i (mm)	θ_i (degree)
1	0	90	105	θ_1
2	105	0	0	θ_2
3	100	0	0	θ_3
4	0	90	0	θ_4
5	0	0	150	θ_5

3.1.2 Conveyor Belt

The conveyor belt is an endless belt moving over two end pulleys at fixed positions. A Lab-Volt conveyor belt model 5118 with an electrical power source is used for moving objects, as shown in Figure 1. Table 3 demonstrates the specifications of the conveyor belt.

Table 3: Specifications of conveyor belt

Parameter	Value
Motor	DC stepper motor
Conveyor Belt	Lab-Volt model 5118
Length	959 mm
Width	102 mm
Dimensions (H×W×D)	(165×965×260)mm
Net Weight	8.4 kg

3.1.3 Work Surface

The work surface is ametal sheet with dimensions (883×584×41 mm) containing holes with a diameter of 8 mm and a hole pitch of50 mm, as shown in Figure 3. The work surface is used to install the robotic arm, conveyor belt, and the three containers (discharge stations).

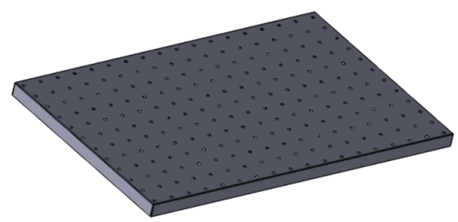

Figure 3: The work surface.

3.1.4 Objects Manufactured

Three containers were used as discharge stations, each of which is divided into four sections (50 × 50 mm), which sort the parts according to their color and geometric shape. Figure 4 illustrates the container. The test objects were manufactured from wood with dimensions shown in Figure 5.The specifications of these objects are illustrated in Table 4.

March - April 2020
ISSN: 0193-4120 Page No. 7190 - 7198

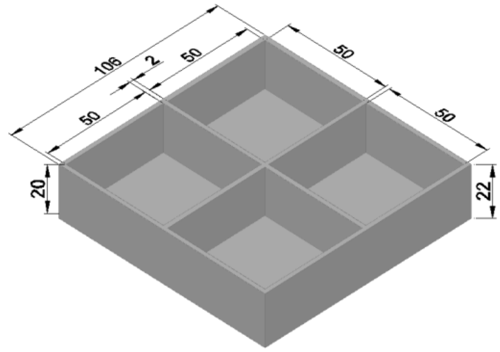

Figure 4: The container.

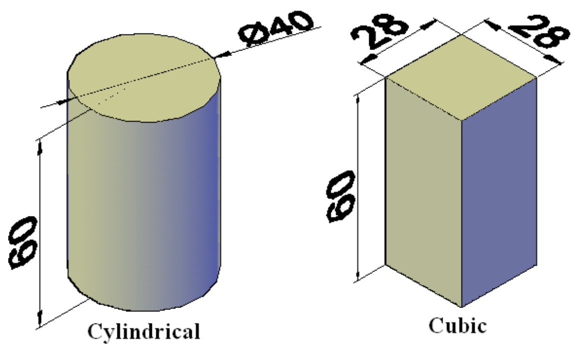

Figure 5: Objects dimensions.

Table 4: The specifications of objects

Geometry	Color	Diameter (mm)	Height (mm)	No.
Cylindrical	Red	40	60	2
	Blue	40	60	2
	Green	40	60	2
Geometry	**Color**	**Dimensions (L*W) mm**	**Height (mm)**	**No.**
Cubic	Red	28×28	60	2
	Blue	28×28	60	2
	Green	28×28	60	2

3.2 Electronic subsystem

The electronic subsystem is comprised of many components:Arduino Mega 2560, I2C LCD Module (20 × 4), Relay,Switch, led (green and red), sensors (IR and Ultrasonic (HC-SR04)), and webcam.

3.2.1 Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on ATmega 2560. In this system, the Arduino is used to control the movement of the servo motors of the robotic arm, conveyor belt, and the LCD. It is also used to control the Ultrasonic (HC-SR04) sensor, which measures the height of objects and the IR sensor,which detects the object movement on the conveyor belt. The Arduino Mega 2560 is programmed using C++ programming language through the Arduino software (Integrated Development Environment (IDE)). Figure 6 shows the Arduino board used in this work.

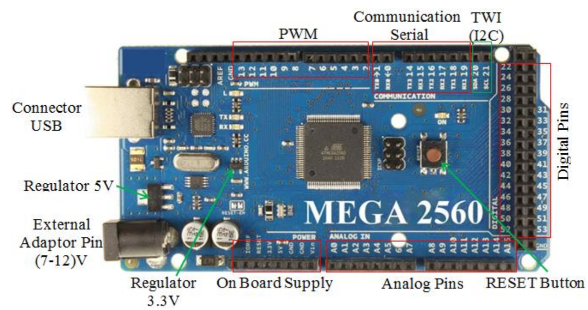

Figure 6: Arduino mega 2560.

3.2.2 IR Sensor

The infrared sensor module combined two infrared sensors: an infrared transmitter and an infrared receiver. The infrared transmitter emits the infrared light through LED light. This infrared light has a certain frequency, and when it is reflected after the collision with any obstacle or object, this light received by the infrared receiver. This infrared sensor module informs the system that an obstacle or an object exists ina specified area. It can easily detect an object within 2 to 30 cm, and its detection angle is 35°. Figure 7 illustrates an IR sensor.

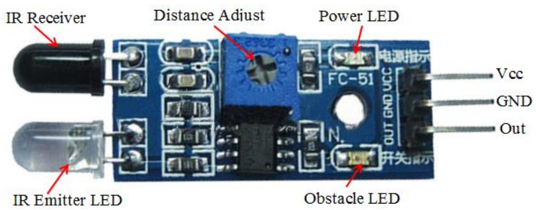

Figure 7: IR sensor.

3.2.3 Ultrasonic Sensor

The HC-SR04 Ultrasonic Module was used in this work to measure the height of objects and is fixed above the conveyor belt. HC-SR04 is a non-contact distance measurement sensor with a range of 2-400 cm and an accuracy of up to 3 mm. The sensor has four pins (VCC, GND, Trig, and Echo), as shown in Figure 8. The Trig and Echo pins must be connected to the digital input/output pins of the microcontroller. The specifications of this sensor are demonstrated in Table 5.

Figure 8: Ultrasonic (HC-SR04) sensor.

Table 5: Specifications of the ultrasonic sensor

Operating voltage	DC 5V
Theoretical Measuring Distance	2 cm to 400 cm
Practical Measuring Distance	2 cm to 80 cm
Accuracy	3 mm
Measuring angle covered	<15°
Operating Current	<15mA
Operating Frequency	40 KHz
Dimension	(45×20×15) mm

3.2.4 Camera

The Web camera Havit (HV-N5081), shown in Figure 9,is used to capture images of the objects. It has 5 Mega Pixels and produces images with a resolution of 640x480 pixels. This webcam is fixed above the conveyor belt.

Figure 9: Havit (HV-N5081) webcam.

3.2.5 LCD Display

A liquid-crystal display (LCD) is an electronic visual display that uses the light modulating properties of liquid crystals. The LCD display used in this work has four horizontal lines comprising a space of twenty displaying characters, as shown in Figure 10. The purpose of using an LCD display is to show the count of the processed objects according to their color and geometry.

Figure 10: LCD.

4. Control Board

In order to control the various activities of the proposed robotic system, an electronic board was installed to connect the following electronic components shown in Figure 11:

- A 600W power supply to provide the system with a 5V and 12V, with a 20A and 14A current,respectively. Two wires of 5V are connected to the relay and I2C LCD Module 20 × 4. Three wires (12 V) are connected to regulators.Every wire is connected with two regulators.
- Six regulators, Step-down adjustable converter module DC-DC 3V-40V LM2596,work to provide6V and 7.2V

March - April 2020
ISSN: 0193-4120 Page No. 7190 - 7198

from 12V according to the servo motor type of the robotic arm.

- Vero board with dimensions 180 x 300 mm is used to connect inputs and outputs.
- Relay,two channels 5V Relay Module,is fixed onto the Vero board. It works to controlthe movement of the conveyor belt.
- I2C LCD Module (20 × 4) to display the number of the processed parts (counter).
- A switch with two-led (Green and Red) is used to stop or run the sorting process. Green led is lighting up when the process runs, and red light is lighting up when the switch stops the process.
- An IR sensor, ultrasonic (HC-SR04) sensor and webcam are fixed on the conveyor belt.
- A fan (12V) is fixed on the front wall of the board.
- The Terminal pins fixed on the Vero board are used to communicate between inputs and outputs.
- Arduino Mega (2560) is fixed on a Vero board and works to controlvarious activities.

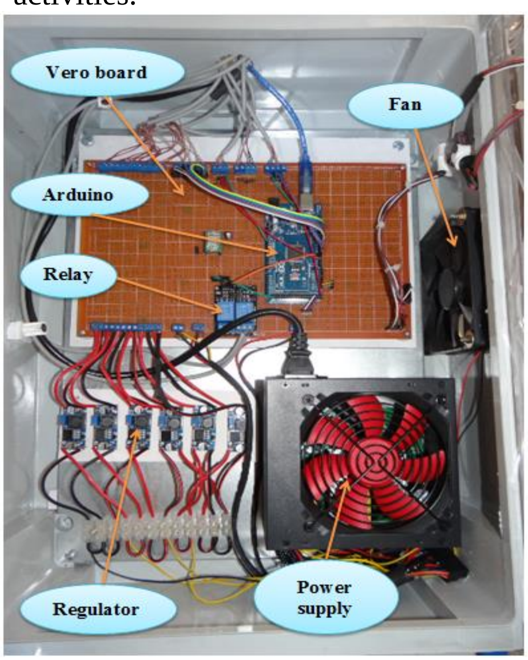

Figure 11: Control board.

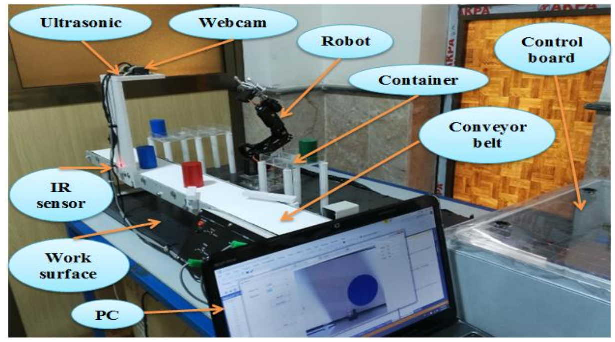

Figure 12: Robotic system.

5. Sorting Algorithm

The sorting process is achieved according to the following steps:

- The objects are fed to a conveyor at specific periods. These objects will move along a conveyor belt.
- When objects appear in front of the IR sensor, They get detected, and a signal is sent to the microcontroller (Arduino).
- The microcontroller sendsa signal tothe relay to stop the movement of the conveyor belt. The ultrasonic (HC-SR04) sensor will then begin to measure the height of the object.
- C# with EmguCV library runs the webcam to capture the image ofthe object, then uses image processing to analyze this image to detect the color and dimensions of the object.
- The color and dimensions of the object are sent to the microcontroller, as feedback. The microcontroller moves the robotic arm to pick the object from the conveyor and perform the sorting process by placing it on the desired container according to its dimensions and color. After finishing the sorting process, a microcontroller sends a signal to the relay to move the conveyor belt to bring another object.

These steps are repeated to process the next object. Figure 13 illustrates the sequence of these steps.

Published by: The Mattingley Publishing Co., Inc.

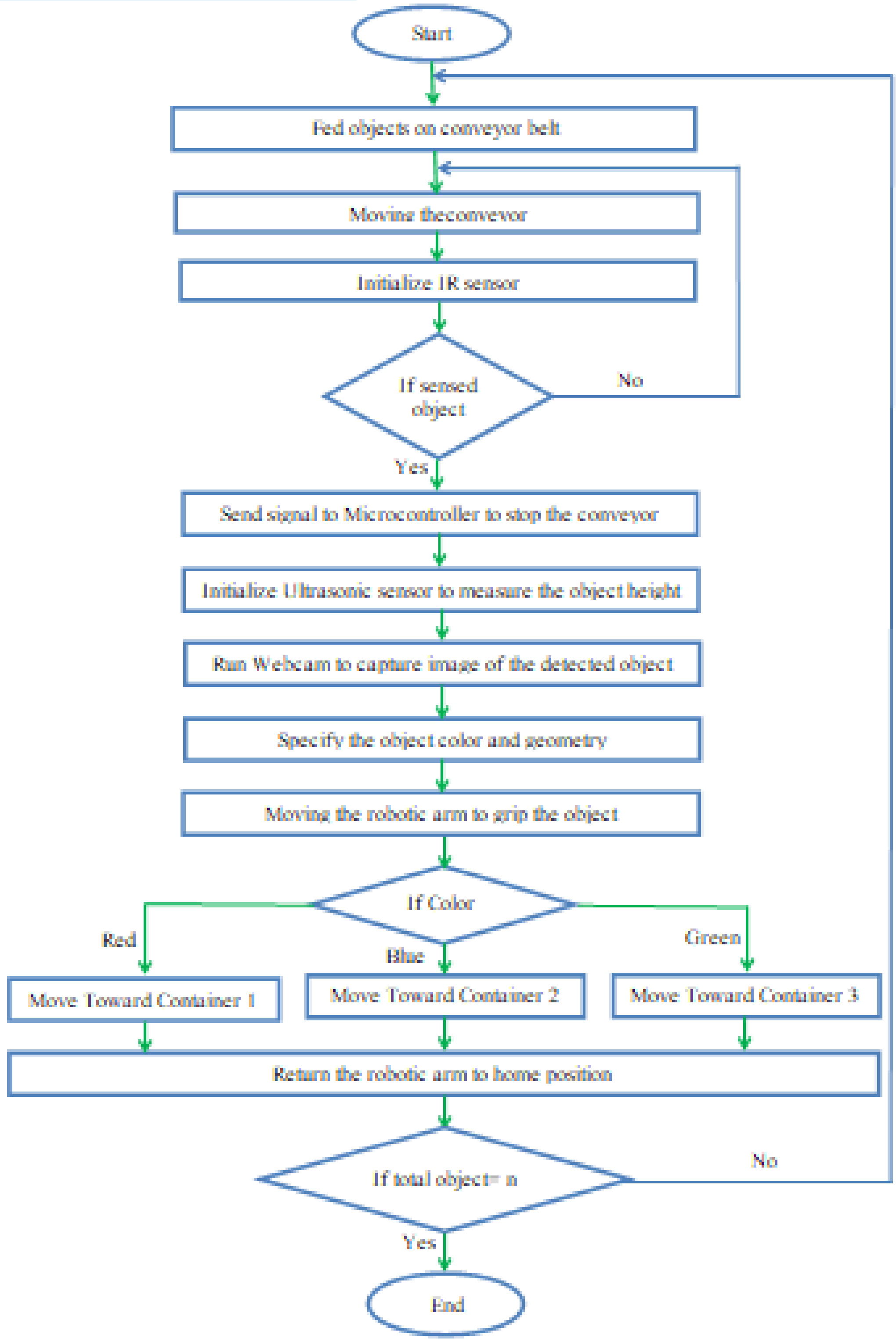

Figure 13: Sequence of the sorting process.

6. Testing the System

The C# and EmguCV library, as shown in Figure 14, are used to perform the image processing for detecting objects and determining their color, geometry, and dimensions.

The sorting process for two different objects' geometry (cylindrical and cubic) with three different colors (red, green, and blue) was tested. Three containers were used as discharge stations, two of which were placed to the left of the robotic arm, one for the red color, and the second for the blue color, while the third container for the green color was placed on the right hand of the robotic arm. Each container consists of four sections, and the locations in the containers were specified according to the shape, geometry, and color of the objects, as shown in Figure 15.

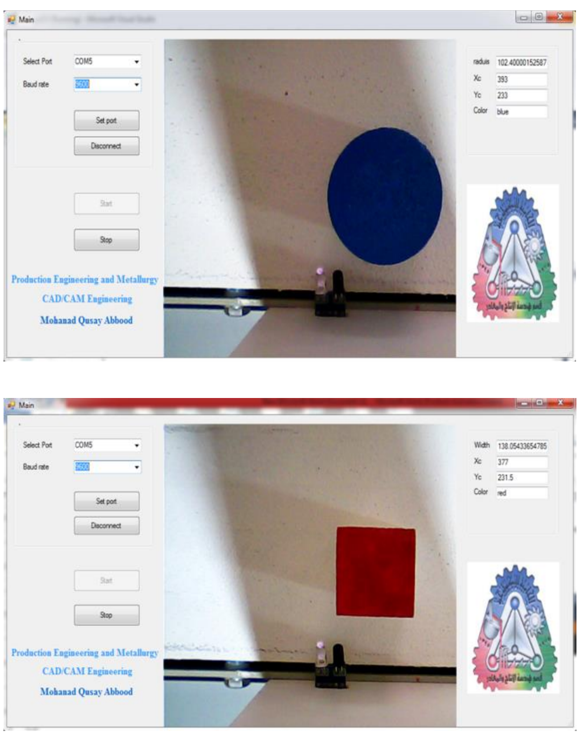

Figure 14: Communication software between Visual Studio and Arduino IDE.

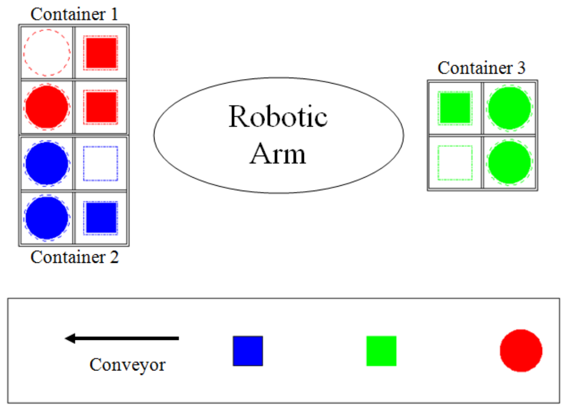

Figure 15: Locations in containers.

7. Results and Discussion

The objects' geometry, color, and dimensions were detected using image processing, and these parameters were converted from pixel units to millimeter units using a scale. An inverse kinematic solution was used to obtain the angles of the robot arm required to move it from one position to another to perform the sorting process.

Figure 16 shows the results of the sorting process according to the objects' geometry and color in the desired container. It is shown that the proposed robotic system demonstrated in the laboratory, has successfully performed both pick and place processes as well as the sorting process.

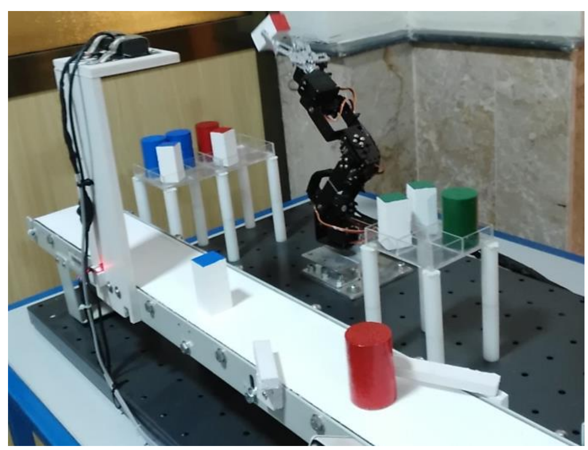

Figure 16: The Sorting process.

TEST Engineering & Management

March - April 2020
ISSN: 0193-4120 Page No. 7190 - 7198

8. Conclusion

The proposed system for areal-timesorting process according to geometry and color using image processing proved successful. An implemented image processing algorithm gives accurate results in detecting objects and their colors (red, blue, and green). The system can be extended to manipulate further object geometries and colors. The robotic system in the sorting process has achieved 100% accuracy. However, insufficient lighting affects the image capturing and image processing program. Thereforesuitable lighting is required for optimum functionality.

9. References

1. Selver M. Alper, Akay Olcay, Alim Fikret, Bardakc Sibel, and O¨lmez Mehmet, "An automated industrial conveyor belt system using image processing and hierarchical clustering for classifying marble slabs", Robotics and Computer-Integrated Manufacturing, Vol. 27, pp. 164-176,2011.
2. Raza Kazim, Khan Tauseef Aized, and Abbas Naseem, "Kinematic analysis and geometrical improvement of an industrialrobotic arm", Journal of King Saud University – Engineering Sciences, Vol. 30, pp. 218-223, 2018.
3. Canal Gerard, Escalera Sergio, and Angulo Cecilio, "A real-time Human-Robot Interaction system based on gestures for assistive scenarios", Computer Vision and Image Understanding, pp. 1-13, 2016.
4. Kurka Paulo Roberto Gardel and Salazar Aldo André Díaz, "Applications of image processing in roboticsand instrumentation", Mechanical Systems and Signal Processing, Vol. 124, pp. 142-169, 2019.
5. Ramesh H. R. and Pooja, "Colour Sorting Robot in LabVIEW Using Image Processing", International Journal of Science and Research, Vol. 6, Issue 12, pp. 47-50, 2017.
6. Patil Madhav D, "Robot Manipulator Control Using PLC with Position Based and ImageBased Algorithm", International Journal of Swarm Intelligence and Evolutionary Computation, Vol. 6, Issue 1, pp.1-8, 2017.
7. V. Priyadharshini, L. Saranya, and R. Srinivasan, "Robotic Arm for Pick & Place Operation using MATLAB Based on OFFLINE Surface Clustering Algorithm", International Journal of Research in Computer Applications and Robotics", Vol. 5, Issue 5, pp. 32-37, 2017.
8. Dandekar Yayati, Gawand Shubham, Kushal Deshmukh, and Adepu Akshay, "Object Sorting Robotic Arm using OpenCV", Imperial Journal of Interdisciplinary Research, Vol. 3, Issue 4, pp. 875-877, 2017.

9. Ali Md. Hazrat, K.Aizat, K.Yerkhan, T.Zhandos, and O.Anuar, "Vision-based Robot Manipulator for Industrial Applications", International Conference on Robotics and Smart Manufacturing, pp. 205-212, 2018.