International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 7, Issue 2, pp: (50-62), Month: April - June 2019, Available at: www.researchpublish.com

Image Processing Based Automatic Color Object Sorting Using PLC System

RajaaAl Hinai[1], Abdelhamied farh[1], Sulaiman Al hasani[1]

[1]Department of Electronics and Telecommunications Engineering, Global College of Engineeirng and Technology -Oman
Email: r.hinai@gcet.edu.om

Abstract: **In recent years, there is a clear growth and development in the field of automation both in industry and residential areas. The rates of products of industries have considerably increased leading to increase the needing of more employment or new techniques. Product sorting process plays an important role as these industries cannot afford any human errors for sorting products. Therefore, it becomes necessary to develop a system that could sort these products with higher accuracy and with minimum human interference. The use of image processing to automatically sort objects based on their colors is an interesting area of research. In this, products would be sorted according to the colors using an accurate and high level technique. So, this project focused in a highly automated system which uses Raspberry pi 3 and it is interfaced with camera module to detecting the, Arduino Uno which interfaced with Ultrasonic sensors to tracking the products and then sorts them using PLC system.**

Keywords: **Raspberry pi 3, PLC system, Conveyor belt, Arduino Uno, CD drives.**

I. INTRODUCTION

It is in the nature of a human to make mistakes however a company or factories may experience significant monetary losses due to human error due variability of products being produced. In some businesses it can mean loss of inventory and profits; in the case of healthcare or pharmaceuticals, it could even cost lives. Almost 30% of quality defects were attributed to human error and investigations into these root causes are generally poor and superficial. There were often no sustainable CAPAs (corrective and preventive actions) defined, and the corrective action was mainly just re-training. So, the most common approach to correcting this is re-training, however it often fails to produce the desired result, and training is only responsible for about 10% of the human errors that occur. This is because it only takes care of issues related to lack of knowledge, skill or ability (Howtomechatronics, 2016)

From this point, sorting based on color is done in many industries to ensure the quality of the object is reliable and up to the mark. The error cased due to human negligence are avoided by the use of automated system because of that, this project was developed. During the starting of this project, it was clear that automated sorting systems play an integral part in ensuring goods and products across a range of industries are organized and distributed correctly and the manufacturers now understand the speed, accuracy and capacity benefits automated sorting machinery brings to the production line (Amol, 2018).

In this project, a low cost automation system will developed as a part of an industrial project for sorting the objects according to their colors. The project mainly focuses on sorting 4 different color objects using image processing, ultrasonic sensors and DC geared motors interfaced with Programmable Logic Controller (PLC) to sort the products. The system consists of conveyor belt which takes the objects in front of sensors and thus sorting logic is decided by PLC.

II. OBJECTIVES

This project purposed to automate the sorting process of products in the industries based on their colors. In addition, it aimed to automate the process of sorting products to eliminate human errors in sorting products and hence the manual effort, time consumed and avoids danger which happed when humans work in dangerous places. Moreover, the project aimed to developing this system with long durability, low cost, less maintenance, and try to make this system as user friendly as possible. Therefore, color object sorting system will be developed by using the image processing and PLC system which will serve the factories with the production of high quality and accurate products that will raise the reputation of the company and will also provide customers satisfactory products.

III. LITERATURE REVIEW

Without the right ways, sorting the product without any errors can be an almost impossible task for the human. Therefore, the sorting machines were developed to solve this problem. There are many different machines manufactured in this field and each machine have a special features and parts distinguish them from others. A lot of research has been done on how to overcome sorting problems. The main subject areas related to my project include:.

A. IMAGE PROCESSING

Image processing or a computer vision is a technical discipline that deals with searching the ways to automate all the work that a human visual system can do. Usually, image processing contains of several stages which are image import, analysis, manipulation and image output.

Avadhoot et all, (2015) used image acquisition device which is work to scan the object and after the image is checked the color is sensed. Also, Lekha, (2016) was detected the color using image processing technique. In detail, web camera E-20 MP was used to capture images of coloured products. This images were used by MATLAB for detection of color and according to basis of that color products are get sorted. This web camera has 20 MP resolution, excellent quality, and it gives clear, sharp, still picture and it has adjustable lens. On the other reference paper, Taniksha et all, (2016) were used used Zebion opal 2231 camera. It offers image input on which the algorithm is performed. This web camera is plug and play unit and it is contained of CMOS sensor, adjustable focus of 3 cm to infinity, and a frame rate up to 30 FPS.

B. TRISTIMULUS THEORY OF COLOUR PERCEPTION

In previous cases, an image is defined as a two-dimensional function, R (x,y). X and Y are spatial coordinates and the amplitude of R at any pair of coordinates (x,y) is called the intensity of that image at that point. When x,y and amplitude values of R are finite, it will called a digital image. Therefore, the images can be defined by a two dimensional array arranged in rows and columns (Lekha, 2016).

The human mesh has 3 kinds of cones. Each type of cone represented as a function of the wavelength of the incident light. The peaks for each curve are at 440nm (Blue), 545nm (Green) and 580nm (Red).

C. COLOR MODEL

As Stephanie, (2018) mentioned, a color model is a method that uses three primary colors to generate a larger range of colors. There are several types of color models used for several aims, and each has a slightly different range of colors they can create. The whole range of colors that a definite type of color model creates is called a color space. All color results from how our eye procedures light waves, but reliant on the type of media, creating that color comes from several methods.

1. THE RGB COLOR MODEL

There are two main types of color models. The most common one is Red/ Green/ Blue (RGB). This color model uses light to generate color, and it is used for digital media. RGB is also named an additive color model as when the three colors of light are shown in the same intensity at the same time, they produce white. On the other hand, If all the lights are out, the result will be black. As Stephanie, (2018) explain, an image in RGB contains three independent image planes, one in each of the primary colours: red, green and blue. Stipulating a particular colour is by specifying the volume of each of the primary components present. The following figure shows an additive model. The additive mixing of red, green and blue to procedure the three secondary colours yellow (red + green), cyan (blue + green), magenta (red + blue), and white (red + green + blue).

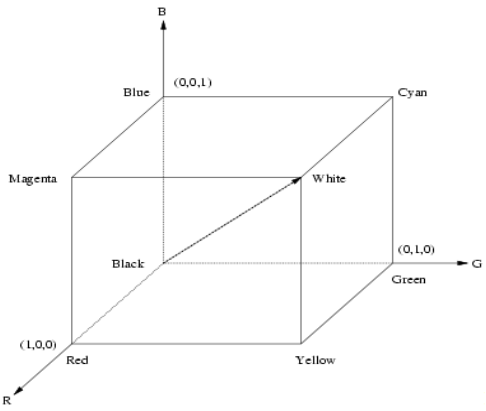

Figure 1: The RGB colour cube Stephanie, (2018).

2. The CMY Model

The CMY (Cyan/ Magenta/ Yellow) model is a subtractive model is suitable to absorption of colours. A subtractive color model adds pigment in the method of ink or dye that reasons an absence of white. As Stephanie, (2018) explain, to print a color image on paper, it must to use ink. Beginning with the bright white paper surface, the colors are printed related to a pattern. The more color is applied, the more the white surface is masked. That is why it is called subtractive. Therefore, the CMY model is used by printing plans and filters.

3. The HSI Model

The HSI color space is very significant color model for image processing requests as it represents color s likewise how the human eye senses colors.

The HSI color model represents each color with three components: Hue/ Saturation/ Intensity (HIS). The hue component describes the color itself in the method of an angle between 0 to 360 degrees. 0 degree is red, 120 is green, 240 is blue, 60 degrees is yellow and 300 degrees is magenta (Stephanie, 2018).

According to that, the image processing was more useful to use because the color sensors focus in detecting the color only but, it can be added a lot of other commands to the system in using of image processing.

D. CONVEYOR BELTS

As Nasif, (2017) explained, it is significant to system-arise the production of multiple varieties of goods, in moderate extent, as well as achieving higher inclusive productivity and requiring minimum investment and equipment. Therefore, Conveyor Belt is commonly used to convey material from a station to another one, particularly in flexible manufacturing system (FMS). Generally, A conveyor belt comprises of two or more pulleys, with an unremitting loop of material that exchanges about them.

E. SORTER TECHNIQUE

There are a difference sorting technologies available to choose from such as: Pop-Up Wheel Sorter, MDR Divert, Sliding Shoe Sorter, Belt Slat Sorter, Tilt-Tray Sorter and Pusher which is the technology which it was used in this project (Fleischer, 2014). Pusher technique depend on sorting the project by displace it (pushing the product to a specific place).

IV. EXISTING SYSTEM

The system aims to detect three colors using image processing which is done by using the raspberry pi 3 and camera module. After detecting the color, ultrasonic sensor will detect the presence of this object in the right place. So, if the color and its ultrasonic are ON, then the specific CD drive will open to sort the product based in there color or it will go forward the conveyor belt (depend in the color). This process controlled using the PLC system. So, the raspberry (which connect to the camera to detect the color) and Arduino (Which connect to ultrasonic sensors to detect the presence of the project) send their signals to different colors of LEDs. These LEDs was connected directly to the relays which are connected to the PLC system and according to the signals the appropriate command will be sent to the CD drives which are also connected to relays. According to that, the block diagram of the system was illustrated as following:

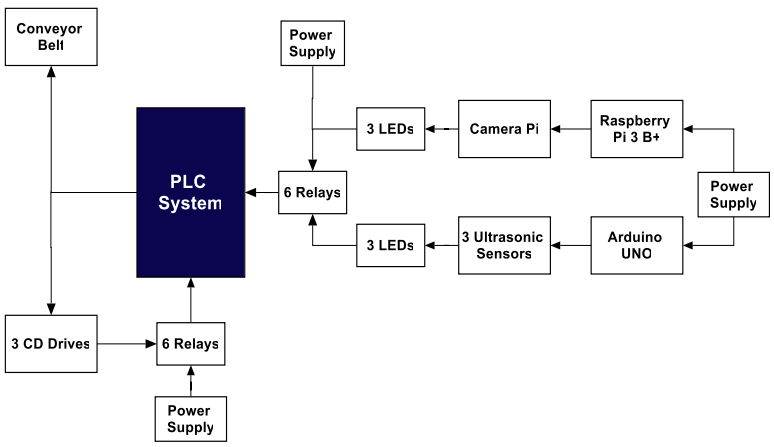

Figure 1: Block Diagram of the System.

In addtion the flow chart was desigen as shown belwo:

V. PROJECT DESIGN

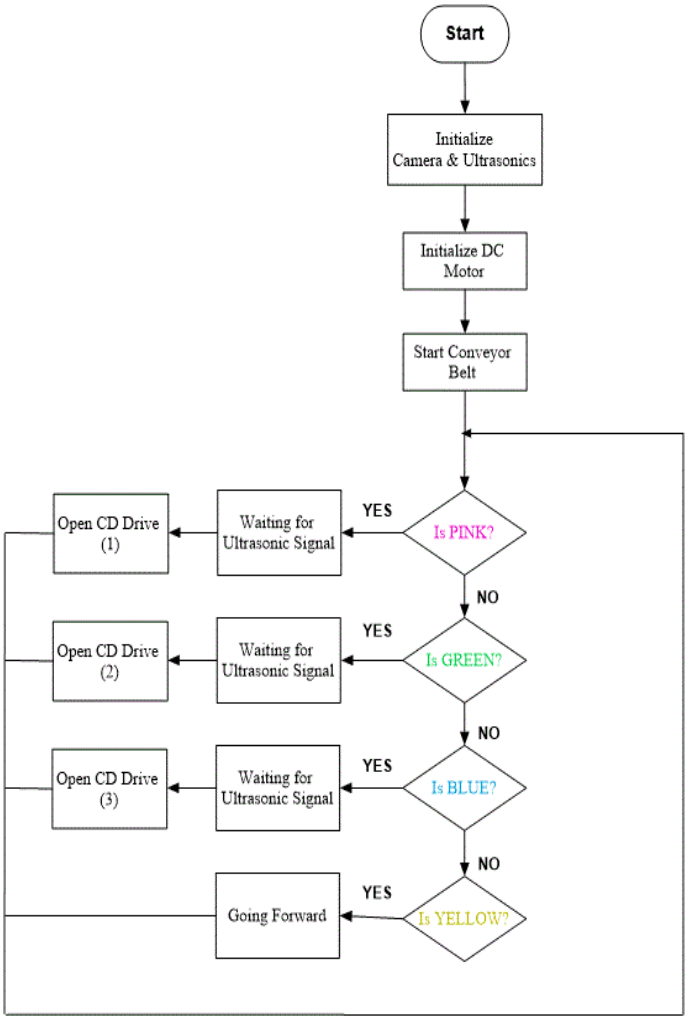

Figure 2: Flow Chart of the System.

The idea of the project is combines the mechanical, electronic and software aspects. Therefore, using Solidworks program, the mechanical design was designed as following:

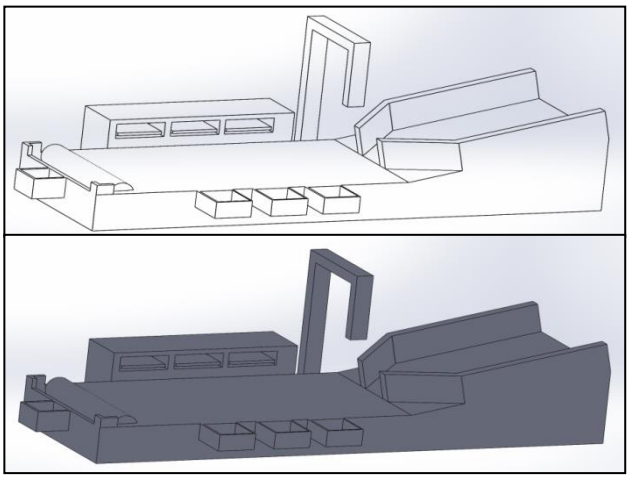

Figure 3: The Mechanical Design of the Project Using Solidworks Program.

After a long planning, the overall design which is represented by conveyor belt was built as shown in the following figure:

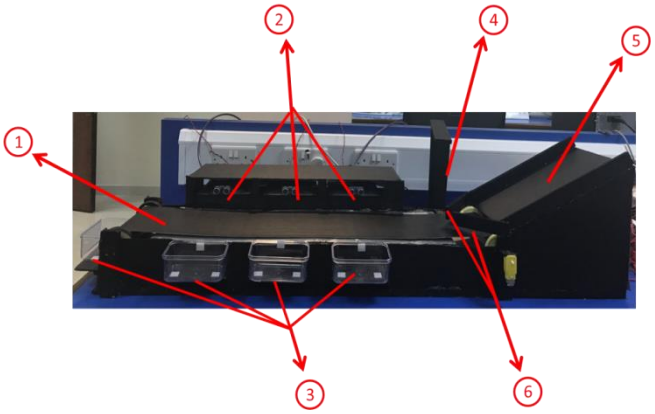

Figure 4: Project Design.

1. Belt: The production line, which is designed to facilitate products moving.
2. Three CD drives: Represents the sorter, which aims to push the products for sorting process.
3. Four boxes: These boxes are intended to receive and assemble products after pushing them.
4. Camera stand: This stand is designed to set the raspberry camera.
5. The slope: It is designed to facilitate product entry.
6. Barriers: These barriers are designed to regulate the entry of products into the belt so that products enter one after the other.

VI. IMPLEMENTATION

As it was mentioned before, the system consists of three different system. Each system has an own function. The PLC is the main system which compile the two other system together to send the specific command. These two systems were illustrated as following:

A. COLORS DETECTION:

The colors were detected using camera pi which was interfaced with raspberry pi 3. After installing OpenCV, Python language was used to programming this task. As it was explained, the machine will sort four different colors (Pink, Green, Blue, Yellow). However, it is no need to illustrate the fourth color because it will go forward in the conveyer belt as it is not a part of the python code. So, each color has a specific BGR color code which distinguish it from the other colors. According to that, the BGR range of the colors was illustrated as shown:

Table 1: The Range of the Colors.

Color/Range	Lower	Upper
Pink	**[136,87,111]**	**[180,255,255]**
Green	**[36, 202, 59]**	**[71, 255, 255]**
Blue	**[103, 86, 65]**	**[125, 255, 255]**

This was written in Python language as:

```
#Definig the Range of Pink color
  pink_lower=np.array([136,87,111],np.uint8)
  pink_upper=np.array([180,255,255],np.uint8)

  #Defining the Range of Green color
  green_lower=np.array([36, 202, 59],np.uint8)
  green_upper=np.array([71, 255, 255],np.uint8)

  #Defining the Range of Blue color
  blue_lower=np.array([103, 86, 65],np.uint8)
  blue_upper=np.array([125, 255, 255],np.uint8)
```

On the other hand, the LEDs were used to ensure color detection process. This was happened by control the outside world by being connected to electronic circuit. Therefore, using General Purpose Input Output (GPIO), the Raspberry Pi was able to control LEDs with the detection of the colors. The following figure shown the connections of GPIO with LEDs circuit:

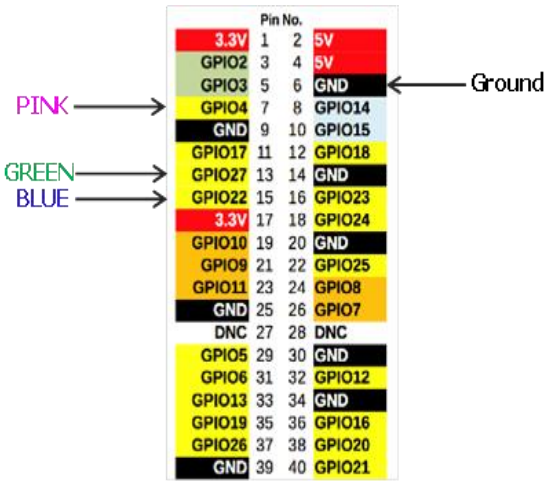

Figure 5: The Connections of GPIO with LEDs Circuit.

Therefore, the overall connections between raspberry pi 3 and LEDs electronic circuit was illustrated as shown:

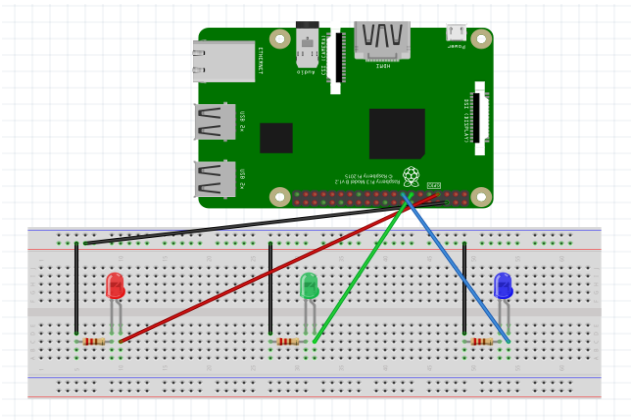

Figure 6: LEDs Circuit with GPIO Raspberry Pi 3 Connections.

The LEDs circuit was built in the Breadboard then in the Stripboard and finally in printed circuit board (PCB) as shown below:

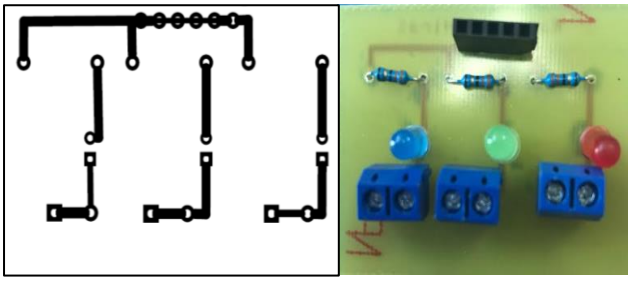

Figure 7: PCB of Raspberry Pi 3 LEDs Circuit.

B. PRODUCTS TRACKING:

After detected the colors, the system should track the presence of the objects. Therefore, Arduino UNO was interfaced with three ultrasonic sensors which were connected to three different LEDs. The following table shows the pins connections between Arduino and the circuit:

Table 2: Pins Connections between Arduino and its circuit.

Colors/Pins	LED Pin	Trig Pin	Echo Pin
PINK	3	6	7
GREEN	4	8	9
BLUE	5	10	11

This was written using Arduino program as shown:

```
int ledPin1 = 3;
int ledPin2 = 4;
int ledPin3 = 5;

int trigPin1 = 6;
int echoPin1 = 7;

int trigPin2 = 8;
int echoPin2 = 9;

int trigPin3 = 10;
int echoPin3 = 11;
```

Moreover, the distance between the object and the sensor was determined to be no more than 40cm as it is depend on the distance between the object in the center of the belt and the location of the sensor. This was illustrated as:

```
if (distance1 < 40) {  // Determining the distance to be less than 40
cm
   digitalWrite (ledPin1, HIGH); // LED is ON
  } else {
   digitalWrite (ledPin1, LOW); // If the distance is less than 40cm
the LED well be OFF
```

Therefore, the overall connections between Arduino and its electronic circuit was illustrated as shown:

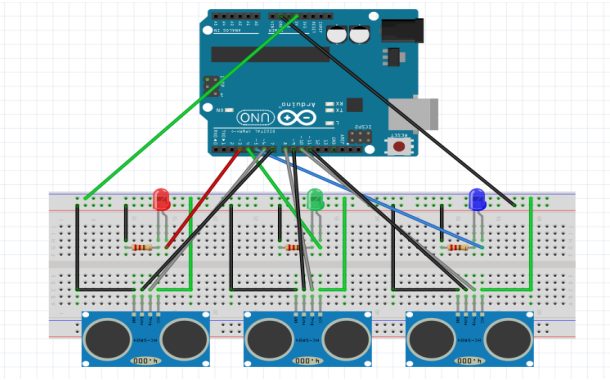

Figure 8: Tracking Circuit with Arduino Connections.

As raspberry pi 3 LEDs circuit, this circuit was built in the Breadboard then in the Stripboard and finally in printed circuit board (PCB) as shown below:

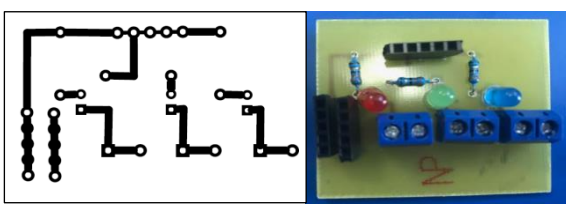

Figure 9: PCB Arduino Circuit.

VII. PLC LAYOUT WIRING OF THE SYSTEM

Generally, PLCs are using in automated industrial to control machines which using different power supply (AC (single phase 110/220),AC (3phase 320/440) and DC 24) because of that most of company whose product PLC putting different ways for PLC powering supply and also for feeding input and output devices until 1993 when first standards "IEC 61131-3 for PLC" Which unity all types of PLC power sources to run 24volts DC and 220 volts AC.

In this project, different input devices were used like ultrasonic HC-SR04 which interfaced with Arduino UNO with 5 volts output, DC motor which interfaced inside CD drives with 20 volts and raspberry pi 3 that output 5volt DC. With this different between the volts of all these components, it was impossible to use them directly with Siemens s7-200 smart PLC. So, the buffer stage was used with 5 volts Relay Single Pole Double Throw SPDT in both input and output channels. The following table illustrates the different powers (Volts) which were used in the project:

Table 3: Different Power supply which were used in the system.

The device	The Power (Volts)
Relays	**5 V**
Raspberry pi 3	**5 V**
Arduino UNO	**5 V**
CD motor Drives	**20 V**
DC motor	**2 V**
PLC System	**24 V**

In input sides, six relays (5 DC volts) coils were connected with Arduino and raspberry pi 3 while NO (normally open) contact are connected with input channels by taking consider that input channels are DC (sink type) NPN transistor. In output sides, it was consider that output channels are DC (source type) PNP transistor. Therefore, seven relays (24 DC volts) coils are connected with output channels while NO (normally open) contact are connected to drive a seven 5 DC volts relays to run forward motor of belt conveyor (KM1) and for forward and reveres of CD motor drivers for three color as every CD motor need to two relays to run forward and reverse (KM2 to KM7). The following figure illustrate the connection of these relays:

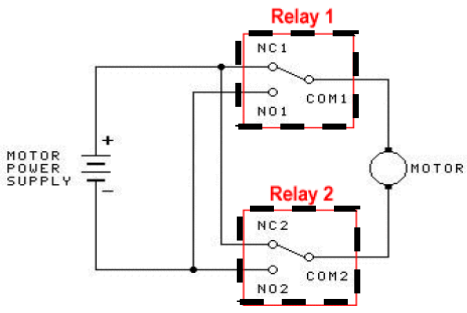

Figure 10: Two Relays to Run Forward and Revers CD Motor.

VIII. ADDRESSING OF I/P AND O/P DEVISES

Addressing means to give every i/p device and o/p device especial names similar to the names that locate in input and output channels. So, using ladder program, switch (sw1) written as I0.0 in input channels. Therefore, when switch active the input channels will active too. The program will run base on the action of i/p and o/p will active base on ladder code. The following tables illustrate the addressing of whole system.

Table 4: Addressing of I/P Device of the System.

I/P Device	Addressing in PLC s7-200	From
Sw1	I0.0	Stop Switch
Sw2	I0.1	Start switch
KA1	I0.2	Pink – Raspberry Pi
KA2	I0.3	Pink – Arduino
KA3	I0.4	Green – Raspberry Pi
KA4	I0.5	Green – Arduino
KA5	I0.6	Blue–Raspberry Pi
KA6	I0.7	Blue –Arduino

Table 5: Addressing of O/P Device of the System.

O/P Device	Addressing in PLC s7-200	To
Km1	Q0.0	Belt Conveyor
Km2	Q0.1	CD (Pink) Forward
Km3	Q0.2	CD (Pink) Reverse
Km4	Q0.3	CD (Green) Forward
Km5	Q0.4	CD (Green) Reverse
Km6	Q0.5	CD (Blue) Forward
Km7	Q0.6	CD (Blue) Reverse

IX. TESTING

After each system was implemented separately, each of them was tested as follows:

A. COLORS DETECTION TEST:

As it was explained, using Pyhton language, the color code was built to detect the colors then to send a specific signal to the LEDs circuit. Firstly, the code was built to detect the colors by adding a rectangle contour around them as it shown below:

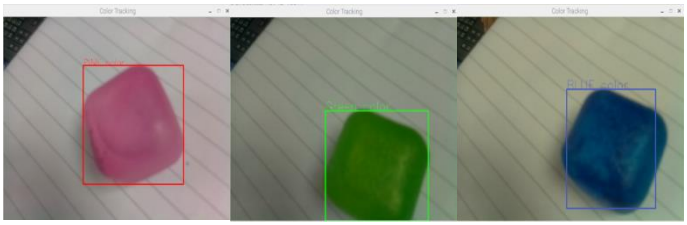

Figure 11: Test the Color Detection by Using a Rectangle Counter.

After that, a specific signal was sent to a specific LED when the camera detect the color as it is illustrated below:

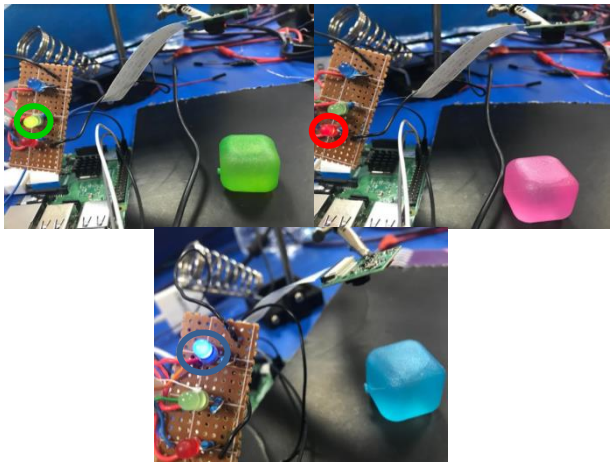

Figure 12: Sending a Signal to the LED when the Camera Detect the Color.

B. PRODUCTS TRACKING TEST:

As it was explained, ultrasonic sensors were connected with LEDs to track the object with a specific distances. The following figure shows that clearly:

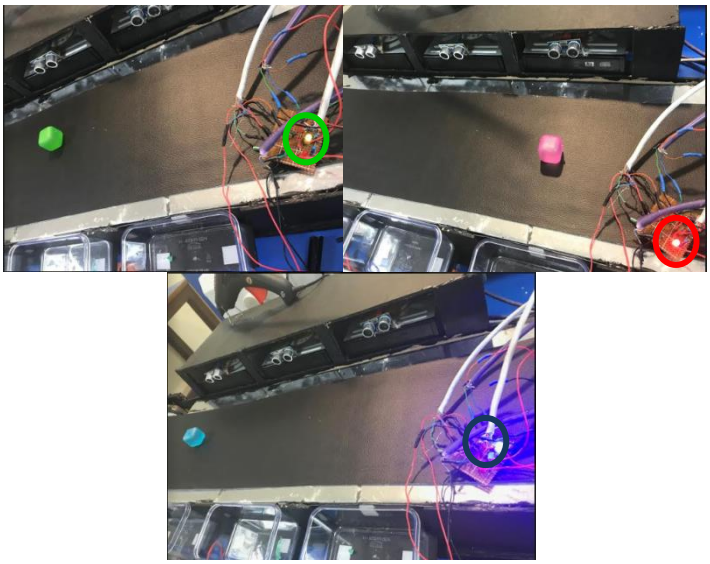

Figure 13: Test the presence of the object using ultrasonic sensor and LED.

C. PLC SYSTEM TEST:

Regarding to tables 4, 5 and by using ladder language, the test of PLC system was illustrated as shown below:

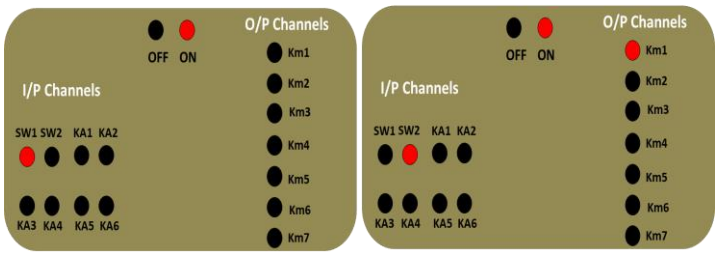

Figure 14: OFF/ON the System.

As it was mentioned in table 4, SW1 shows the stop case. So, if SW1 ON the system is still in stop mode. On the other hand, SW2 shows the start case. Therefore, if SW2 is ON the conveyor belt (Km1) will start working as well the whole system cases.

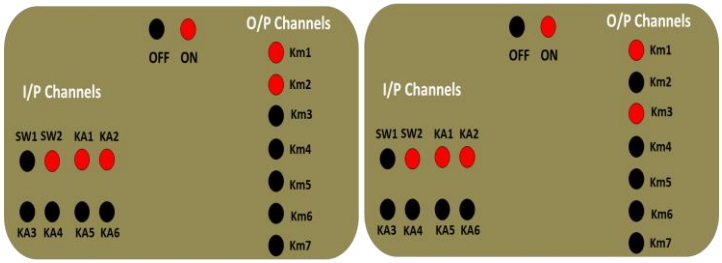

Figure 15: Forward/Revers (Red CD Drive).

When the system is in run mode (SW2 ON) and the signals of red colors are ON (KA1 and KA2) which show the signal from the camera pi and ultrasonic Sequentially, CD motor drive will start run forward (Km2) then it will reversed (Km3).

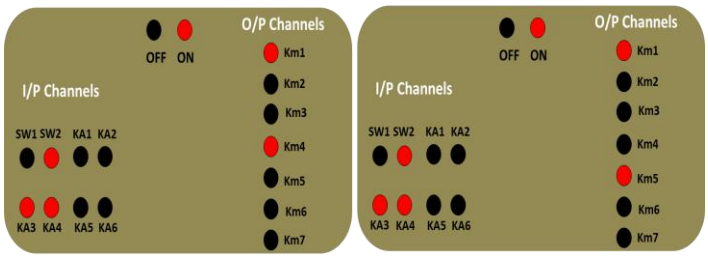

Figure 16: Forward/Revers (Green CD Drive).

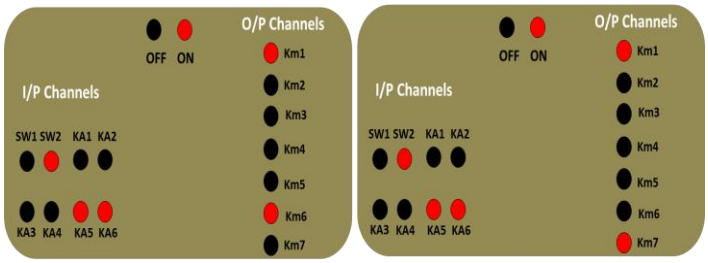

Figure 17: Forward/Revers (Blue CD Drive).

The same process was repeated for green and blue colors. When the signals of green colors are ON (KA3 and KA4), CD motor drive will start run forward (Km4) then it will reversed (Km5). As well as the blue color, when the signals are ON (KA5 and KA6) CD motor drive will start run forward (Km6) then it will reversed (Km7).

X. ANALYSIS OF RESULTS AND DISCUSSION

The final result was quite satisfactory. Firstly, The design was carefully chosen as each part of it has a particular function and specific aim (See Figure 4). On the other hand, the camera was detect the colors well so, it was able to detect pink, green and blue products. In addition, a specific signals were sent from the camera to run a LED which depend in the color detected (See Figure 11 & 12). Moreover, the product was tracking well by using Ultrasonic sensors. So, three ultrasonic sensors were interfaced in the specific location in conveyor belt design and when the object was become in the range of the sensing, it was sent a suitable signal to a specific LED to inform about the presence of the product (See Figure 13). Also, DC motor (2V) was used to get torque for the movement of the conveyor belt as well as CD motor drives (20V) which were used to push the object to sorting process. All these processes (Colors detection, Tracking the objects, Conveyor belt movement and sorter technique) were combined in PLC system. Therefore, the overall results were illustrated as following:

1- When the system is in the run status, the PLC will send a signal to DC motor so, conveyor belt will start moving (See Figure 14).

2- When the system is in run status and the PINK color was detected by the camera then ultrasonic sensor will sense the presence of PINK object in its specific location, these signals will send to the relays and then the relays will send them to PLC system. Then, PLC will send a signal to the FIRST CD MOTOR DRIVE to open it in forward direction to push the object then it will reversed to go back in the normal case (See Figure 15).

3- When the system is in run status and the GREEN color was detected by the camera then ultrasonic sensor will sense the presence of GREEN object in its specific location, these signals will send to the relays and then the relays will send them to PLC system. Then, PLC will send a signal to the SECOND CD MOTOR DRIVE to open it in forward direction to push the object then it will reversed to go back in the normal case (See Figure 16).

4- When the system is in run status and the BLUE color was detected by the camera then ultrasonic sensor will sense the presence of BLUE object in its specific location, these signals will send to the relays and then the relays will send them to PLC system. Then, PLC will send a signal to the THIRD CD MOTOR DRIVE to open it in forward direction to push the object then it will reversed to go back in the normal case (See Figure 17).

5- When the system is in run status and the YELLOW color product was presence in the conveyor belt, no signal will send to the PLC system. Therefore, the product will not sorted by any CD motor drives and it will continue move in forward direction to received by the fourth box.

XI. SPECIFICATION AND ADVANTAGES

The specifications that distinguish this project than others are:

1. Tracking products range: 40cm.
2. Length of sorting machine: 1.25 meter.
3. The distance between the camera and the product: 5cm.
4. Length of the slope of the design: 45cm
5. Combining between raspberry pi and Arduino Uno in one system.
6. Comprehensive system control using PLC system which enables to add a lot of others inputs and outputs.
7. Fully automatic operation.
8. Accurate detection of the colors.
9. Accurate object tracking .

Therefore, the advantages of this system are:

1. Reduce labor cost.
2. Improves productivity
3. Less human interference.
4. Increases in production capacity and quality.
5. Easily developed.
6. Time saving and efficient

XII. CONCLUSION

In conclusion, sorting systems are used to sort items based on various criteria so they can be packaged accordingly. So, manual sorting is a time and effort intensive process. it has been reported to be complex and a global problem. Therefore, automatic sorting systems allow for fast and efficient sorting of products. According to that, this project was designed and developed to sort products in a specific conveyor belt design which has been chosen with taken into consideration the requirements of the process. In addition, the system able to incorporate flexibility and separate products of different colour and at the same time sort objects automatically to the right section using the main controller which is the Programmable Logic Controllers (PLC). The main benefit of PLC system is it is been controlling several inputs and outputs, the whole conveyor model can be controlled by a single PLC along with sensors connected throughout. By the end of this project, the sorting problems can be solved successfully with a high technique using this system and it can be developed easily using an additions process such as shape and weight detections.

XIII. RECOMMENDATIONS FOR FURTHER WORK

A lot of developments can be add in the system to increase the production rate as well as to minimize cost. The following points illustrate that:

1. Using Laser sensor rather than Ultrasonic sensor, the accurate of the tracking will increase due to decreasing the area of sensing which lead to increase the speed of the process.
2. Adding a shape and weight detections with the color to increase the production specifications.
3. Increasing the numbers of conveyors belts to increase the possibility of adding another detections tasks.
4. Adding a LCD screen to display the amount of sorted products.

REFERENCES

[1] Amol Nandu Ahire, Manoj Ravindra Fegade, Gurpreet Singh Bhatt, Nikhil Nandu Ahire., 2018. Rgb Color Sensor Based Object Detection & Scada.

[2] Avadhoot R.Telepatil , Prashant M. Jadhav., 2015. Colour Object Counting And Sorting Mechanism Using Image Processing Approach. Scientific Journal Impact Factor (Sjif), 1.

[3] Howtomechatronics., 2016, February. A Novel Design Of A Robotic Object Sorter Based On Color Differences Using Image Processing Techniques. In 2016 International Conference On Computer, Communication, Chemical, Material And Electronic Engineering (Ic4me2) (Pp. 1-4). Ieee.

[4] Nasif Hassan Khan, Deb Kumar Sarkar, Asif Siddique, Md. Mamunur Rahman, Swarup Chakraborty., 2017. Fabrication Of A Conveyor Belt With Object Sorting And Counting Facility. International Journal Of Advancements In Research & Technology.

[5] Stephanie Przybylek., 2018. What Is A Color Model? - Uses & Definition. Study-Academy-Lesson.

[6] Fleischer, R.C., Mcintosh, C.E. And Tarr, C.L., 2014. Product Handling Concepts. Molecular Ecology, 7(4), Pp.533-545.

[7] Lekha Bhausaheb Kachare., 2016. Object Sorting Robot Using Image Processing. International Journal Of Electronics, Electrical And Computational System.