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Technical paper

Automatic Color Sorting Machine Using TCS230 Color Sensor And PIC Microcontroller

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Abstract

Sorting of products is a very difficult industrial process. Continuous manual sorting creates consistency issues. This paper describes a working prototype designed for automatic sorting of objects based on the color. TCS230 sensor was used to detect the color of the product and the PIC16F628A microcontroller was used to control the overall process. The identification of the color is based on the frequency analysis of the output of TCS230 sensor. Two conveyor belts were used, each controlled by separate DC motors. The first belt is for placing the product to be analyzed by the color sensor, and the second belt is for moving the container, having separated compartments, in order to separate the products. The experimental results promise that the prototype will fulfill the needs for higher production and precise quality in the field of automation.

Keywords: *Color sorting, Conveyor belt, DC motor, PIC 16F628A, TCS230 color sensor.*

1. Introduction

Machines can perform highly repetitive tasks better than humans. Worker fatigue on assembly lines can result in reduced performance, and cause challenges in maintaining product quality. An employee who has been performing an inspection task over and over again may eventually fail to recognize the color of product. Automating many of the tasks in the industries may help to improve the efficiency of manufacturing system. The purpose of this model is to design and implement a system which automatically separates products based on their color. This machine consists of three parts: conveyor belt, color sensor, and dc motor. The output and input of these parts was interfaced using PIC microcontroller.

To reduce human efforts on mechanical maneuvering different types of sorting machines are being developed. These machines are too costly due to the complexity in the fabrication process. A common requirement in the field of color sorting is that of color sensing and identification.

1.1. Color Sensing and Identification

Color sensor systems are increasingly being used in automated applications to detect automation errors and monitor quality at the speed of production line. They are used in assembly lines to identify and classify products by color. The objectives of their usage include to check the quality of products [1-3], to facilitate sorting and packaging [4-6], to assess the equality of products in storage [7,8], and to monitor waste products [9]. Consequently, there is an abundance of color sensors and the choice is often application-driven [10, 11]. Low cost and simple color sensors are preferred over sophisticated solutions for less demanding applications where the top priority is cost and power consumption.

Color names can be used and conjure reasonably consistent perceptions. There have eleven basic color names that have been identified such as white, gray, black, red, yellow, green, blue, orange, purple, pink, and brown. Most or all colors can be described in terms of variations and combinations of these colors [12]. Due to the fact that human color vision is accomplished in part by three different types of cone cells in the retina, it follows that three values are necessary and sufficient to define any color. Color theory describes that there are three values that can be thought of as coordinates of a point in three-dimensional space, giving rise to the concept of color space. Hue, saturation, luminance is one such color co-ordinate system, or color space.

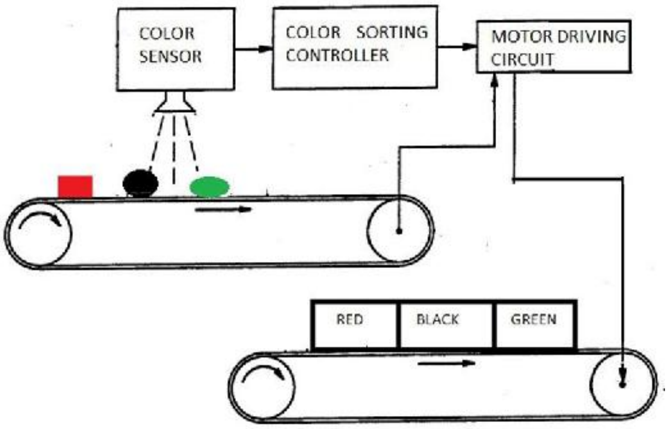

Figure 1: Block Diagram

1.2. Color Sorting

Bickman, et al [13] described in the article about automated color-sorting using optical technology that has evolved from early designs intended to remove ceramic contaminants. The system configuration is similar to automated ceramic removal equipment, but color-sorting equipment used a different light source. Automated systems can generally be instructed to remove any one or a combination of the three glass colors. Industrial applications require some sort of automated visual processing and classification of items placed on a moving conveyor. Bozma and Yal-cin [14] state that items may be randomly positioned and oriented while moving on a conveyor. A camera located above the conveyor views the items orthographically. Boukouvalas et al [15] describes an integrated system developed for the detection of defects on color ceramic tiles and for the color grading of defect-free tiles. The integrated system developed under the ASSIST project (automatic system for surface inspection and sorting of tiles) is used for the detection of defects on color tiles and for the color grading of defect-free tiles. Many have proposed advanced solutions for the sorting of recyclable packaging towards process automation. Mattone et al [16] had explained about a technique for detecting and classifying objects. Most of the authors prefer to use 2D Vision techniques to separate the objects from the known belt background and to get some of their geometrical parameters.

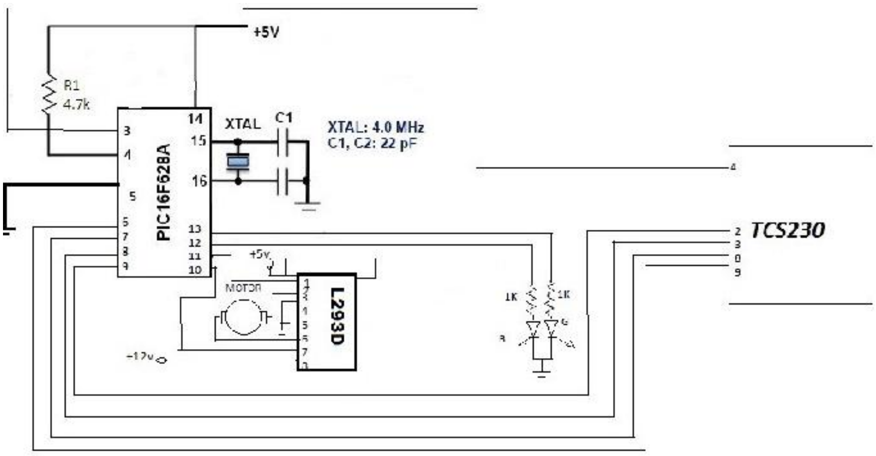

Figure 2: Circuit Diagram

2. Methodology

2.1. Prototype Design Parameters

The proposed system is designed for automatic sorting of Red or Green or Black colored products. The prototype consists of two DC motors, two conveyor belt, a PIC and a color sensing circuit using TCS230 (Fig. 3). DC motors are used to control the conveyor belts. After integrating the programmed PIC and the TCS230 circuitry with the structure of the model, we measure the frequency of signals corresponding to each color by observing them on a CRO. Based on this study the timer delay value is adjusted by reprogramming the PIC. The time required for the product to reach the corresponding container in the separator placed on second conveyor belt is also considered. L293D Hybrid IC is used to drive the second motor both in clock wise and anti-clock wise direction, which provides the to and fro movement of the container of dimensions 9cm x 30cm x 7cm (Width x Length x Height). Separators were used to create compartments of equal sizes meant for collecting objects of same color. The end section consist of a DC motor (12V, 30rpm), which is used to control the movement of the second conveyor belt in order to position the separator according to the sensor output.

The whole framework, excluding the DC power supply, weighed 1.5kg approximately and was 27cm tall, 35cm wide and 77cm long.

Figure 3: Side view of our prototype.

2.2. TCS230 Color Sensor

The TCS230 is a programmable color sensing module equipped with GY-31 light-to frequency converter that combines configurable 8x8 silicon photodiode array as single monolithic CMOS integrated circuit [17]. The output is a square wave (50 percentage duty cycle) with frequency directly proportional to light intensity (irradiance). The full scale output frequency can be scaled by one of three preset values via two control input pins. Digital inputs and digital output allow direct interface to a microcontroller or other logic circuitry. Output enable (OE) places the output in the high-impedance state for multiple unit sharing of a microcontroller input line. The light-to-frequency converter reads an 8 x 8 array of photodiodes. Sixteen photodiodes have blue filters, 16 photodiodes have green filters, 16 photodiodes have red filters, and 16 photodiodes are clear with no filters. The four types (colors) of photodiodes are inter-digitated to minimize the effect of non-uniformity of incident irradiance. All 16 photodiodes of the same color are connected in parallel and which type of photodiode the device uses during operation is pin-selectable. Photodiodes are 120 mm x 120 mm in size and are on 144-mm center.

2.3. Constraints on Object Dimensions

The test objects were soft drink bottle caps with cylindrical shape having 2.5cm diameter and 1cm height. The distance between the top surface of the object and the color sensor, during the time of detection process, must always be the same. The reason for such a constraint is owed to the fact that TCS230 produces output signals of different frequencies while detecting the color of the same object kept at different distances from the sensor. We have used four aluminum rods and a fiber plate to suspend the color sensor above the first conveyor belt so that a 17cm wide and 6cm high rectangular window is provided for the object to move under it. In other words, deducting the height of our test object, the sensor and the top of the object is kept 5cm apart.

2.4. Working of the Model

When a supply of 3.4V is given to the DC motor (12V, 3.5rpm) it starts to rotate. It will control the movement of the conveyor belt on which the product is placed.

When the light falls on the product it is reflected back to the color sensor. As mentioned before, color sensor TCS230 has 4 color filters for green, red, blue and black (no color), which is opted by its select pins. Filters are selected by the program saved in the microcontroller. Frequency output from color sensor depends on the color of the object as well as the select pin configuration input from microcontroller. Select pin can select one of the four photo diode filters which can give output according to the color of the object. When there is no object in front of sensor it produces an output of 330Hz range frequency and when there is an object it produces an output frequency of 7-14 KHz.

The microcontroller can find the frequency of the output from TCS230 by counting falling or rising edge of sensor given to its TOCK1 pin using pre-scalar settings set by option register configuration. The pre-scalar was set for 1:16 arrangement and the time for counting is 50ms. Hence PIC counts the frequency using its timer at the rate of one increment for sixteen falling edges of input frequency given to TOCK1.

When there is no object in front of sensor it produces an output of 330Hz range frequency. Hence we set a break down value of 32H for deciding whether there is an object on the conveyor belt or not. Therefore the PIC can only proceed to the next step after checking this condition. If there is an object the sensor produces an output frequency which is proportional to the color of the object and the selected photo diode configuration in such a way that it provides maximum frequency for the respective color to the respective photo diode. Hence sensor gives maximum frequency for red colored object when red filter is selected, and in the same way other colored object are also sensed by corresponding filters. Frequency received during each filter selection is counted and saved to separate registers and these values are examined for taking the greater one, in order to identify the color of the object.

The second DC motor is in contact with another conveyor belt, on which a container is placed. The container has three sections; first section for Green, middle for Black, and third for Red. According to the color, the container will be moved in forward or backward direction by the conveyor belt, which is made possible by connecting the DC motor to L293D hybrid IC. The products will finally fall to the corresponding sections in the container.

Fig.2 shows the circuit connections between different components of the model. The PIC, has 18 pins, out of which five pins are connected to TCS230 color sensor, and two pins are connected to L293D IC.

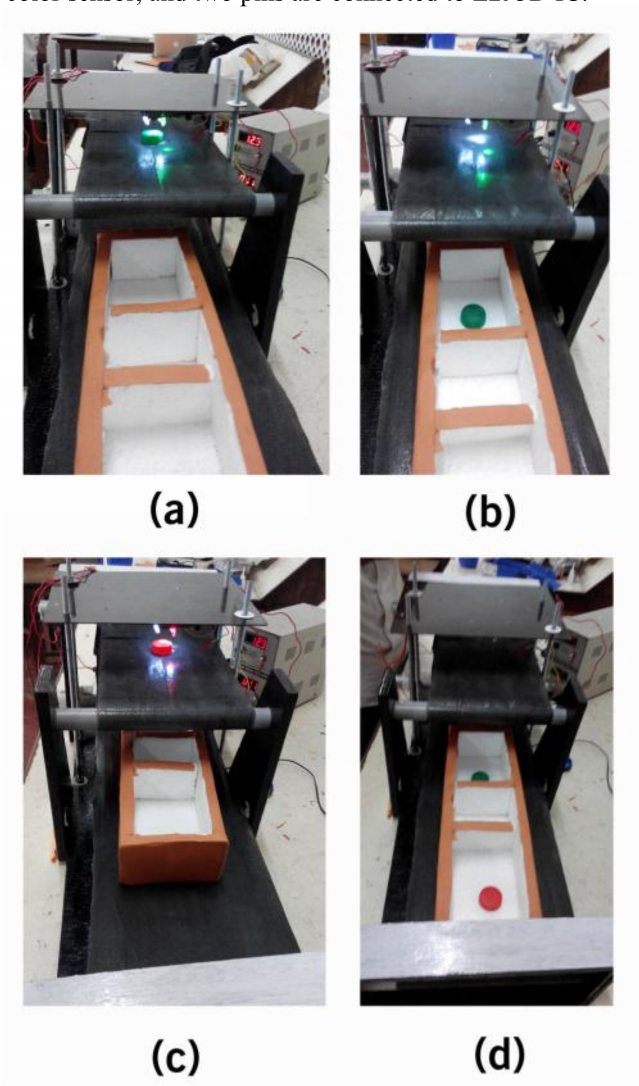

Figure 4: (a)The color sensor identifying the color of object 1, (b)the object 1 (Green) falls into the first section of the container, (c) The color sensor identifying the color of object 2, and (d)the object 2 (Red) falls into the third section of the container.

3. Results and Conclusion

We have developed a sorting machine using PIC for automatic color sorting, taking in to consideration three colors namely Green, Red and Black. We consumed two months to produce the prototype with the expense of Rs.2000. Fig.4 shows different stages involved in the process. You may note that the green object and the red object lying in different sections of the container placed on the second conveyor belt.

3.1. Dimensional Analysis

The prototype is designed for sorting objects of any shape but having fixed sizes of 1cm. We can of course change this parameter by adjusting the aluminum frame of the color sensor. But one may note that it usually results in a change in the light ambience forcing us to do further frequency analysis of the sensor output for test colors. The prototype will get more complicated as we increase the number of colors that have to be detected.

The placement of the object on the first conveyor belt is very crucial. It must be so placed that the centre of the object and that of the sensor should be aligned with the same vertical plane, so that perfect detection takes place.

3.1. Time Cost

The object once placed on the first conveyor belt takes less than half a second to reach the sensor. It takes another 200ms for the sensor to detect the color. An additional 0.6secs is required if the color of the object is not black so s to position the correct compartment in the sorting container, which implies that an additional 0.6secs will be consumed to reposition the container back the normal position on the second conveyor belt. Of course, these time values are dependent on the speed of the DC motors used.

3.1. Trails

As mentioned before we have used objects of standard size and having any of the three colors for testing our prototype. We conducted a continuous trail with 100 objects and we got 100% correct detection. As long as the colors of the objects do not deviate from the preset values and as long as the placement on the belt is perfect, the detection process seldom fails.

4. Future Work

It is very useful in wide varieties of industries along with the help of PLC and SCADA, especially in the packaging section. Automatic sorting machine enhances efficiency, practicality, and safety of operators. It ensures remarkable processing capacity as well as peerless performance including color detection. Of course we need to add high speed DC motors and sensors with appreciable response to speed up the system for industrial application.

The model can be improved by making some changes in the program and components. Some suggestions are given below.

- We can add a load cell for measurement and control of weight of the product
- We can also add a counter for counting the number of products
- Speed of the system can be increased accounting to the speed of production
- The system can be used as a quality controller by adding more sensors
- The sensor can be changed according to the type of product
- The DC motor can be replaced with stepper motor
- The PIC can be replaced with PLC

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