Automated Shape and Color Based Component Sorting Using Image Processing in Mechanical Industries

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Abstract: In manufacturing industry efficient transfer of materials calls for an equally effective sorting system. The sorting operation augments machining, storage, handling, recognition and disposal of varied form of materials in business unit. Automated material handling and sorting system can enhance productivity and delivery accuracy and benefit logistics activity in terms of reduced speed, cost and labor fatigue. Optical sorting employs camera and appropriate sensors and software platform to sort components with respect to color, shape, size, dimensions, surface finish, chemical composition, etc. The grabbed images undergo image processing to extract vital information in the form of image or characteristics that assists in sorting task. The paper deals with an automated material sorting and handling system developed for classifying the metal components moving on the conveyor on the basis of color and shape and placing them in the pre-determined location. It includes the discussions on various system components and the results in terms of sorting accuracy are also presented.

Keywords: **Automated sorting, Image processing, Sensor, MATLAB, Programmable Logic Controller (PLC)**

1. Introduction

The sustenance of manufacturing industries in global market calls for providing highly accurate multiple products at optimum cost to the customer in least possible time. Integrating automation knowledge with production processes results in enhancing productivity, efficiency and quality of these activities hence more research is needed to be done. The prime elements of automation system are program unit, sensors and actuators, controller and related hardware.[1] Sorting is a significant task in manufacturing industries in the material handling activity and with automation incorporated in it can reduce the labor efforts, accidents, process time and defects in sorting. Pneumatic systems prove to be beneficial in automation system owing to cleanliness, faster speed and less weight than hydraulic design.[2]

The sorting activity makes material handling of components of various colors, shapes, sizes, etc. viable and generally conveyors are employed to handle the components during sorting. Optical sorting is gaining popularity and object recognition which is crucial in computer vision domain is the base for sorting of components.[3]

This paper talks about an automated sorting system including conveyor developed for sorting components on the basis of color and shape and disposing them to set locations. Programmable Logic Controller (PLC) was selected as controller while image processing was carried out using MATLAB software. Sufficient number of components of decided shapes and colors along with some odd shapes too were tested for accuracy of the system and the results are discussed in detail.

2. Materials and Methods

2.1. System design

The automated sorting system built in the manufacturing industry for handling various shape and color components comprises of conveyor belt system equipped with motors, a monocular camera for grabbing images, pneumatic system controlled through PLC and a moving arm for pick and place operation of components on the belt. This

system was developed for handling red, green and blue components having circle, triangle and square shapes. Figure 1 illustrates the actual set up for sorting and handling components which is mounted on a wooden base.

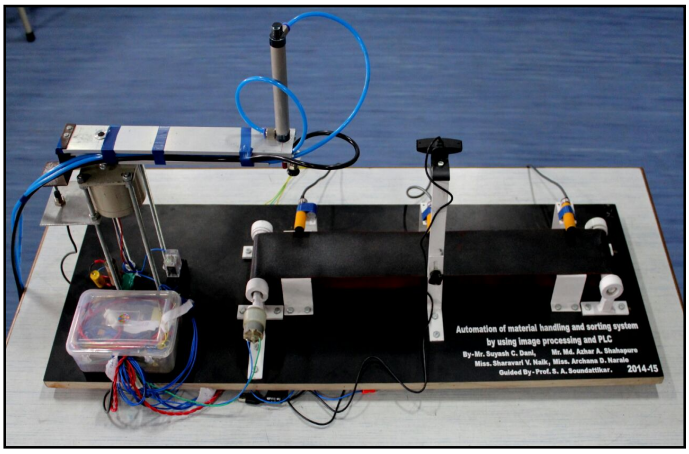

Figure 1. Actual set up for sorting and handling components

Conveyor assembly consists of four bearings to minimize the friction torque. Nylon and rubber conveyor belt painted in black for better image capturing by creating a constant background for thresholding. One DC Gear Motor is used to run the conveyor assembly operating on 12V DC, 750mA max current and 30 rpm.

Pick and place mechanism includes a 12V DC synchronous motor associated as PLC output device. The motor is mounted vertically and the horizontal hollow square pipe is mounted on the motors shaft. The horizontal hollow shaft acts as an arm and vacuum gripper of 2 kg capacity is mounted on it with help of pneumatic cylinder. The pneumatic circuit for the setup was designed using FluidSim software.

An overhead monocular camera used here takes the images of the object which are then processed by image processing using MATLAB. The camera is a USB or PC webcam and supports Skype, messengers and capable of rotating in 180 degree. Its transmission rate is 640*480/ 30 fps; 1280*960/ 10~15 fps while it supports the seizure of both still and moving images.

Three capacitive proximity sensors were used in the setup. The first sensor or job sensor near to loading station was used to start the conveyor only when the component was placed on the belt thus ensuring energy saving. The second sensor or camera position sensor detected the component under overhead camera and stopped the conveyor for capturing images and subsequent image processing. The third sensor or manipulator sensor was employed to stop the conveyor again so that the component can be picked up by the manipulator and based on the image processing output based on color or shape and be placed at various set positions. The positions of these sensors were set according to application requirements i.e. time for image processing, length of base and speed of belt.

PLC of Allen Bradley 1200 make was selected for the process control while the programming was done using RSLogix 500 software. PLCs can replace labors in tasks carried out in hazardous conditions or involving extensive work resulting into fatigue and musculoskeletal disorders.[4] In order to reduce the load on PLC it can be sometimes used in integration with Raspberry Pi where RPi can perform the image processing task while the hardware control can be accomplished using PLC.[5] Figure 2 shows the operational flowchart of the system for color wise sorting. A similar process takes place for shape wise sorting but the angles for circle, triangle and square are 180°, 225° and 270° respectively.

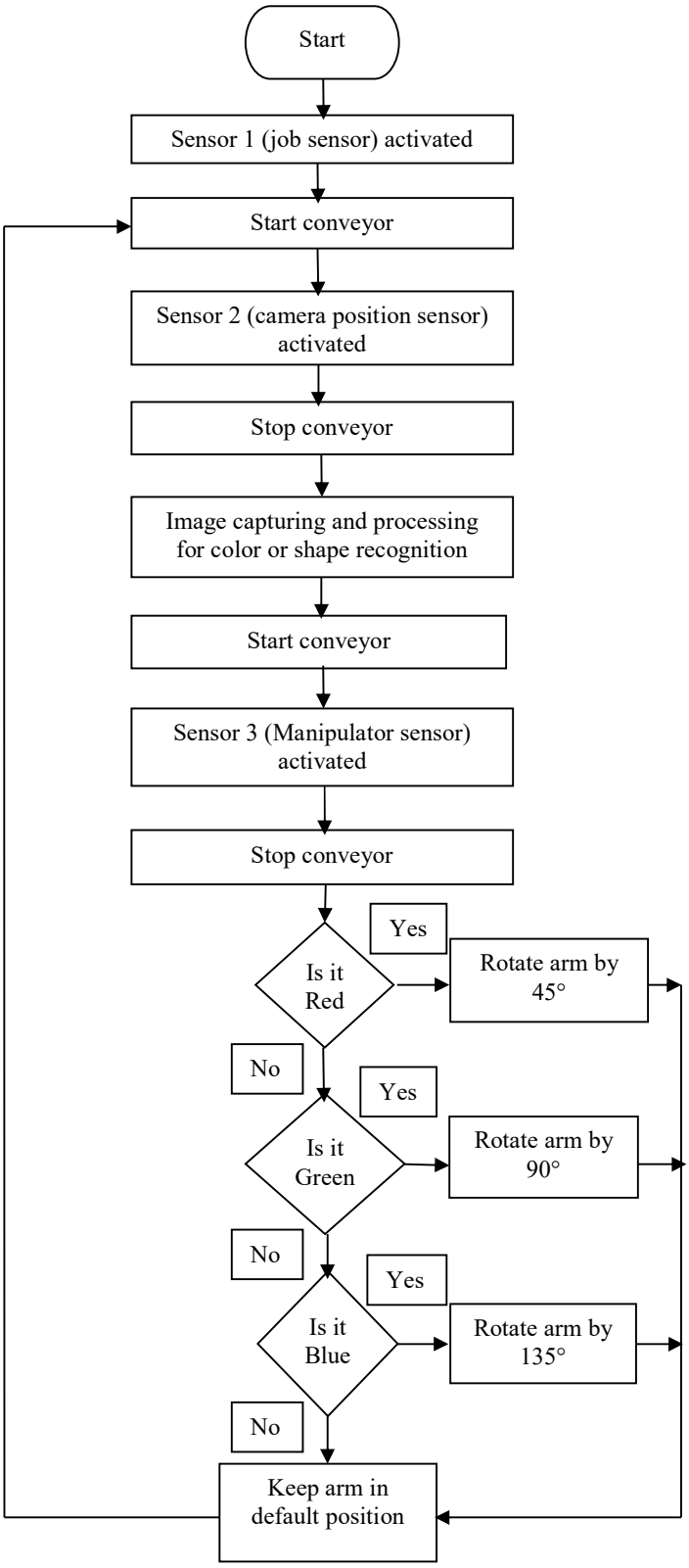

Figure 2. Operational flowchart of sorting system

When an object is sensed by the job sensor conveyor belt is turned ON and the component moves until it is detected by the camera position sensor. The conveyor stops

and the image of the component is grabbed by the overhead camera followed by image processing based on shape or color and a timer in PLC programming is used for the same. When the MATLAB result is obtained the conveyor starts again and when the manipulator sensor detects the component, the conveyor stops and manipulator is activated. A vacuum gripper holds the component on its surface and places it at suitable angular location based on the color or shape of the same.

2.2. Image Processing [6][7]

MATLAB platform was opted for image processing as it integrates computation, visualization and programming in easy to use environment where problems and solutions are expressed in recognizable mathematical notations. It is used to solve many technical problems which require matrix and vector formulations and computations. It offers application specific results knows as toolboxes which include the MATLAB functions and is widely used in the application areas of signal processing, neural networks, control systems, etc to name a few. MATLAB has huge built-in library of functions for predefined tasks and is platform independent which make the error detection and removal easy.

Image processing has multiple facets like image enhancement, restoration and segmentation for extracting most of the information from the image. Thus in general the image processing starts with image capture followed by pre-processing operations like noise reduction, blurring, etc for image enhancement. Image segmentation is then carried out which differentiates the object under study from its background and edge detection is done for shape recognition. Finally the processing results for the characteristics in consideration are presented. Image processing also finds applications in the medical, agriculture, law enforcement, communication and textile domains too. The steps followed in processing the images of components are as follows:

i. Image capture

The image is first acquired from a live video feed or an existing image can be loaded from the memory. The image is in RGB format where each pixel is represented by an element of a matrix whose size corresponds to the size of the image.

ii. RGB to Binary conversion

This process is done in two steps. The RGB image is first converted to a two dimensional grayscale image and then to binary image using thresholding. A threshold is set and the luminance of each pixel is compared with this threshold. All values that are greater than this threshold are replaced with a logical one (white) and the values below this threshold are replaced by a logical zero (black).

iii. Boundary recognition

Boundaries of the objects are recognized by first setting a single pixel on the object-background interface as a starting point and then other object pixels are searched either diagonally or in vicinity.

iv. Area finding and filtering

After boundary recognition, the area of that object was calculated by summing the number of pixels within the boundary extent and the noise if present is removed using appropriate filters to get a better image.

v. Estimation of object inclination

It is an important step as the component placed in any inclination in the plane perpendicular to the camera's axis should be recognized. This is achieved by enclosing the component's four extreme corners in an ellipse and then estimating the counter-

clockwise angle between the major axis and the x axis and the object is turned around in clockwise direction by the same angle. In case of squares and circles, the major and minor axes are the same. In MATLAB, the value of this angle is obtained by using the Orientation option under the region props command.

vi. Bounding box of object

The bounding box of an object which is an imaginary rectangle that completely encloses the given object is determined. The sides of this box are always parallel to the axes and due to the different angles of inclination of an object, the dimensions of the bounding box change in proportion. But to make the shape recognition independent of object orientation, the dimensions of the bounding box must be constant and hence the object was rotated in the opposite direction by the angle of orientation as mentioned in the previous step.

vii. Determination of ratio of areas of object

This involves finding the ratio of the area of an object to the area of its bounding box which is a crucial parameter and in MATLAB it is termed as Extent. For circles, this value is fixed at 0.7853, irrespective of the radius. The analogous value for rectangles and squares is 1.0000, provided the sides are parallel to the axes and the bounding box and sides overlap while in case of triangle, this value ranges from 0.25 to 0.5.

viii. Color recognition

If the components are sorted on the basis of shape only, the process ends with above step. Further if color sorting is also required, it can be achieved by averaging the RGB content within the boundaries of the objects.[8][9]

3. Results and Discussions

The trials were conducted for twenty five times per shape per color and Table 1 illustrates the results in terms of exact characteristic obtained in these trials as MATLAB output. The object characteristics included three shapes and three colors as mentioned above. When defective objects were tested, the odd shape objects were sorted with 90% accuracy while colored objects other than RGB color were sorted with 100% accuracy.

Table 1: Results of automated sorting system trials

Shape of object	Color of object	Number of correctly placed / Number of objects tested
Circle	Red	25 / 25
	Green	25 / 25
	Blue	25 / 25
Square	Red	25 / 25
	Green	25 / 25
	Blue	25 / 25
Triangle	Red	25 / 25
	Green	25 / 25
	Blue	25 / 25
Results for Odd shape and color other than specific RGB		
Odd shape	Red	22 / 25
	Green	21 / 25
	Blue	22 / 25
	Other than RGB	25 / 25

4. Conclusion

The automated sorting and material handling system developed was found to be highly accurate sorting the components based on shape and color. With components having shapes other than circle, triangle and square that sorting accuracy was 90% while the components of colors other than specifically red, green and blue were precisely distinguished from the lot. This setup was designed for certain shapes and colors only but can be extended to other shapes and colors too with other job parameters added up for classification and sorting. The components can also be sorted based on dimensional accuracy as well and such systems would be crucial in several industries.

Despite PLC is accurate, fast and time saving, it can be replaced by more sophisticated Raspberry Pi employing Python platform for better processing and control. The application of Machine Learning algorithms can make the system intelligent and computer vision can impart even better results and requires more research to be carried out in this area. A system similar to this sorting system with suitable modifications in sensors, controller and handling mechanism can find extended use in medical, manufacturing and food processing sectors thus reducing operator fatigue to greater extent thereby improving accuracy with reduction in sorting and product delivery times.

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