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Cost Effective Object Recognition and Sorting Robot Using Embedded Image Processing Techniques

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***Abstract*— This paper presents an application to sort objects based on its colour using a robotic arm. In many small scale industries, the major obstacle faced is shortage of time and laborers to efficiently sort and pack the products. This hurdle can be overcome by using the developed robotic arm which is cost effective and user friendly. This method of packaging is faster and does not require continuous monitoring, thereby increases the production and growth of the industry. In this paper, computer vision is carried out with the aid of OpenCV and the robotic arm is powered by Arduino microcontroller. The eBox-3300MX is used as the hardware to integrate OpenCV with robotic arm.**

***Index Terms*— Arduino, dominant colour detection algorithm, eBox-3300MX, OpenCV.**

I. INTRODUCTION

In today's industrial environment, a robot or rather a robotic arm to be precise is not something hard to find. These robots and robotic arms provide mechanical assistance for human workers in many factories. The influence of digital imaging in Science and Technology is huge. Hence, incorporating vision to robots to mimic certain features of a human eye would address several obstacles faced by mankind. By coalescing image processing and embedded techniques, this paper proposes a robotic arm that can recognize colour to effectively sort objects.

OpenCV (Open Source Computer Vision) is a library of programming functions for real time computer vision. OpenCV is free for both academic and commercial use. It has C++, C, Python and Java interfaces running on Windows, Linux, Android and Mac. The library has more than 2500 optimized algorithms [1]. This paper elaborates on effectively using the aid of OpenCV to determine the dominant colour.

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Advances in camera technology has dramatically reduced the cost of cameras and also given rise to high resolution imaging. This ensures webcam to be an excellent choice to provide vision to low cost robots.

Emergence of Computer-on-chip architecture has reduced the size of the computers. It also works similar to a normal computer and is available at a relatively low price. One such computer on a chip architecture, eBox-3300MX which has Microsoft XP as operating system is used in this paper for carrying out image processing operations and to interface robotic arm.

The working of the robotic arm can be briefly explained in three stages. Firstly, the image of the object to be sorted is captured using a webcam. Secondly, this image is processed using the developed image processing algorithm to detect the dominant colour of the object. Finally the robotic arm carries out the 'pick and place' operation based on the colour detected. The developed robotic arm can be employed on any environment where sorting is deployed using colours.

II. DESIGN

The sorting is done using the developed robotic arm which consists of three degrees of freedom which depicts the shoulder joint, elbow joint and wrist joint of a human arm and works in a similar fashion. It is designed in a way to reach confined areas and fold its way back out. They offer enormous assistance in packaging and it can act as host for many 'pick and place' operations. The robotic arm is controlled by an Arduino microcontroller.

The vision to facilitate 'pick and place' operation is provided by the webcam which is interfaced to the OpenCV running on eBox-3300MX. The images captured by webcam are processed using the developed OpenCV algorithm. The dominant colour which is the result of the developed algorithm is send to Arduino microcontroller by invoking serial communication. The overall block diagram is depicted in Fig. 1.

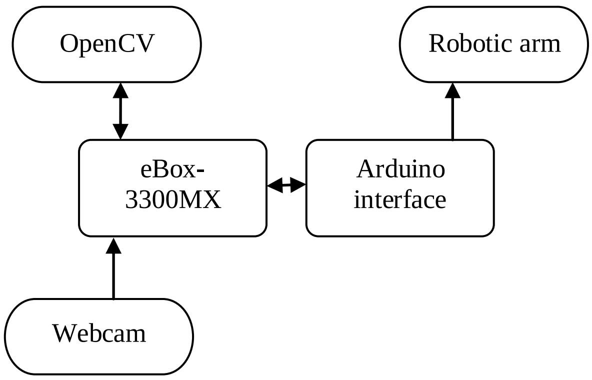

Fig. 1. Overall block diagram of the system

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III. IMAGE PROCESSING

The colours that humans and most animals perceive in an object are determined by the wavelength of the light reflected from the object. Human eye determines colours based on the amount of red, green and blue in an image. Mathematically an image consists of N x M pixels where N and M relies upon the resolution. The amount of red, green and blue component present in a pixel decides the colour of the pixel. Each pixel is represented by 24 bits where the amount of red, green and blue are represented by eight bits each. This type of representation is known as RGB colour model.

RGB is not an intuitive way in which colour can be described. Colour description is in terms of hue, saturation and intensity values, which is often known as HSV model of representation. Hue is the wavelength within the visible-light spectrum at which the energy output from a source is greatest. In other words, it is a colour attribute which defines the pure colour. Saturation is an expression for the relative bandwidth of the visible output from a light source and it gives a measure of how much a pure colour is diluted with white light. Intensity value is the energy output of a visible light source which is synonym to brightness. Processing in computers requires image description and hence it becomes mandatory to convert RGB image to HSV image.

The objects to be sorted are sent out in a conveyer belt. The webcam is first installed and initialized on OpenCV which starts up a continuous video stream. The webcam which is primarily meant for video capture uses a format called YUV. The YUV model defines the colour space in terms of luminance and chrominance. Initially black and white systems used only the luminance information. Later, colour was added via subcarrier so that black and white receiver would still receive the same information along with colour in the same format.

The object to be sorted is captured by obtaining a snapshot from the video, which is then subjected to further processing. Once the image is acquired noise is removed through two dimensional median filtering with a window size of 3x3. Then the image is subjected to two transformations, firstly YUV colour space to RGB colour space and secondly the obtained RGB image is converted to HSV model of representation. These conversions are carried out using the formulae given below.

The conversion from YUV to RGB colour model is done by applying the following formula given by (1) (2) and (3) pixel by pixel. It is a mandatory to clamp the values of every pixel to the range [0,255] before the transformation.

$$B = 1.164(Y-16)+2.018(U-128) \quad (1)$$

$$G = 1.164(Y-16)-0.813(V-128) -0.391(U-128) \quad (2)$$

$$R = 1.164(Y-16)+1.596(V-128) \quad (3)$$

The obtained RGB image is later subjected to HSV transformation. Before converting to HSV model it is required to normalize the pixel values which is done by dividing every red, green and blue values in a pixel by 255, this ultimately clamps every pixel to the range [0, 1].

$$R' = R/255 \quad (4)$$

$$G' = G/255 \quad (5)$$

$$B' = B/255 \quad (6)$$

$$Cmax = max(R',G',B') \quad (7)$$

$$Cmin = min(R',G',B') \quad (8)$$

$$\Delta = Cmax - Cmin \quad (9)$$

$$H = \begin{cases} 60^\circ \times \left(\frac{G'-B'}{\Delta} mod 6\right) & , Cmax = R' \\ 60^\circ \times \left(\frac{B'-R'}{\Delta} + 2\right) & , Cmax = G' \\ 60^\circ \times \left(\frac{R'-G'}{\Delta} + 4\right) & , Cmax = B' \end{cases} \quad (10)$$

$$S = \begin{cases} 0 & , \Delta = 0 \\ \frac{\Delta}{Cmax} & , \Delta <> 0 \end{cases} \quad (11)$$

$$V = Cmax \quad (12)$$

The dominant colour of every pixel is given by the hue value of that pixel. As the objective is to determine the dominant colour of the given object, it is sufficient and necessary to extract the hue values alone from every pixel and store it as a new image.

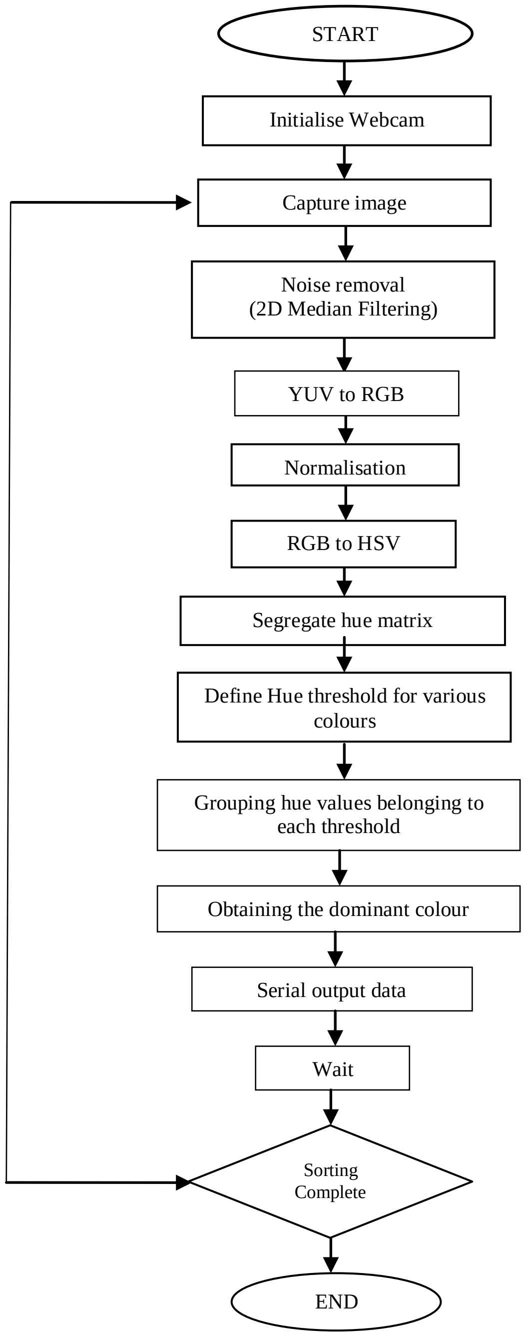

Fig. 2. OpenCV algorithm to obtain dominant colour

The hue values are usually represented in degrees which range from 0 to 360. In HSV model, each of the primary colours is separated by 120^O and each of the secondary colours are separated by 60^O from the primary colour.

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The pictorial representation of hue is shown in Fig.3. Based on number of colours required for sorting, ranges of hue are defined to the algorithm. HSV colour wheel is used to find the hue value of every possible colour. In this paper HSV colour wheel has been divided into six parts to determine six colours which are the three primary and three secondary colours namely red, green, blue, magenta, yellow and cyan.

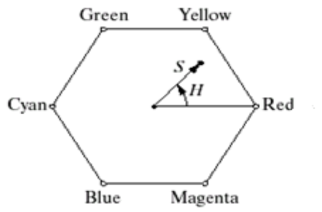

Fig. 3. Measurement of Hue in HSV model

To compute the dominant colour, six test variables are first defined. The six test variables correspond to six possible colours that the sorting algorithm can detect. Each of the primary colour and secondary colour has been accommodated with a space of 60^O. Now the hue matrix is scanned pixel by pixel and the test variable corresponding to the hue value in pixel value is incremented. The colour corresponding to the test variable with maximum value is selected as the dominant colour. The overall algorithm is given in Fig. 2.

IV. ROLE OF EBOX-33OOMX

The low power, low cost computer on a chip eBOX-3300MX from DMP electronics has 512MB RAM which ensures the sorting algorithm to run at a high speed. The two USB 2.0. ports are used to integrate webcam and the Arduino microcontroller to the processor. The inbuilt memory provided by 2.5" SATA hard disc drive is not sufficient to run OpenCV on the processor. Hence memory is added to the processor by introducing an SD card.

The processor acts as a platform to run image processing algorithm, enabling OpenCV to access the webcam when required and also to interface Arduino microcontroller. The prime task of the processor is to communicate the image processing results to Arduino through serial communication which would further enable the 'pick and place' operation. On completion of the 'pick and place' operation, Arduino notifies the processor. The processor now reiterates the image processing algorithm to determine the colour of next object and informs the processor. These operations continue till the entire sorting is complete.

V. ROBOTIC ARM

The robotic arm can be fabricated using materials such as metal, plastic, wood, acrylic etc. based on the environment where the arm would be deployed. In this paper, an indoor environment is considered and the weight of object to be sorted is assumed to be less than 500grams. Acrylic sheets of thickness 5mm were chosen to build the robotic arm.

The rotation mechanism in arm joints were developed using servo motors. A gripper was designed to pick, carry and place objects using a gear motor. The motors are driven in a fashion to move towards drop points based on colour detected. The overall operation of the robotic arm is controlled by an Arduino microcontroller.

The Arduino board is programmed to drive the robotic arm to a default position immediately when the supply is ON. The microcontroller continuously scans the serial port to receive command from eBox-3300MX to start the pick and place operation. The pick point and the place point for all the six colours are predefined in the program. Once the information of the colour is available to the microcontroller through serial port, the microcontroller drives the robotic arm to the pickup point which is followed by the picking operation. The picked up object is now dropped at the destination corresponding to the colour of the object. The microcontroller now informs the processor about completion of task and returns to the default position.

To carry out the required operations, three servo motors and one gear motor are required to operate simultaneously. The servo motors require current proportional to the load or the weight carried by motor, which is in terms of amps. Arduino microcontroller which has a drain current in terms of mA will not be able to handle high current drain. This problem is tackled by designing a current amplifier. A special adapter was designed to power the entire arm. This adapter inputs an AC voltage of 230V, which is fed in to a step down transformer with rating 12V and 3A. The step downed AC voltage is converted to DC voltage by passing it through a bridge rectifier. Rectifier output is subjected to a regulator IC 7805 which outputs 5V DC with a current of 3A. This is sufficient to drive all the motors simultaneously.

The gripper which is controlled by a gear motor requires a supply of +5V to grab the object and a supply of -5V to release the object. The logic for providing +5V and -5V is realized by designing an H-bridge circuitry. The block diagram of an H-bridge is shown in Fig. 4.

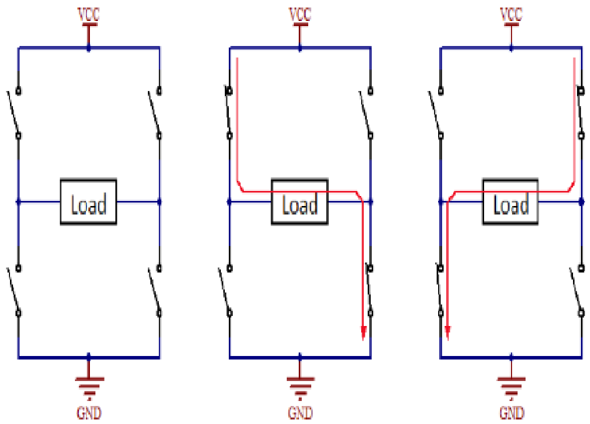

Fig. 4. H- Bridge showing connections for no output, +5 V and -5V

The H-bride is build using two P-channel MOSFET's and two N-channel MOSFET's. A pair of PFET and NFET is connected in series with each other and in parallel with the other pair. The source of the PFET's are connected to the VCC and the drain of the NFET's are connected to the ground. The drain of PFET and source of NFET are shorted to get the output plug. The gates of diagonal PFET and NFET are shorted to act as enable pins. On providing digital zeros to both the enable lines, no output is available. Digital '1' in enable pin1 and digital '0' in enable pin2 will result in obtaining output of +5V and digital '0' in enable pin1 and digital '1' in enable pin2 will result in obtaining output of -5V. The enable logic is controlled by the Arduino microcontroller depending on the grab and release requirements.

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VI. EXPERIMENTAL RESULTS

The designed robotic arm was tested for accuracy and repeatability. The image processing algorithm was checked for colour recognition in various indoor and outdoor environments. Different objects such as chocolates, sharpeners, colour pencils and marbles were among the samples which were subjected to evaluate colour detection algorithm. Colour detection algorithm yielded an accuracy of 100% and 96.8% for single coloured and multicolored objects respectively.

The every cycle of 'pick and place' operation took an average time period of 6.20 seconds. The accuracy of pick and place operations for single coloured objects was found to be 98.5% and 94.3% for multicolored objects. At a few instances misses were observed and in few other instances objects were dropped midway which resulted in a decrease in accuracy of 'pick and place' operation.

VII. CONCLUSION AND FURTHER RESEARCH

This paper presented an application of incorporating computer vision to robotic arm. The validity was proved by considering an application to sort objects such as pencils, chocolates and marbles based on its colours. The robotic arm can be built using any material based on the working environment. Acrylic sheet and servo motors can be replaced with heavier material and high power DC motors to achieve more torque. The developed robotic arm produced promising results and therefore it can readily be commercialized. Parameters to cancel background light can be added to the image processing algorithm to improve the accuracy of colour detection. The Systems-on-Chip solution is considered eminently suitable for a project of this nature [2] and any similar Computer-on-chip architecture can be used to carry out the project.

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