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Design and Development a Scara Robot for Classify Products Using Image Processing

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ABSTRACT: In this paper, a SCARA robot arm is designed and developed using stepper motor to classify objects according to their color. Four stepper motors are mounted at each joint of the robot to provide precise movement. The Arduino Mega board is used to create signal for stepper motor driver. The mechanical model of the robot is designed on the Autodesk Inventor software. All links of robot is fabrication by laser cutting method. The assembly of the parts of the robot and the motor's mechanical shapes produce the final prototype of the arm. The Arduino has been programmed to provide rotation to each corresponding servo motor to the sliders in the designed mobile application for usage from distance. Product classification algorithm will be developed to detect objects based on color. The robot will pick up the products to different positions according to the detected color.

KEYWORDS: SCARA Robot arm Arduino Uno Stepper motor Mobile application

INTRODUCTION

Robotic and automation have opened up a new development direction for businesses to increase productivity and optimize production processes. Robotic arms are used in production lines due to their ability to work accurately and repeatably; eliminate the errors of workers during operation, create products with high uniformity, reduce defective products [1-4].

Design and development robot arms are a challenge task. It requires knowledge of mechanical design, electronics, control, programing, … There are many studies has been presented many designs for robot arm, from mechanical to control algorithm [5-6].

In the article [7], the design and construction of a 3 degree-of-freedom SCARA robot are discussed. A comprehensive method to fabricate the whole robot by Computer Aided Design and Stress analysis is proposed. The interfacing is achieved by MATLAB with a proper electronic framework for accurate execution. A prototype is also developed as a practical output of this research. This paper also highlights the whole process of mechatronic and software design required to fabricate a robotic arm.

In the article [8], robot trajectories are discussed both in the joint space and the Cartesian space. A new control system is proposed which is tested and validated to confirm the results obtained from this research. With the integration of kinematic analysis, trajectory generation is developed for the simple pick-and-place operation. This acts as a guide to path planning for the end effector in achieving a required operation.

The article [9] details the Inverse dynamic study of a 3 degree-of-freedom PRR Planar robot. A recursive modeling technique is used in the Kinematic and Dynamic analysis of this robot. This technique is used to find position, orientation and angles of the robot. A control motion comparison of parallel robotics is the main motive of this study with various actuation systems.

This paper presents a design of a low-cost 4-DOF SCARA robot arm using stepper motors and the Arduino controller. The robot consists of three rotation degree of freedoms and one translation movement. The stepper motors provide motion for all joints. The Arduino Mega board is used to design the robot controller. Product classification algorithm will be developed to detect objects based on color. The robot will pick up the products to different positions according to the detected color.

METHODOLOGY

Mechanical design: The scara robot arm is desined by using Autodesk Inventor software. The robotic arm has four degrees of freedom with three rotation joints and one prismatic joint. The prismatic joint is used to move the entire robot arm up and down in a vertical direction. To produce linear motion, a ball screw transmission is used. The pitch of a lead screw is 10mm, which means that when the motor rotates one revolution, the screw nut moves a distance of 10mm.

In this project, we use stepper motor to provide rotation motion for all joints. Stepper motors can create highly precise motion with limited torque, and they have lower costs compared to servo motors. Stepper motors lose their step when overloaded, and torque drops sharply at high rotational speeds. However, within a certain limit of speed and torque, a stepper motor is still more efficient than a servo motor. And in our design, the joints of the robot do not require high speed movement and the torque of the joints is very small (because the axis rotates vertically, it is not subject to the weight of the load). In this project, we use the Nema 23 stepper motors for the first three joints. The holding torque of the motors is 3Nm. For the last joint, the Nema 17 stepper motor with a holding torque of 0.55Nm is used. The motors are rotated at a maximum speed of 360 degrees/s to avoid step loss and maintain large torque. Figure 1 shows the Nema 23 and Nema 17 stepper motor.

(a) (b)

Figure 1. Stepper motors (a) Nema 17 stepper motor, (b) Nema 23 Stepper motor

Each link of the robot arm is designed in sheet form and assembled by threaded rods as shown in Figur 3. This design helps to save manufacturing costs but still ensure the rigidity. The metal plates are made by laser cutting to ensure accuracy. The material used is 5050 aluminum alloy, so the weight of the links is relatively light, the inertia force generated when the links start moving is not too great. The outer shell of the joints is made using 3D printing technology. The outer shell helps to shield the internal components, increasing aesthetics.

Electronic design: In this project, to control the robot, the Arduino Mega board is used as the main controller. Arduino Mega creates the pulse signals and send they to the stepper motor driver to turn the motor. Figure 2 shows the components of the electronic system.

Arduino Mega board: is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator. In this project, we need to control four stepper motors and one module relay, read signal from four limit switches and communicate with module buetooth module. Therefore, it is necessary to use 15 digital input/ouput pins. Using Arduino board, we can use the Arduino Libraries to control other devices easily. The libraries are open source and easy to install into the Arduino environment.

Stepper motor drivers: they are used to convert the pulse and direction signal from the Arduino to the current signals to control the rotation angle of the stepper motor. The TB6600 drivers are used in this project. They operate with the input voltage from 9 ~ 42 VDC, provide a maximum supply current of 4A. The micro step can adjust from 1/12 to 1/16.

Limit switches: used to determine the home position of the robot. When the robot arm is started, the joints are controlled to rotate till reaching the limit switches and halt.

Module relay 5V: used to control other devices with the large current and voltage. The output voltage from Arduino is only 5V. So, to control other device with the higher voltage (12V or 24V), the module relay is used. The module relay receives the 5V signal from the microcontroller to turn on an opto inside this. The opto will conduct current through the coil of the relay.

A 24V-10A power is used to supply for stepper motor driver. Each stepper motor needs a current of 2A, so the total current for four motors is about 8A. To supply voltage for Aruino board, we use a LM2596 module to create 9-12V power source from 24V power. Some devices that need 5V power will use the Arduino's 5V pin. The 5V source is mainly used for the signal pins, so using the Arduino's 5V pin is appropriate.

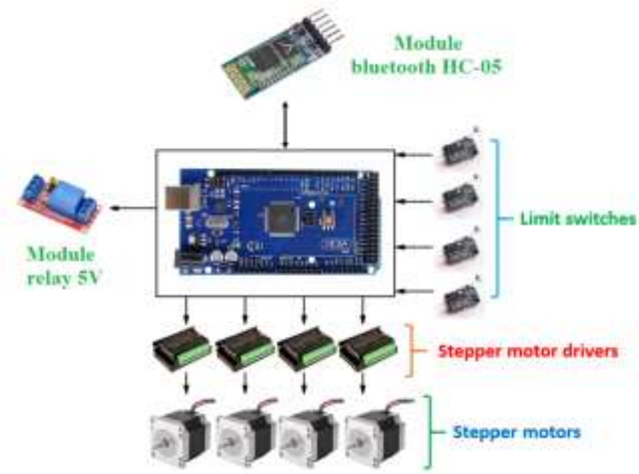


Figure 2. Electronic system components.

Image processing algorithms: In order to develop a computer vision system for classifying objects on the conveyor, a Raspberry Pi Camera Module with a Sony IMX219 8-megapixel sensor is utilized for capturing images of objects. This camera has a focal length of 3.04mm, an angle of view (diagonal) of 62.2 degrees and a resolution of up to 3280 x 2464 pixels. In the project, we only use images with a resolution of 640x480 pixels to achieve faster processing speed. The images are processed by Raspberry Pi 4 computer to classify objects according to their color. Figure 9 shows the flow chart of the image processing algorithm on the Raspberry Pi. The image taken by the camera is converted into HSV (Hue, Saturation, Value) color space. The Hue in HSV represents the color, Saturation in HSV represents the greyness, and Value in HSV represents the brightness. The HSV color space provides better performance when compared to RGB color space and hence it is used widely in the area of computer vision. To convert the BGR image to the HSV image. To detect objects with a specific color, we apply an upper bound and lower bound range for a range of each color in HSV. The results image is determined as follows:

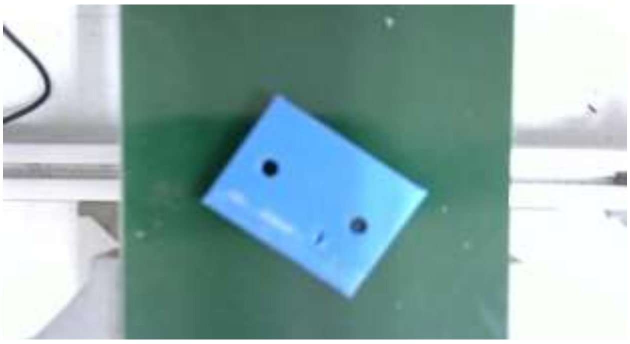
$$\begin{aligned} dst(I) = lowerb(I)_H \le src(I) \le upper(I)_H \wedge \\ lowerb(I)_S \le src(I) \le upper(I)_S \wedge \\ lowerb(I)_V \le src(I) \le upper(I)_V \end{aligned} \quad (1)$$

where src(I) is the source image, dst(I) is the destination image, $[lowerb(I)_H, upper(I)_H]$ is the range of Hue, $[lowerb(I)_S, upper(I)_S]$ is the range of Saturation, $[lowerb(I)_V, upper(I)_V]$ is the range of Value. In this research, objects have RED, GREEN or YELLOW colors.

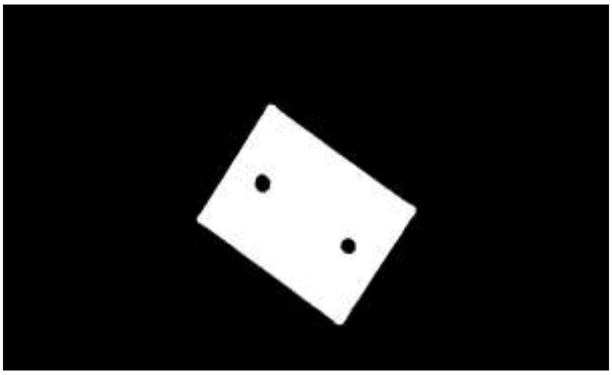
RESULTS

All mechanical parts of the robot arm are fabricated and assembled to create a realistic robot arm as shown in Figure 3. The realistic model has revealed the accuracy of the design. Figure 4 shows the wiring circuit of the robot arm. Electrical and mechanical systems are combined to operate the robot arm. The actual tests have been done. After power on, the robot is controlled to move to the home position. The home position of each joint is the position that its link contacts with the limit switch.

Figure 3. Experiment robot.



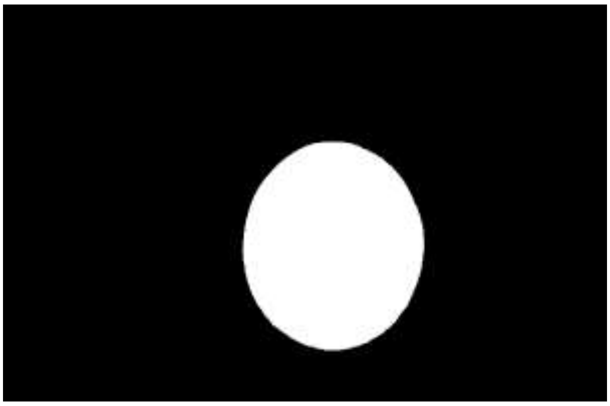
(a) Original image



(b) Result image

Figure 4. Detect object with blue color.

(a) Original image



(b) Result image

Figure 5. Detect object with red color.

Figure 4 and Figure 5 show the results when apply HSV threshold to detect objects with blue and red color. The results demonstrate that objects can be extracted when appropriate thresholds are applied. Each color will have a different threshold, when we need to classify products, we just need to apply the appropriate threshold to extract the necessary object.

The products are then picked up by the robot and brought to the appropriate location.

CONCLUSION

This paper has developed a robotic SCARA arm to sort products by color. Robot is designed on software then machined, fabricated and assembled into a complete model. The Arduino board is used to control the movement of the robot arm. Stepper motors are used for the movement of joints. The HSV threshold-based image processing algorithm is used to detect objects. Experimental results show that the algorithm can detect products with different colors.

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