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Robotic Arm with Robotic Vision for Automated Material Handling Operations

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ABSTRACT: Image processing has become increasingly important in today's world, as it opens up possibilities for a wide range of applications in various technological fields. This paper presents a color and shape sorting system that utilizes image processing techniques. The system involves capturing images of objects using a camera and processing them in MATLAB to identify their color and shape for sorting purposes. The sorting process is based on a functional methodology that includes an operative selection process, where objects are detected and classified using a decision-making algorithm and selected in real time with the assistance of an automated material handling system. Once detected, the object undergoes predefined actions. These actions are simulated by signals sent from a microcontroller to servo motors, which are assembled in a specific configuration to form an arm-like structure for carrying out appropriate operations. After completing the operation, the system returns to its original position, ensuring a continuous flow of results with high speed and accuracy.

KEY WORDS:-Decisional algorithm, Image processing,MATLAB, Microcontroller, Material handling system, Robotic arm, Servo motor.

INTRODUCTION:

Robotic vision involves the extraction, characterization, and interpretation of information from images of 3D objects. It utilizes camera hardware and computer algorithms to enable robots to process visual data from the world. For instance, a system could employ a 2D camera to detect an object for a robot to pick up. Robotic vision focuses on the manipulation and interpretation of images and the application of this information to control robot operations. Unlike pure computer vision research, robotic vision must integrate aspects of robotics into its techniques and algorithms, such as kinematics, reference frame calibration, and the robot's ability to physically 1 interact with the environment. Material handling encompasses the movement, protection, storage, and control of materials and products throughout manufacturing, warehousing, distribution, 2 and consumption. Manual handling refers to the use of a worker's hands to move individual containers by lifting, filling, lowering, or carrying them. This can expose workers to physical conditions that can lead to injuries, accounting for a significant portion of the over half a million cases of musculoskeletal disorders, often involving strains and sprains to the lower back, shoulders, and upper limbs. While many existing material handling systems are only semi-automated due to the need for human operators to perform tasks like loading, unloading, and driving that are difficult or too expensive to fully automate, recent advancements in machine intelligence and robotics have made it possible to fully automate an increasing number of handling tasks by sensing the environment and physical information of materials using robotic vision and various sensors.

SCOPE:

The robotic arm with robotic vision is a working model of color and shape sorting system which can effectively utilized in industries such and production lines, manufacturing lines, packaging industries etc. it canteam up with automatic trolley system which will help them to move to the desired prescribed location after the process of sorting is done. It can also be used in daily life such as sorting of fruits based on its size and shape. After some modification in the robotic arm, it can be used to pick heavy and large objects that will make the system really practical. Using this bot, one can increase the efficiency of his system, increase in productivity and it will be overall cost effective for them.

LITERATURE REVIEW:

Traditionally, the object sorting process used to be done manually. However, this method has many disadvantages such as increase in the cost of the product, slowness and inaccuracy due to the human mistake. Quality inspection, sorting, assembly, painting, packaging etc. were used to be done manually, but after the rapid involvement in the field of robotics, the automation industry has undergone a complete makeover and

the technology of object recognition using robotic vision is used for such work [1].

In many packaging industries, counting and sorting of the object is the major task that needs to be done and that can be fulfilled by the effective use of this technique and the accidents which used to cost human life can no more be seen. It not only increases the production rate of manufacturing industry but also reduces the effort of material handling reducing overhead expenses [2].

The efficient flow of material in production house or any production system is important, therefore material handling is the crutial part of design for most production systems,the refore optimisting the total standard time we should optimize material handling operation [8].

METHODOLOGY:

Robotic vision system may be defined as the process of extracting, characterizing and interpreting information from images of a 3dimentional world. This information is further used to identify an object and determine its location. Robotic vision is primarily targeted at manipulation and interpretation of image and use of this information in robot operation control by which various industrial task can be performed.Function of robotic vision system which will assist robotic arm are:

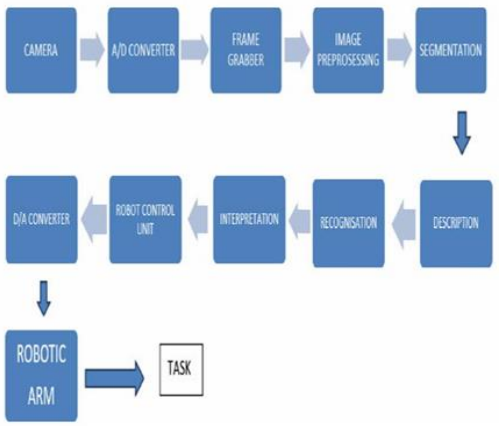


Fig.1 Function of robotic vision system

CAMERA :

Web camera is used to capture images of objects. These images are used by MATLAB for detection of color, size and shape of object.

A/D CONVERTER :

As manipulation of image in MATLAB in done by computer, there is need to convert the Analog signal into Digital signal for computer processing.

FRAME GRABBER :

A frame grabber is an electronic device that captures individual digital still frames from analog video signal or a digital video signal. These still frames are send to image processing unit i.e. in MATLAB.

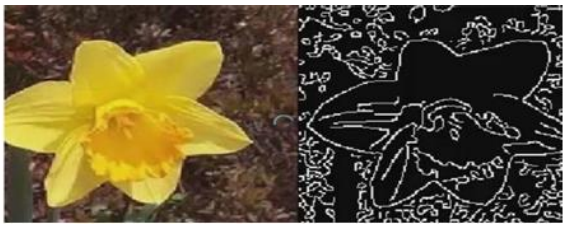
IMAGE PREPROSESSING:

It deals with techniques like noise reduction and enhancement. Captured images contain noise, which must be removed. MATLAB provides various filters for noise removal. Some of the functions available for noise removal are: imadjust, medfilt2. The preprocessed image frame is stored in computer memory for further processing.

Fig 2. Images before and after pre-processing

SEGMENTATION:

It is the process of identifying a group of related pixels for locating connected regions or areas of image having similar characteristics. It consists of Thresholding, Region growing and Edge detection.



DESCRIPTION:

Parameters such as shape, size, and perimeter provide valuable information for describing objects in images. This data is extracted from the image to aid in the subsequent object identification process.

RECOGNITION:

Recognition involves the unique identification of objects within an image. To achieve object identification, image comparison techniques are employed, which utilize previously stored data about the object for comparison purposes.

INTERPRETATION:

Upon object identification within the image, specific tasks are executed by the robotic arm, which are predefined and stored in the Robot Control Unit.

DEVELOPMENT OF ROBOTIC SYSTEM:

Color and shape are two essential characteristics of many objects used or produced in industrial settings. These features enable the system to differentiate between various objects. The system will consist of a camera mounted within the workspace to detect objects based on their features using image processing techniques in MATLAB. This technology can be applied to material handling in logistics and packaging industries where objects moving along a conveyor belt can be separated by a color and shape-detecting robot.

HARDWARE IMPLIMENTATION:

The hardware implementation involves:

1. Arduino Uno: A microcontroller board compatible with webcams and motor drives, serving as the central component of the system. Other components will be connected to it.

2. Webcam: Mounted within the workspace and connected to the USB port of the PC. The camera specifications include: - CMOS sensor with plug-and-play USB connection - Support for various video formats - Frame rate of 30 frames per second.

3. Motor Driver: Connects servo and stepper motors to the main microcontroller board.

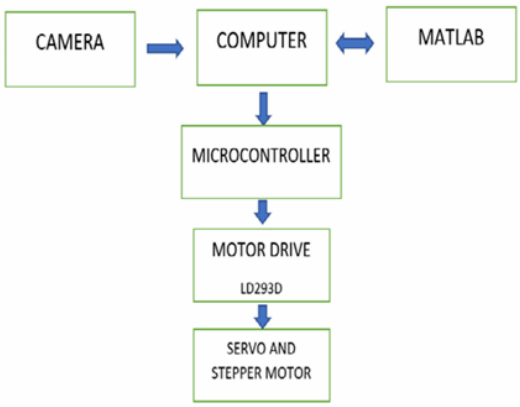


Fig 4. Basic Block Diagram of System

ROBOTIC ARM SETUP:

A variety of motors are available for robotic applications, each with its own strengths and weaknesses. Here's a breakdown of some common options:

Servo Motors: Offer high torque and precise positioning, making them ideal for tasks requiring accuracy.

Stepper Motors: Provide good positioning control but lower torque. They are a cost-effective option for tasks where high torque isn't crucial.

DC Geared Motors: Deliver high torque for applications requiring strong lifting power.

DC Motors: Generate smooth motion, suitable for situations where precise positioning isn't essential.

In this project, stepper motors were chosen due to their affordability despite servos being a better fit for robotics applications.

Stepper motors come in various types like variable reluctance, permanent magnet, and hybrid.

Now, let's move on to designing the robotic arm. Several factors influence the design:

Object to be lifted: The size and weight of the object will determine the arm's strength requirements.

Reach: This refers to how far the arm can extend.

Degrees of freedom (DOF):This specifies the number of independent movements the arm can perform. A 6-DOF arm offers great flexibility.

Considering these factors, a 6-DOF robotic arm was constructed using 4 servo motors and 1 stepper motor. Each motor has a specific function in the arm's operation, which will be explained in detail later.

Servo Motor 1: This servo is responsible for the gripping mechanism, holding the object. A 7 kg-cm servo is suitable for our model.

Servo Motor 2: This servo functions as a wrist servo, similar to a human wrist. Due to the low load factor, a low-torque servo of 15 kg-cm is best suited.

Servo Motors 3 and 4: Servo 3 and Servo 4 represent the elbow and shoulder of the arm, respectively, as illustrated in Figure 5. 20 kg-cm servos are ideal for these positions.

Stepper Motor: The stepper motor provides complete 360-degree horizontal rotation to the robotic arm.

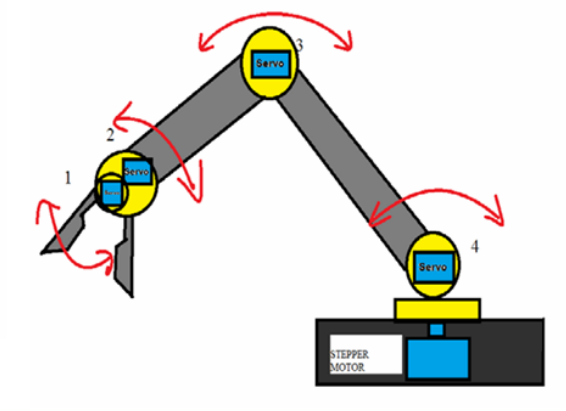


Fig 5. Design of Robotic Arm

SHAPE DETECTION ALGORTHM:

The shape detection algorithm involves several steps:

1. Image Acquisition: Capture the object's image using a camera.

2. Image Conversion: Convert the RGB image to grayscale and then to black and white (binary) format.

3. Object Boundary Recognition: Identify the boundaries of objects within the binary image.

4. Object Area Calculation and Filtering: Determine the area of each object and filter out small, isolated noise pixels.

5. Bounding Box Calculation: Find the imaginary rectangle that completely encloses each object.

6. Area Ratio Calculation: Calculate the ratio of the object's area to its bounding box area. This ratio, known as the Extent, provides valuable information about the object's shape.

By analyzing the Extent value and the coordinates of the bounding box, you can determine the shape of the object, such as square, rectangle, circle, ellipse, triangle, or hexagon.

COLOR DETECTION ALGORTHM:

To determine the color of an object, the algorithm analyzes the RGB color space of the object's image. The colors defined for classification are Red, Green, Blue, and Black.

The first two steps are the same as in the Shape Detection Algorithm.

In the Color Recognition Algorithm, the centroid pixel of the object whose color is to be detected is extracted. A MATLAB function, P = impixel(I, x, y), is used to obtain the pixel values in the specified image, I, where x and y are the centroid coordinates.

Within the 3D matrix of the RGB color space, if the value of the specified centroid pixel is higher in the Red space than in Blue or Green, the pixel is considered Red. Similar logic applies for Green and Blue.

RESULTS:

Result of Color Detection with MATLAB:

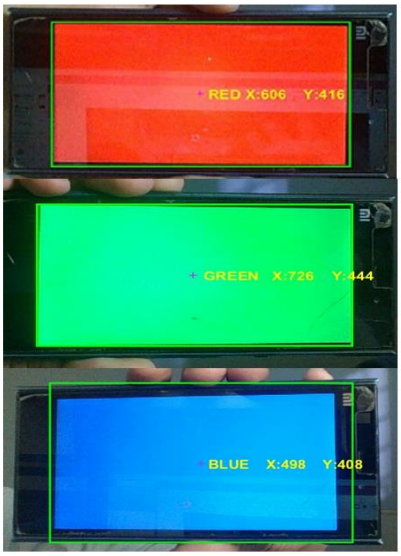


Fig 6. Color Detected (RED, GREEN and BLUE) with their Centroid

Result of Shape Detection with MATLAB:

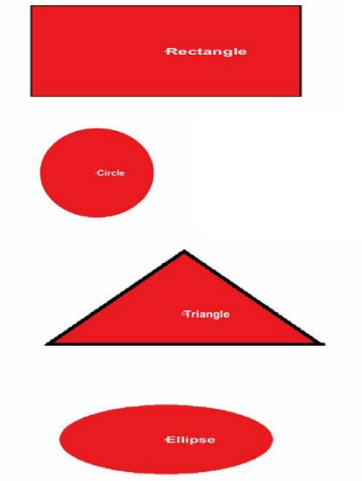


Fig 7. Shape Detected (Rectangle, Circle, triangle and Ellipse)

CONCLUSION:

The system presented in this paper focuses on identifying the shape and color of objects and performing tasks like object sorting and pick-and-place using a 6-DOF robotic arm in various industries such as packaging, assembly, and manufacturing. This system aims to automate material handling tasks, reducing human effort and eliminating the need for manual object management and sorting. Compared to manual and semi-automatic systems, this automated solution is cost-effective and efficient, as it eliminates human errors and provides a fully automated process.

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