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LOW-COST COMPUTER VISION ASSISTED OBJECT SEGREGATION ROBOT

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Abstract— ***Low-Cost Computer Vision Assisted Object Segregation Robot" is a research project related to the field of Mechatronics, Image Processing, and Industrial Automation. The aim of the research is to detect three different regular shapes in a single symmetrical object image through 2D low-resolution camera with machine vision techniques and placement of these objects at their designated positions via two-axis robotic arm manipulator. The prototype system and software have been made locally with scrap materials. This project would be useful in Local industries in Pakistan who are focusing on low-cost solutions based on vision-based data acquisitions and Cost Effective automation for products segregation and quality control operations. Local Industries in Pakistan are quite reluctant to adopt latest robotic techniques due to high CAPEX (imported equipment) and a high cost of maintenance. Consequently, the majority of industries in Pakistan are utilizing obsolete sensor-based information for their automation and data acquisition process. The sensor-based system has some drawbacks due to limited information sensing. Majority of complex tasks like inspection of products or segregation of different type of products are mostly done by humans or occasionally with sensor-based approaches. However, said approaches are costly due to of labor cost and also less efficient due to slow operating speeds. Foregoing in view, a locally developed, cost-effective and easily configurable vision-based intelligent robotic solution would be highly beneficial for local industries within Pakistan to streamline their various automation processes which might provide low production cost with strict quality control. Additionally, Pakistan is also an agricultural based economy where major churn of export contain fruits, vegetable, and grains. The countries around the world have strict standards for imported food items. Therefore, the subject project would be beneficial for exporters for intelligent automation of quality inspections, grading of fruits and vegetables according to the quality standards of international markets***.

Keywords- ***Computer vision system, Mechatronic systems, Quality Control, Inspection and industrial automation.***

I. INTRODUCTION :

The goal behind the Idea is to develop a Cost-effective simplified Prototype to demonstrate the application Concept for Local Use within the country. As a proof of concept algorithm and prototype is demonstrated in University Lab environment.

The research Prototype is based on following domains:

a. Acquisition of different geometric objects shape via machine vision techniques
b. Extraction of shapes through Shape Factor, boundary tracing, and edge detection techniques
c. Decision-making algorithms for identification of the geometric structure of objects
d. Low-cost Automation process for object placement at particular container via easily configurable two-axis robotic manipulator with feedback motion limiting I.R Sensors.

The system in the discussion would be able to detect various objects via camera-based machine vision system. Furthermore, a 2-axis robotic manipulator comprising of microcontroller, automotive DC motors and motion limiting I.R feedback sensors have been developed for grabbing and placement of the object at designated locations. Initially, the prototype is able to recognize three different objects with placement at specified three locations. Moreover, the capability of the system can be enhanced by incorporating additional profiles of different objects.

II. RELATED WORK:

Object recognition and segregation is a widely researched topic in the field of cognitive robotics in the world and Developing day by day according to its application in various domains. For Development and application with incountry, the Cost-effective system with a simplified algorithm with Local Commissioning of the system is the motive behind the development of this prototype with intended area of application. The techniques for object recognition mostly rely on a set of descriptors. In which, a picture is taken from a camera and individual entities in the picture are determined by computing certain values of descriptors. The relations between the 'distances' between these descriptor vectors is what determine the object parameter for shape. A major focus of this project is to apply Matlab Shape Factor Analysis on 2-D Image with improved acquisition with edge detection operator and classifying the shape with Metric Ratio Based Decision Making Algorithm in simplified form.

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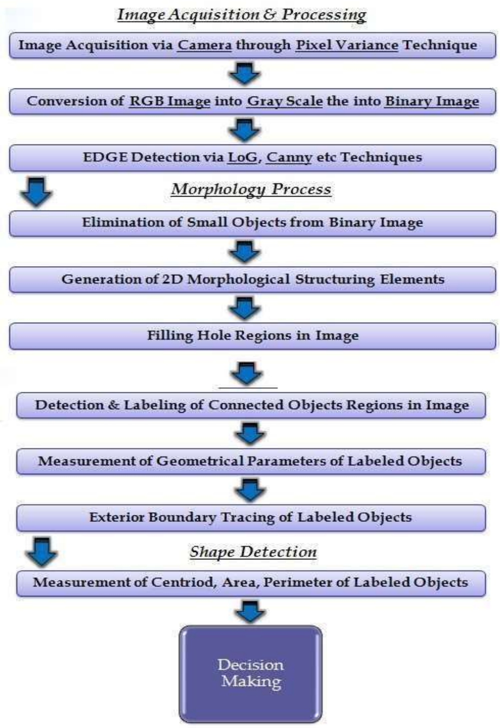
a. METHODOLOGY



The main section of this research is information acquisition via image sensing. Initially, three types of object shapes i.e. Triangle, Circle, and Square were selected for this research. When an object is placed in front of the robotic arm, a snapshot is taken from the camera mounted over aforesaid manipulator. Pixel variance technique is used for video triggering. This technique is based on observing deviation in pixels between multiple video frames. Whenever an object is placed in front of a camera it changes the number of pixels within multiple frames and any pixel changes in the idle frame would trigger the camera to take a snapshot automatically and image of an object having a resolution of 320X 480 jpeg with a black background will be saved accordingly. Due to variant light conditions following steps have been followed for proper edge detection and boundary tracing of objects:

b. Acquisition of RGB (colored) image
c. Conversion of the image from (RGB) to gray image
d. Conversion of gray image to black and white binary image
e. Edge Filtration
f. Boundary Tracing

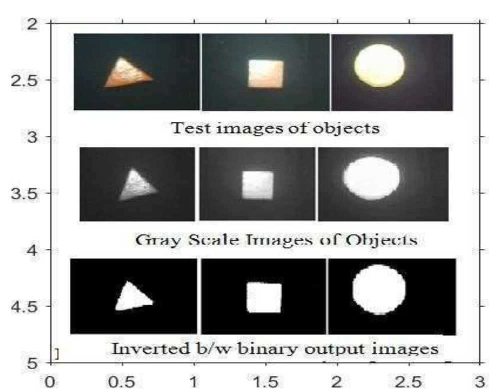


Figure .1 showing output images of the process

III. EDGE DETECTION METHOD:

Edge detection is an image processing technique for finding the boundaries of an object(s) within image through discontinuities in brightness. Two edge detection algorithms i.e. Sobel and Canny were used. The results from both filters revealed that canny filter

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performed well in multiple lighting conditions, resultantly, same will compliment successful boundary tracing. Results of all three shapes are depicted below:

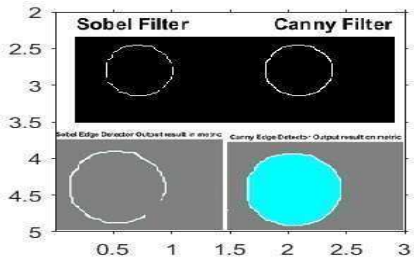

Figure .2 Edge detection Result of a circular object

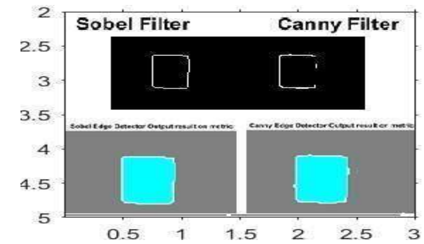

Figure .3 Edge detection Result of square object

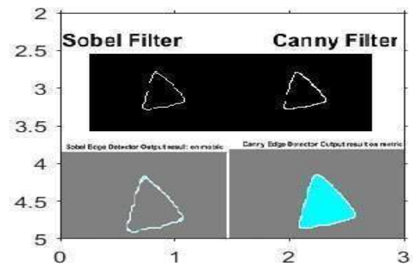

Figure .4 Edge detection of Triangular object

1. MORPHOLOGICAL PROCESS:

The morphological operations implemented on the image after edge detection for removing unwanted shapes and noise errors from the image to enhance the prominent region i.e. shapes within the image. After processing, noises and unwanted pixels which do not belong to the object of interest were removed. Additionally, holes and gaps were also filled for proper tracing of boundary and area of shapes. Morphology process is shown in Figure 2~5 with a grey background and cyan colored objects.

2. SHAPE DETECTION ALGORITHM:

Shape factor Metric is used which is commonly used in computerized Dynamic Image Analysis (DIA) for particle shape characterization. Shape factor for circularity determination is applied. Shape factor reflects the roundness of an object. A value close to 1 indicates that the object is smooth and round and value close to 0 means that it is elongated and/or rough. Roundness of objects is depicted below:

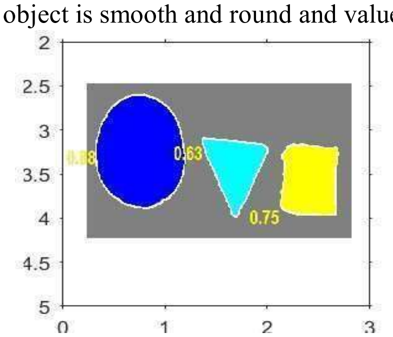

Figure .5 Shape factor computations Result

Shapes	(opaque)	(transparent)		
Shape Factor	1	<0.1	0.785	0.604
Aspect Ratio	1	1	0.707	0.577

Figure .6 Shape factor metrics for perfect shapes

The values after computation were compared with the threshold of perfect shapes calculated via shape factor as shown Figure 6. The computed value of any particular shape will be the result of metric of roundness. The circularity of any object is calculated through R= 4*pi*A/P^2; where A is an area in pixels, P is Perimeter.

Consequently, the segregating process is managed via comparison of threshold values against each shape as depicted in figure .6. Other shapes can be added after compiling through shape factor metric for thresholds values. Meanwhile, three shapes have been tested successfully and the system is able to make a decision from their respective threshold values depicted in the following flowchart and figure.6.

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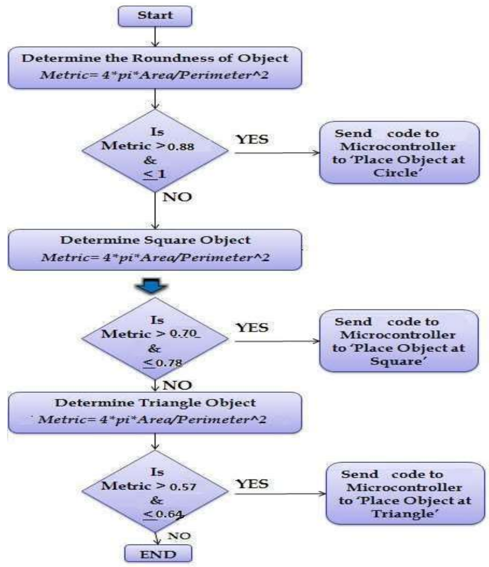
3. DECISION-MAKING ALGORITHM

Decision-making algorithm works by comparing threshold values of each shape:



4. MECHATRONIC MANIPULATOR

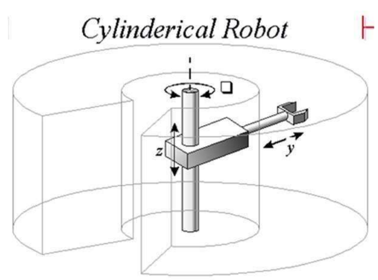


Figure .7 Manipulator Design

The design of electromechanical prototype is based on the category of service robot commonly used in industries. The electromechanical system contains two-axis robotic arm with motion clearance of 6 meters, a camera, a moveable base and a gripper. Other electrical parts include DC motors with gears, relays and infrared sensors for position identification Mechanical slit mechanism is implemented between I.R sensors to limit the horizontal and vertical motion of robotic arm manipulator built with locally available scrap material.

5. MANIPULATOR CONTROLING HARDWARE

Atmel 89C51 microcontroller based embedded system has been developed for controlling the motions of the robotic arm, gripper, and base. Following components were used:

1. AT89C51 Microcontroller
2. MAX 232 for serial interface
3. ULN2803 for relay driving
4. RELAYS for electromechanical switching
5. ILD74 as optocoupler digital signal isolator
6. Infrared sensor for motion feedback
7. Power Supply

Movement limitation is achieved through sensing positions via I.R sensors. Microcontroller receives an 8-bit binary code via a serial port of the computer and via MAX 232. MCU connectivity is tabulated in Table 1.

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Table .1 Ports and Pin Connectivity's

S.N	Pins and Ports	Driving ICs	Connected Modules
1.	Port2 pin 0-3	ULN2803	Vertical Axis Motor
2.	Port 2 Pin 4-7	ULN2803	Horizontal Axis motor
3.	Port 3 Pin 5	ILD74	Gripper DC Motor
4.	Port 3 Pin6	MAX 232	Serial port connectivity
5.	Port0 pin 0-5	Feedback IR Diodes	Position Sensing

Programming of microcontroller has been done in assembly language. The 8-bit position data is transmitted from the computer for each shape after detection of shape. The code from Matlab is compared with already stored code within microcontroller's memory. When the digital code is matched microcontroller executes the routine of specified code and drive the motors of the base, arm, and gripper towards specified positions. Data codes are shown in Table 2.

Table .2 Data Transmission

Detected Shape	Data Transmitted to MCU by Matlab	Manipulator Moment
Square	00100000	1st Position
Circle	00010000	2nd Position
Triangle	00001000	3rd Position

The position data through the I.R sensor is received by the MATLAB via MCU for validating the position and task fulfillment. In case of failure or fault, the computer will resend the data again with three attempts if it fails to respond system will automatically move towards halt state and indicate fault via Matlab.

IV. EXPERIMENTAL RESULTS

In test Case this project was designed to recognize any of the three 2d objects (sphere, Square, Triangle) in any colors thus making a total of 3 identifiable objects. During testing, it was found that all 3 objects are successfully identified by shape factor analysis and segregated into their respective positions by the robot also two edge detection filters applied in which canny filter gave good result under test condition shown in figure 2,3,4. Expansion of the code was also successful in specific ambient light conditions for detection of more shapes by comparing the threshold with perfect shapes With GUI implementation The Result and accuracy of detection are shown in Computational Figures 5 & 6 above and Performance of shape detection algorithm and Manipulator is shown below.

CASE	IMAGES	OBJECT SHAPE	SHAPE FACTOR	EDGE DETECTOR	RESULT
CASE 1	IMAGE 1	CIRCULAR	0.98	CANNY	DETECTED 98%
CASE 2	IMAGE 2	TRIANGULAR	0.603	CANNY	DETECTED 63%
CASE 3	IMAGE 3	SQUARE	0.75	CANNY	DETECTED 75%

Figure .8 Performance of Shape detection Algorithm

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CASE	OBJECT	PLACEMENT	RESULT + %	RESULT - %
CASE1	CIRCULAR	1ST POSITION	SUCCSESS 80%	SUCCSESS -20%
CASE2	TRIANGULAR	2ND POSITION	SUCCSESS 65%	SUCCSESS -35%
CASE3	SQUARE	3RD POSITION	SUCCSESS 75%	SUCCESS -25%

Figure .9 Performance of end effector

Figure .10 Original Picture of the Prototype

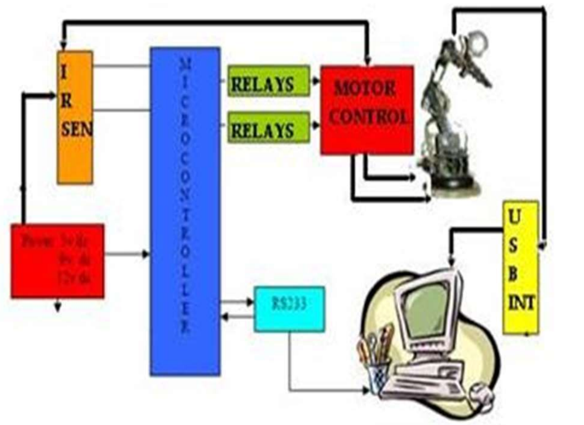

Figure.11 Block Diagram of the Prototype

V.CONCLUSION:

Robot successfully performed detection in various light conditions and various arbitrary objects were detected and robotic arm manipulator successfully did its placement task. The prototype has low-cost components and system is configurable for multiple movements and objects detection. Although this project is a prototype it has a vast field of future enhancement in A.I, robotics, automobile and machine learning applications.

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