# Implementation of Vision System for Object Sorting Application

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***Abstract:*** The futuristic vision of using industrial robotic systems that work in complex, uncertain and diverse environments is beginning to become reality because of advances in computational means, innovative sensors and controllers as well as introduction of concept of Industry 4.0. This paper proposed a novel and efficient approach for developing the integrated Vision System for sorting application. This paper discusses the implementation of a sorting methodology for standard shaped objects using single camera. The general architecture of Vision System that is based on the digital image processing is elaborated. The sorting methodology for sorting the objects based on shape and size include 3 extracted variables including Area Ratio or Extent, Compactness and two side edge length difference. The developed sorting methodology is applied successfully to sort square, rectangle, circle and hexagon shaped objects. According to this sorting methodology program is developed for object detection as well as recognition with the help of image processing toolbox of MATLAB. To extract the world co-ordinates of detected objects various camera calibration techniques are studied and camera calibration is carried out by adopting Pinhole Projection model. Evaluation of vision system is carried out by finding average error in percentage for position and orientation of detected objects.

***Keywords*** **- Vision system, Image Processing, Camera Calibration, Object Detection and Recognition.**

## I. INTRODUCTION

As today the utilization of robots in every kind of field is growing very fast, it is very important to increase the capabilities of robots by incorporating decision making and motion control which purely depend on visual data of the environment. Also, the environment information required for preventing the collision between robots and humans in a collaborative work area. To get the surrounding information of the field, there is a need to implement the vision system into robot with the help of which it can extract the surrounding information and can make decisions according to analysing that information.

Robot Vision System also known as “Computer vision” and it works on the principle of “Digital Image Processing”. The purpose of the robotic vision is to extract, characterize and interpret various information reside in the image and provide the guidance to the robot for manipulation in effective manner. The utilization of Vision System to manipulate the robot in accordance of analysing the information captured using the camera in a closed loop manner sometimes also called as ‘Visual Servoing’. This research work is focused to develop and validate Vision System for sorting objects based on shape and size using principle of digital image processing. The approach of sorting methodology and thoroughly step by step image processing yields a base for the further researches related with computer vision in robotics. The program for digital image processing is developed in MATLAB. The Pinhole Camera projection model is adopted for vision system calibration and ultimately to achieve the world co-ordinates of detected objects.

## II. LITERATURE REVIEW

There is a fruitful evolving research in the field of development of the vision system or visual servoing system exists. The review of literature is divided into various subtopics as described below.

### A. Vision system

Yi-Ting Chen et al. developed the integrated vision system that works in 3D using two CMOS cameras and position reliable visual servo technique with a view to achieve vision-based robot control, that manipulates in the 3D workspace and utilizes real-time image processing algorithms for performing tasks of various feature extraction and gives the orientation and position of the object for positioning control [1]. The Integrated 3D Vision System mainly contain 3 modules: Image Processing Module, System control module and Servo Control Module. Also, for exploring the integration between three-dimensional vision and robot motion control, system design is carried out using single FPGA (field programmable gate array) chip to detect the object motion information. Due to parallel computation with FPGA chip, better performance and response speed can be achieved.

Chi-Yi Tsai et al. discussed a novel switched reactive-based visual servo control approach to handle pick and place operation of 5 DOF robot. The control system consisting of hybrid switching controller involving of image and position based reactive planning approaches, which results in improvement in the robustness and effectiveness of the visual servo system [2]. Weiyang Lei et al. have proposed a monocular vision system that is compact and used for a power transmission line inspection robot. The vision system contains a camera, an image processing module, and video transmission devices [3]. Mohamad Bdiwi et al. have integrated a vision and force feedback control system for a sorting robot that is used to sort books in library. Vision system having CCD camera will extract the form, position, orientation and the alphabetic/numeric code of the object using SIFT (Scale Invariant Feature Transform) [4].

### B. Digital Image Processing

Digital image processing involves processes whose inputs and outputs are images and also involves processes that find out attributes from images [5]. Digital image is containing finite elements, each of which is characterized by specific location and value. These elements are known as picture elements, image elements, pels or pixels. Arya M S et al. have used the image processing concept for the detection of disease in plants for agriculture field. Affected area of disease and the difference in the color of the disease affected area are measured with the help of image processing toolbox of MATLAB. The steps implemented for detection of leaf diseases are image acquisition, image pre-processing, disease spot segmentation, feature extraction and disease classification [6].

Huidan Cao et al. have developed the application for utilization of MATLAB image processing in sewage monitoring system. The alarm will be started automatically when the percentage of the bubbles crosses the limiting value [7]. For removing the small particles caused by noise in image which are not bubbles and also for smoothening of bubble edge, several morphological operations are applied. Tejaswi B. et al. have developed methodology for droplet measurement after impingement on flat surfaces using image processing algorithm that is applicable in spray cooling of hot surfaces [8]. The effect of histogram equalization on the components of a grey scale image is to increase the contrast for facilitation of the detection of the regions of interest that is have a higher contrast than the other parts of the image. Canny edge detector is utilized to measure the dimensions of drop including the height and spreading radius of drop.

Lu pei et al. have proposed a method for the digital image measurement that is based on embedded DSP system for achieving automated and fast measurement of shower spray angle [9]. For reducing the effect of noise, median filtering is utilized on the image data before applying image threshold. Omkar Prabhune et al. have explained various methods of image processing like incorporation and extraction of digital watermark, image compression, point operations performed for enhancements, filtering techniques, specifically noise reduction from the image with the help of singular value decomposition method [10]. A decomposition method is a method to express any general matrix in terms of other special matrices like orthogonal, unitary, diagonal, triangular etc. Histogram equalization is a method that is widely used for contrast stretching. In histogram equalization, cumulative distribution function of every intensity values in the matrix is calculated that ensures that all the important intensities of the image get enhanced. Mask operations are performed for blurring, sharpening, edge detection, noise reduction. Generally, convolution operation is performed between the mask and the corresponding matrix of a digital image.

Hongchao Song et al. have elaborated the suitable image enhancement algorithms using different conceptual methods like median filtering, average smoothing, homomorphic filtering and histogram equalization [11]. Median filter is a type of non-linear filter that is based on statistical sort. Different from the average smoothing when filtering it does not affect the introduction of neighboring pixels, so that for some random noise, median filtering has a more impressive effect. Homomorphic filtering is mainly applied for improving the image uneven illumination. In this method the image is expresses as a product of lighting function and reflection function. In order to eliminate the heterogeneity in uneven illumination, weakening of the lighting function of the composition in the frequency domain and enhancing the composition of reflection function is done for improving the dark areas of the image.

Ashutosh Sharma et al. have presented a comparative analysis of different edge detectors utilized in digital image processing [12]. The basic idea behind edge detection is to first apply image enhancement operator for highlighting the edge, then estimate the pixel 'edge strength' and select the threshold for extracting the edge point set. There are various methods for performing the edge detection viz. Sobel, Canny, Prewitt. The edge detection is mainly composed of two parts, Gradient and Laplacian detection. In gradient edge detection technique, the edge detection is carried out using maxima and minima of the first derivative. On the other hand, in Laplacian edge detection technique, the detection has been made by searching zero crossing in the second derivative. The canny edge detector is an ultimate or optimal edge detector. The canny edge detection involves multiple stages known as multistage edge detection algorithm. The important steps of canny edge detector are involving operations like (1) Preprocessing, (2) Gradient calculations, (3) Non-maximum suppression, (4) Thresholding with hysteresis.

Rahul Kumar et al. have developed the algorithm for feature extraction in order to detect different objects present in an image [13]. The method used for thresholding operation is Otsu's method. The threshold is selected by Otsu's method in such a manner so as to minimize the intra-class variance of black and white pixels. In image filling operation, the dilated edges are filled so as the outline of the edges are clearer and more visible. Connected objects with the strong filled edges forms BLOB and are detected as an object in BLOB's analysis. After detection of the objects, a rectangular bounding box will be generated around the detected object and it will be cropped from bounding box outline.

### C. Object Recognition Methodology

In integrated vision system with robotic arm, recognition of the shapes of an object by computing the compactness which is a ratio of square of perimeter to the area of the object. The value of compactness helps in identifying the geometric shapes of the objects [14]. During the target detection process, the size of the target may be changing due to the movement of the robot therefore a rectangle template has been created for template matching. Therefore, the template is also scaled into different sizes for effective matching result. The system can effectively locate the target within the searching region to reduce redundant computation [15].

To develop the vision controlled robot that is used for military application, Sum of Absolute Difference (SAD) algorithm is utilized for implementing the proposed image processing algorithm which works based on the principle of image subtraction [16]. For hybrid switched reactive-based visual servo control to classify different objects, color segmentation algorithm and a Support Vector Machine (SVM)-based shape classifier are applied to extract and classify objects. Based on classified results, a coordinate conversion approach based on the camera calibration technique is adopted to convert the center position of all objects from image coordinate to world coordinate. The orientation is also estimated via an image-based object orientation estimation algorithm [2].

Steps involved in development of a stereo vision system are: Image grabbing, Stereo image rectification, Stereo correspondence, Disparity calculation, Depth calculation and finally Co-ordinate estimation. The depth map of the scene is created with the help of the SAD (Sum of absolute differences) algorithm [17]. In the structured light 3D vision system, the employed CCD camera mathematical model is the pinhole projection model which simplify the equation complexity. According to mathematical model rapid calibration method is developed. This method includes two steps: (1) calibration of the camera (2) calibration of the structured light plane [18].

### D. Camera Technology

Camera technologies mainly can be categorized as Active Vision and Passive Vision Technology. Passive vision technologies only require ambient lighting, works by comparing the location of the same point in multiple images and computing the intersection of the projection lines. Active vision technologies emit a visible or infrared pattern towards the scene and determine the depth from the returning time in case of time of flight, the deformation of the pattern in case of light coding or trigonometric calculations in case of laser triangulation and structured light [19]. Passive vision techniques need multiple cameras for 3D reconstruction whereas active vision techniques only utilize a single camera.

In stereo vision, the same point is to be searched in other image for calculating the intersection of the projection lines and obtaining the 3D position [19]. Nishank Kumar et al. have developed the visual servo loop by utilizing stereo vision system that is used in robotic arms suitable for space applications. In stereo vision system, using the stereo camera the two different images of the scene are taken using different point of view. The rectified images are then processed using stereo vision algorithms for obtaining the disparity map of the scene [17].

A Time of Flight (ToF) camera also known as range camera utilizes light pulses. According to the distance between object and camera, the emitted light experiences a time delay and based on time of flight depth information of the object is estimated [19]. The Kinect V2 sensor is used as a vision sensor for detecting position, shape and dimensions of an object in order to planning the end effector path which works based on time of flight technology. The results ensured it as an alternative with law cost to the well consolidated 3D measuring devices which are much more expensive [20].

Structured light equipment consists of a light projector and one or two cameras that receipts the reflected light. Depth is determined from the deviations utilizing a method similar to triangulation which involves calculating the intersection between planes and lines. In laser triangulation technology, the object point, the camera and the laser emitter generate a triangle. With the known laser emitter to camera distance and known angle of the laser emitter corner, the camera corner angle can be determined. These three values of information completely determine the shape and the size of the triangle and return the location of the laser dot corner that is actually 3D point [19].

Recently a novel unique type of sensor technology known as light coding is available for purchase at very small price with reference to other 3D range finders. Light coding uses an entirely different methodology in which the light source is constantly turned on which greatly reducing the need for precision timing of the measurements. From knowledge of emitted light pattern, lens distortion, and distance between emitter and receiver; the distance to each point can be estimated from measurement of the deformations in shape and size of the projected points. Light coding offers depth data at a very low cost but not provide a dense and accurate depth map [19].

## III. OBJECT SORTING METHODOLOGY

The vision system is validated with sorting application based on shape and size of different objects. For that 4 different shaped objects as Rectangle, Square, Circle and Hexagon are selected. Sorting of the different shape objects is done based on 3 variables: (1) The Area ratio or Extent (2) Compactness and (3) Two side edge length difference for the object.

MATLAB image processing toolbox provide a region descriptor named as ‘BoundingBox’ that is determined by function ‘regionprops’. BoundingBox can be characterized by a {1 x 4} vector representing the smallest rectangle containing a region. BoundingBox is defined by [ul_corner width], where ul_corner is in the form [x y] that represents the upper-left corner of the bounding box, and width is in the form [x_width y_width] that specifies the width of the bounding box along each dimension [5]. The area of bounding box is named as Area2. ‘bwarea’ function of the image processing toolbox of MATLAB determines the area of all of the ‘on’ pixels of an image by summation of the areas of each pixel in the image. The area of each pixel is determined according to 2-by-2 neighbourhood around it. The area of binary image region is decided using ‘bwarea’ function and designated it as Area1. Then finally area ratio or extent is defined by the ratio of Area2 to Area1. According to specified range of this area ratio sorting is done for the different shaped objects in the research.

The definition of the compactness can be represented as the ratio of the area of an object to the area of a circle with the same perimeter. The formula for the compactness is as per the equation (1) as below:

$$\text{Compactness} = (\text{perimeter})^2 / (4 \times \pi \times \text{Area}) \qquad (1)$$

The minimum value of the compactness is 1 for a circle. Objects having complicated, irregular boundaries have larger compactness. In the formula for compactness Area is calculated by the ‘bwarea’ function of MATLAB image processing toolbox whereas perimeter is calculated using ‘bwboundaries’ function of MATLAB image processing toolbox, that extracts the actual coordinates of boundary pixels of the image for all the regions of the image [5].

Using the ‘corner’ function of the MATLAB image processing toolbox the corner point co-ordinates of region in the image are extracted. Using corner point coordinates, the adjacent side edge lengths are calculated using mathematical operations on corner co-ordinates. Finally, difference between two side edge length is calculated and used it as a basis for detection of square and rectangle objects, as for square object this difference is zero whereas for rectangle this difference is nonzero.

## IV. IMAGE PROCESSING

The digital image processing program is developed in MATLAB using MATLAB image processing toolbox for sorting square, rectangle, hexagon and circular shaped objects according to sorting methodology defined. The Image processing algorithm follows the workflow as shown in **Figure 1**.

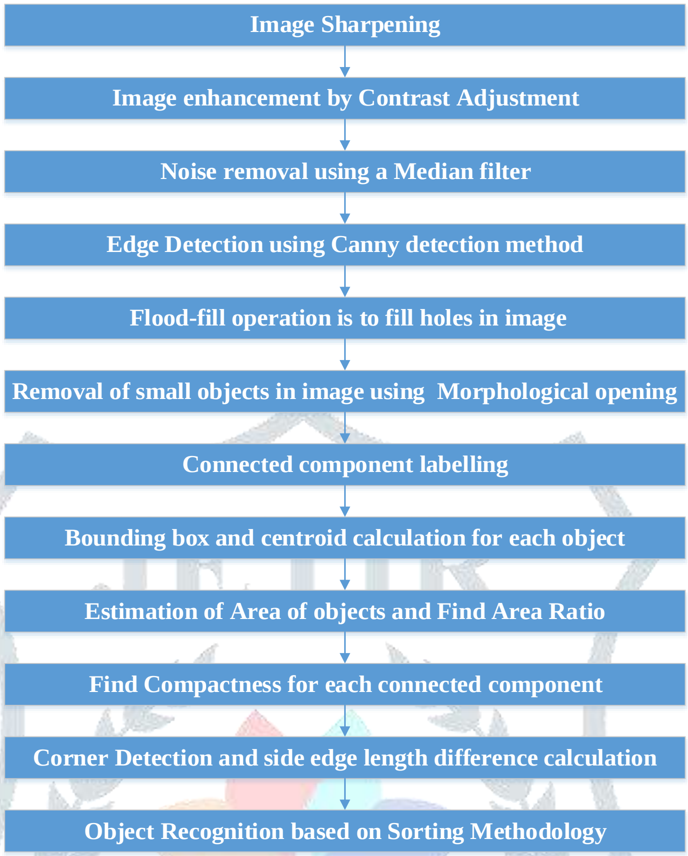


**Figure 1: Image Processing program workflow**

First an image is read in MATLAB environment using ‘imread’ function. Then image sharpening is performed using unsharp masking by ‘imsharpen’ function. Sharpening of images enhances the contrast at the edges where different colors meet. The sharpened RGB image is then converted into the grayscale image using ‘rgb2gray’ function. The ‘rgb2gray’ function converts RGB images to grayscale with the elimination of the hue and saturation information while residing the luminance. After that, ‘medfilt2’ function applies median filtering on the image in two dimensions for removing noise from the image. Each output pixel contains the median value in a 3-by-3 neighborhood surrounding the particular pixel in the input image. The ‘medfilt2’ function effectively removes noise from the image with less blurring of edges in image. Also, the contrast is enhanced using ‘imadjust’ function that changes the intensity values to new values by saturating the bottom 1% and the top 1% of all pixel values.

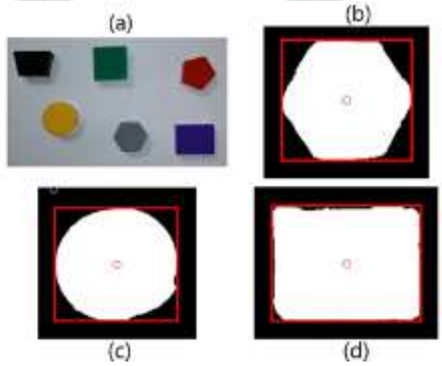


**Figure 2: Detection of different shaped objects in MATLAB: (a) Original Image, (b) Hexagon object, (c) Circular object, (d) Rectangle object. Red Rectangle represents the Bounding box and red circle represents centroid of detected object.**

Edge detection is carried out using ‘edge’ function with Canny method. ‘edge’ function gives a binary image containing 1s where the function finds edges in the input image and 0s elsewhere. By default, ‘edge’ function uses the Sobel edge detection method, but one can specify other methods like Canny, Prewitt, Roberts, or Zero-crossings. This function search for the places in the image where the intensity value changes very fast, using one of these two criteria: (1) Places where the first derivative of the intensity is larger in magnitude than some threshold, (2) Places where the second derivative of the intensity has a zero crossing. The powerful and robust edge detection method that ‘edge’ function supports is the Canny method. The Canny method is different from the other edge detection methods in the fact that it utilizes two different thresholds for detection of strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is hence less prone to noise, and more likely to detect actual weak edges.

The 'imfill' function carries out a flood-fill operation on binary and grayscale images. For binary images, 'imfill' function changes connected background pixels (0s) to foreground pixels (1s) until it reaches object boundaries. A general use of the flood-fill operation is for hole filling in images. Then, 'bwareaopen' function removes all connected components containing fewer than specified pixels from the input binary image and producing another binary image. This operation is also known as an area opening. The 'strel' function is utilized for creating the flat morphological structuring element, which is an essential component of morphological operations. Then, 'imopen' function performs morphological opening on the grayscale or binary image with the structuring element (specified as an argument). The morphological open operation is an erosion followed by a dilation, using the same structuring element for both operations. This function utilizes morphological processing for removing small objects from a binary image while retaining the shape and size of large objects. Dilation operation adds pixels to the boundaries of objects in an image, while erosion operation removes pixels from object boundaries. The 'bwconncomp' function is utilized for finding connected components in binary image. Connected component labelling is the procedure of detecting the connected components in an image and assigning each one a particular label.

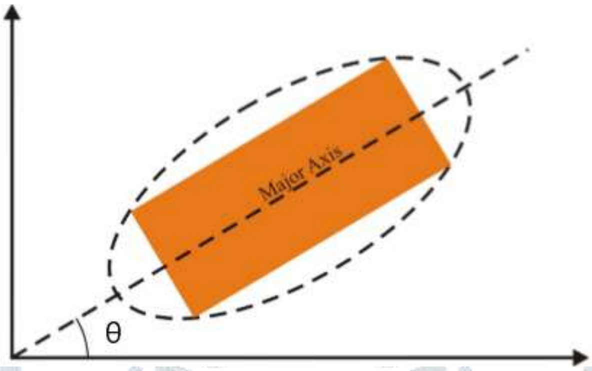


**Figure 3: Measurement of Orientation of the Object**

The centroid position of object and object orientation are the final outcome of the image processing algorithm. For determining the orientation of the object, 'regionprops' function with 'orientation' as an argument is used. It will give orientation in the form of angle between horizontal axis and the major axis of the ellipse having the same second moments as the region as shown in **Figure 3**. The object orientation value is in degrees having range from -90 degrees to 90 degrees.

## V. CAMERA CALIBRATION

Camera calibration is the technique for the estimation of the internal camera geometric and optical characteristics known as intrinsic parameters, and/or the 3-D position and orientation of the camera frame relative to a certain world coordinate system known as extrinsic parameters for determination of the world co-ordinates of the detected objects [21]. Physical camera parameters are usually categorized into extrinsic and intrinsic parameters. Extrinsic parameters are needed for transforming the object coordinates to a camera centered coordinate frame. In multiple camera systems the extrinsic parameters also describe the relation between the cameras. The intrinsic camera parameters generally include the focal length f, scale factor that adjusts the image aspect ratio and the image center also known as a principal point [22]. The camera projection is approximated by utilizing Pinhole Camera projection model. The origin of the camera coordinate frame is at the projection center having the location ($X_0$, $Y_0$, $Z_0$) with respect to the object coordinate system, and the z-axis of the camera frame is perpendicular with respect to the image plane as shown in **Figure 5**. For validating the vision system using single camera, the platform is made for taking the images from camera. The world and camera co-ordinate system are as shown in **Figure 4**.

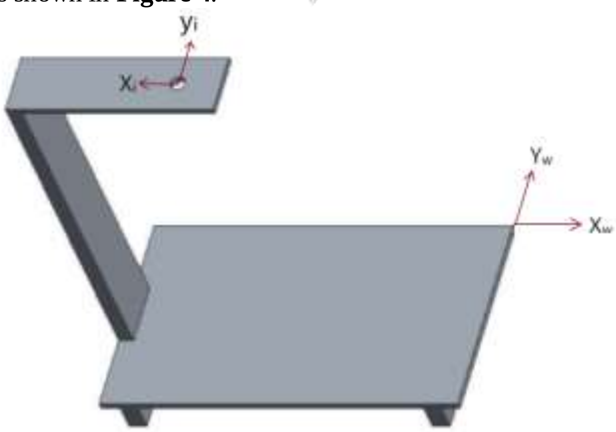


**Figure 4: Platform of vision system for Capturing Images**

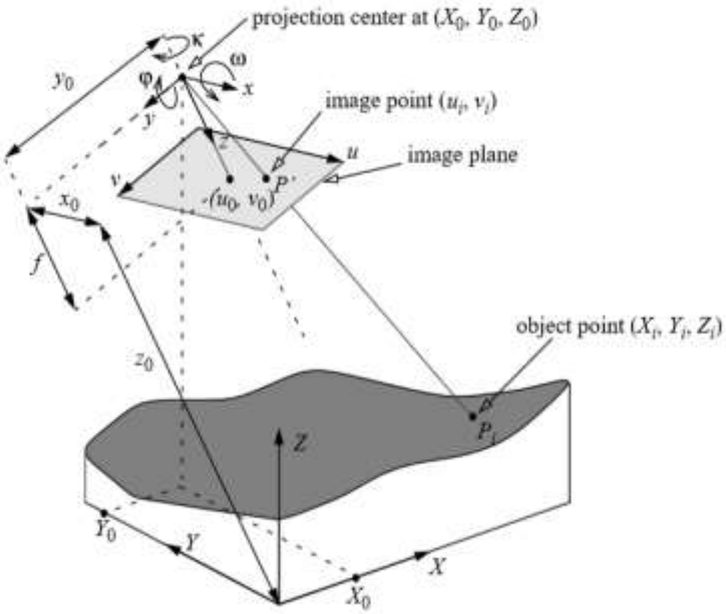


**Figure 5: Object and Camera Coordinate systems**

Real world co-ordinate frame is fixed at upper right corner of the platform and considered as the Left-Handed Co-ordinate system. In order to express any object point $P_i$ at location ($X_i$, $Y_i$, $Z_i$) in image coordinates, we first need to transform it to camera coordinates ($x_i$, $y_i$, $z_i$). This transformation consists of translation and rotation, and it can be performed using the following matrix equation (2).

$$\begin{Bmatrix} x_i \\ y_i \\ z_i \end{Bmatrix} = [R] \begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix} + \begin{Bmatrix} X_0 \\ Y_0 \\ Z_0 \end{Bmatrix} \quad (2)$$

By using the pinhole projection model, the projection of the point ($x_i$, $y_i$, $z_i$) to the image plane can be represented using equation (3).

$$\begin{Bmatrix} u_c \\ v_c \end{Bmatrix} = \frac{f}{z_i} \begin{Bmatrix} x_i \\ y_i \end{Bmatrix} \quad (3)$$

The unit of the image coordinates is in pixels, and therefore conversion factors $D_u$ and $D_v$ are required to change pixel unit to metric unit. Also, in Pinhole camera model the z axis of camera frame passing through image center ($u_0$, $v_0$) of the image plane. But the actual image co-ordinates start from upper left corner of the image. Considering above facts, corrected relation for image coordinates from the world coordinates is given by equation (4).

$$\begin{Bmatrix} u_i \\ v_i \end{Bmatrix} = \begin{Bmatrix} D_u u_c \\ D_v v_c \end{Bmatrix} + \begin{Bmatrix} u_0 \\ v_0 \end{Bmatrix} \quad (4)$$

Based on the above relations between the image coordinates and world coordinates of the object, the world coordinates of the centroid of detected objects can be found out from the image coordinates of the centroid with the help of equation (5) and (6) for X and Y direction respectively.

$$X_w = -\left[\frac{z_i(u_i - u_0)}{f D_u}\right] - X_0 \quad (5)$$

$$X_w = -\left[\frac{z_i(u_i - u_0)}{f D_u}\right] - X_0 \quad (6)$$

Above final equations of camera calibration are implemented in MATLAB for finding the detected object centroid's world coordinates from the image coordinates.

## VI. EXPERIMENTAL RESULTS

By implementing the Image processing algorithm that is developed in MATLAB and using proper camera calibration methodology, detection of Square, Hexagon, Circle and Rectangle is carried out from various different shaped objects. The Average error for the developed vision system in x as well as y-direction for each detected object is calculated based on actual experimental results as shown in **Table 1**.

The average error of vision system for detection of objects in x-direction is 10.01% and in y-direction is 5.87%. The probable reasons for such an error are camera optical system's several types of distortions like radial and tangential distortions. Also, non-uniform lighting conditions affect the detection accuracy of the objects. The average error for orientation estimation is calculated around 2.79%.

**Table 1: Evaluation of effectiveness for detection of objects**

| Object Shape | Actual Centroid position (mm) | Detected Centroid position (mm) | Error in X (%) | Error in Y (%) |
|---|---|---|---|---|
| Rectangle | (-325, -82) | (-338.25, -90.54) | 4.07 | 10.41 |
| Hexagon | (-258, -87) | (-273.89, -94.61) | 6.15 | 8.74 |
| Square | (-232, -200) | (-253.81, -191.74) | 9.40 | 4.13 |
| Circle | (-169, -118) | (-203.57, -118.27) | 20.45 | 0.22 |
| Average Error | | | 10.017 | 5.875 |

## VII. CONCLUSIONS AND FUTURE WORKS

In this research, Vision System is implemented for sorting different objects based on shape and size. Vision system is developed using the single camera with proper calibration methodology using Pinhole Projection model. With the help of the developed image processing algorithm in MATLAB, detection of the objects with different shape like Hexagon, Square, Rectangle and Circle is done successfully by using proper range of Compactness and Area Ratio. The average error of vision system for position detection in x-direction is 10.01% and in y-direction is 5.87%. The average error of vision system for orientation is 2.79%. From Experimental Results, it is observed that the adopted Pinhole projection model for camera calibration is an approximate model and used initially for validation of single camera vision system. In reality, one should also consider various camera optical system distortions for accurate results.

This research paper yields a base for several researchers in the era of robot vision based on digital image processing. In future, one can develop the vision system that can also be able to sort the objects based on color as well as texture of the surface of an object. Also, one can develop the more accurate vision system by using non-linear optimized calibration methods that also consider the various lens distortions of the camera. Also, one can develop object detection and recognition algorithm using machine learning and deep learning techniques.

## REFERENCES


[1] Y.-T. Chen, C.-L. Shih and G.-T. Chen. An FPGA Implementation of a Robot Control System with an Integrated 3D Vision System. Smart Science, vol. 3, no. 2, pp. 100-107, 2015.

[2] C.-Y. Tsai, C.-C. Wong, C.-J. Yu, C.-C. Liu and T.-Y. Liu. A Hybrid Switched Reactive Based Visual Servo Control of 5-DOF Robot Manipulators for Pick-and-Place Tasks. IEEE systems journal, vol. 9, no. 1, pp. 119-130, 2015.

[3] L. W., L. E., Y. G., F. C., J. F. and L. Z. An Embedded Vision System for a Power Transmission Line Inspection Robot. International Conference on Intelligent Robotics and Applications, Springer, 2009.

[4] M. Bdiwi and J. suchy. Robot Control System with Integrated Vision/Force Feedback for Automated Sorting System. IEEE International Conference on Technologies for Practical Robot Applications (TePRA), 2012.

[5] R. C. Gonzalez, R. E. Woods and S. L. Eddins. Digital Image Processing Using MATLAB. Second ed., Mc Graw Hill Education (India), 2010, pp. 552-597.

[6] A. M. S, A. K and M. D. Unni. Detection of unhealthy plant leaves using image processing and genetic algorithm with Arduino. IEEE International Conference on Power, Signals, Control and Computation (EPSCICON), Thrissur, India, 2018.

[7] H. Cao and Y. Shen. Application of MATLAB Image Processing Technology in Sewage Monitoring System. IEEE 9th International Conference on Electronic Measurement & Instruments, Beijing, China, 2009.

[8] T. B., S. P. and V. M. Image processing algorithm for droplet measurement after impingement. IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), Chennai, India, 2016.

[9] L. pei, Y. juntao and H. ji. Measuring on Spray Angle of Shower Nozzle Based on Embedded Image Processing System. IEEE 2nd International Congress on Image and Signal Processing, Tianjin, China, 2009.

[10] O. Prabhune, P. Sabale, D. N. Sonawane and D. C. Prabhune. Image Processing and Matrices. IEEE International Conference on Data Management, Analytics and Innovation (ICDMAI), Pune, India, 2017.

[11] H. Song, Y. Shang, X. Hou and B. Han. Research on Image Enhancment Algorithms Based on MATLAB. IEEE 4th International Congress on Image and Signal Processing, Shanghai, China, 2011.

[12] A. Sharma, M. D. Ansari and R. Kumar. A Comparative Study of Edge Detectors in Digital Image Processing. 4th IEEE

International Conference on Signal Processing, Computing and Control (ISPCC), Solan, India, 2017.

[13] R. Kumar, S. Kumar, S. Lal and P. Chand. Object Detection and Recognition for a Pick and Place Robot. IEEE Asia-Pacific World Congress on Computer Science and Engineering, Plantation Island, Fiji, 2014.

[14] R. Reddy and N. S. R. Integration of Robotic Arm with Vision System. IEEE International Conference on Computational Intelligence and Computing Research, Coimbatore, India, 2014.

[15] L. Cai, F. Chang, S. Li and X. Zhang. Control System of the Explosive Ordnance Disposal Robot Based on Active Eye-to-Hand Binocular Vision. International Conference on Artificial Intelligence and Computational Intelligence, Springer, 2011.

[16] S. Bhat and D. M. Meenakshi. Vision Based Robotic System for Military Applications – Design and Real Time Validation. IEEE Fifth International Conference on Signals and Image Processing, 2014.

[17] S. G. R., N. Kumar, H. P.R. and S. S. Implementation of a Stereo vision based system for visual feedback control of Robotic Arm for space manipulations. International Conference on Robotics and Smart Manufacturing, 2018.

[18] Z. Yin, X. Yuan, G. Zhang and H. Zhao. Structured Light 3D Vision in the Remanufacturing System based on Robotic Arc Welding. IEEE Proceedings of the 10th World Congress on Intelligent Control and Automation, Beijing, China, 2012.

[19] L. Perez and N. Rodriguez. Robot Guidance Using Machine Vision Techniques in Industrial Environments: A Comparative Review. Sensors, vol. 16, no. 3, pp. 335-361, 2016.

[20] L. Caruso, R. Russo and S. Savino. Microsoft Kinect V2 vision system in a manufacturing application. Elsevier's Robotics and Computer-Integrated Manufacturing, vol. 48, pp. 174-181, 2017.

[21] R. Tsai. A Versatile Camera Calibration Technique for High Accuracy 3D Machine Vision Metrology Using Off-the-shelf TV Cameras and Lenses. IEEE Journal on Robotics and Automation, vol. 3, no. 4, pp. 323-344, 1987.

[22] H. Janne. Accurate 3-D Measurement Using A Single Video Camera. International Journal of Pattern Recognition and Artificial Intelligence, vol. 10, no. 2, pp. 139-149, 1996.