An Approach for Position Detection of Industrial Objects

Veska Georgieva[1] and Plamen Petrov[2]

***Abstract* – In this paper, an approach for position detection of industrial objects by using a monocular camera mounted on a pick-and-place manipulator is presented. The proposed algorithm is based on Circular Hough transform. The camera-manipulator configuration is described in order to obtain information for the relative position of an object with respect to the end-effector.**

Keywords – **Monocular camera, Edge detection, Circular Hough transform, Position camera-manipulator model.**

I. Introduction

During the last decades, the computer vision has been used to locate objects in an industrial environment [1, 2]. By using a fixed or moving camera, the manipulator can obtain information for the relative position of an object with respect to the end-effector.

In this paper, an approach for position detection of industrial objects by using a camera mounted on a pick-and-place manipulator is presented. The proposed algorithm is based on Circular Hough transform. The camera-manipulator configuration is described in order to obtain information for the relative position of an object with respect to the end-effector.

The highly-reflective nature of the metal object surface may cause unwanted side effects such as glare that can make problems in precisely identifying position of the industrial objects. In addition the illumination in the room may cause low contrast and shadows by obtained images with the camera. These problems can be dealt with in post-processing.

The rest of the paper is organized as follows: In Section 2, the basic stages in the proposed algorithm for image processing is presented. The camera-manipulator configuration is described in Section III. Some experimental results are given in Section IV. Section V concludes the paper.

II. Basic Stages in Algorithm for Image Processing

In the paper is proposed an effective pre-processing algorithm to position detection of the industrial objects. It consists of:

- Image Enhancement
- Edge Detection via the Sobel Operator
- Circle Detection via the Circular Hough Transform

[1]Veska Georgieva is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: vesg@tu-sofia.bg

[2]Plamen Petrov is with the Faculty of Mechanical Engineering at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: ppetrov@tu-sofia.bg

The first step in pre-processing is image enhancement. It includes noise reduction and contrast enhancement. As first is proposed to use a median filter in order to reduce some kind of noise, introduced by the creating of digital images. The median filtering is a specific case of order-statistic filtering, in that the value of an output pixel is determined by the median of the neighbourhood pixels. The median is much less sensitive than the mean to extreme values (outliers). Median filter is therefore better able to remove the outliers without reducing the sharpness of the image and with less blurring of edges [3].

The intensity of the image can be adjusted as next. So can be increased the contrast in image in order to obtain better visualization on the boundaries of the object, which are obscured by the shadow. It is made on the base of calculation the histogram of the image and determination the adjustment limits [4].

As next step in detecting the position of the disk on the cube is proposed to perform edge detection via the Sobel Operator, applied in both the horizontal and vertical axes [5]. It is necessary to detect circular edges and reject some of more linear edges. A threshold is applied to thin the edges as well as avoid detection of non-circular shapes.

Although edge detection can successfully extract most of the circle from the image, we must now focus on extracting the circular shapes and their position on the disk. The proposed method for this is the Circular Hough Transform [6].

The Circular Hough Transform is useful for detecting circles of known radius as well to detect circles of various radii. This method is based on creating an accumulator matrix of size of the original image to be processed and is illustrated in Fig.1, [7].

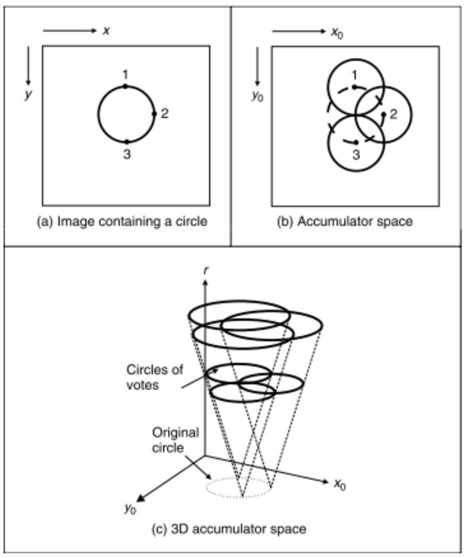

Fig. 1. Principle of Circular Hough Transform

An accumulator is an array used to detect the existence of the circle in the Circular Hough Transform. The local maxima in accumulator space are obtained by voting procedure. Parameter space is defined by the parametric representation used to describe circles in the picture plane, which is given by Eq.1[8]:

$$r^2 = (x - x_0)^2 + (y - y_0)^2 \tag{1}$$

It implies that the accumulator space is three-dimensional (for three unknown parameters x_0, y_0 and r) and defines a locus of points (x, y) centered on an origin (x_0, y_0) with radius r. Points corresponding to x_0, y_0 and r, which has more votes, are considered to be a circle with center (x_0, y_0) and radius r.

III. Camera–Manipulator Configuration

The camera-manipulator configuration considered in this paper is shown in Fig. 2. The kinematic scheme of the pick-and-place robot consists of three links connected by prismatic joints, and a gripper connected by a revolute joint. The robot has four degree-of-freedom. Complete derivation of the manipulator position and orientation kinematics is given in [9]

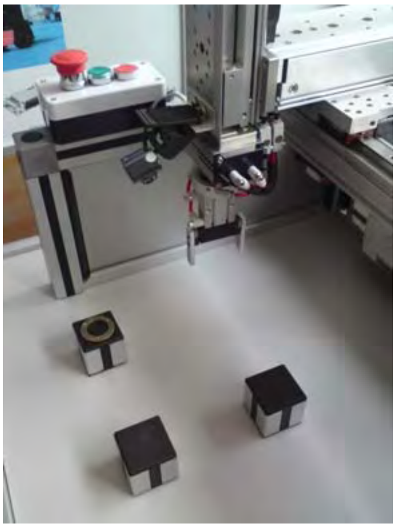

Fig. 2. Experimental platform: 4-DOF manipulator with a moving camera

The camera is fixed to the third link of the manipulator, as shown in Fig. 3.

An auxiliary coordinate frame $Dx_Dy_Dz_D$ is introduced which is fixed with respect to $O_4x_4y_4z_4$ coordinate frame and has his center D on O_4y_4 axis at distance d_{y4} from O_4. The axes of $Dx_Dy_Dz_D$ are parallel to those of $O_4x_4y_4z_4$. The origin of the camera frame $Cx_Cy_Cz_C$ coincides with the center of the coordinate system $Dx_Dy_Dz_D$ but rotated at angle β about the x_D axis.

Let us denote the position of a feature point G with respect to the camera frame by

$$^{C}p_G = \begin{bmatrix} ^{C}x_G \\ ^{C}y_G \\ ^{C}z_G \end{bmatrix} \in \Re^3 . \tag{2}$$

The corresponding pixel coordinates in the image plane are obtained as follows given in Eq.3:

$$^{I}p_G = \begin{bmatrix} u_G \\ v_G \\ 1 \end{bmatrix} = \frac{1}{^{C}z_G} T_C \, ^{C}p_G \tag{3}$$

where the 3x3 invertible matrix T_C (Eq.4)

$$T_C = \begin{bmatrix} fw_u & 0 & u_0 \\ 0 & fw_v & v_0 \\ 0 & 0 & 1 \end{bmatrix} \tag{4}$$

is the so-called intrinsic camera calibration matrix [10],(w_u, w_v) are the camera scaling factors, and f is the focal length.

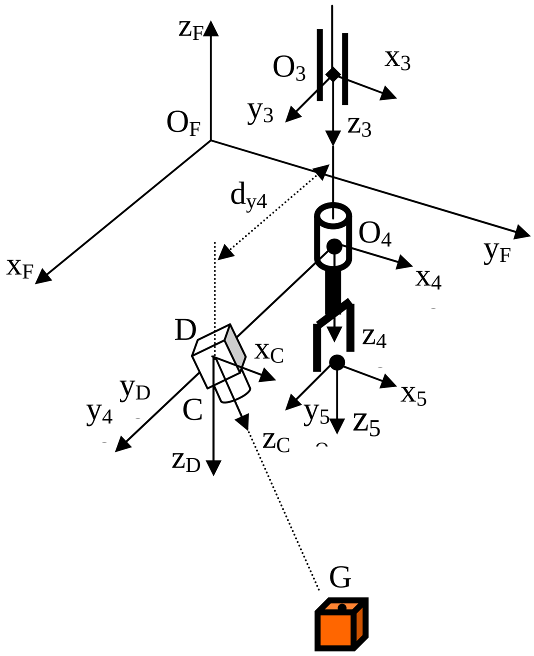

Fig. 3. Schematic of the camera-manipulator configuration

Using Eqs. (2), (3) and (4), the coordinates of point G in $Dx_Dy_Dz_D$ are obtained as follows

$$^{D}p_G = \begin{bmatrix} ^{D}x_B \\ ^{D}y_B \\ ^{D}z_B \end{bmatrix} = {}^{C}z_G R_{x,\beta} T_C^{-1} \, ^{I}p_G \tag{5}$$

where $R_{x,\beta} \in SO(3)$ is a rotation matrix about the x_D axis by angle β. Finally, the coordinates of point G in $O_4x_4y_4z_4$ are obtained as follows

$$ {}^{O_4}p_G = {}^{D}p_G + {}^{O_4}d_D \quad (6) $$

where ${}^{O_4}d_D = \begin{bmatrix} 0 & d_{y4} & 0 \end{bmatrix}^T$. It should be noticed that the axes O_4z_4 and O_5z_5 point out at the same point. In this way, by using the coordinates of a detected feature point G in $O_4x_4y_4z_4$, we obtain information for the relative position of an object with respect to the end-effector. The manipulator is moving from one position to another over different objects placed in the operational space in order to detect an object with a specific feature (a circular element in our experiment).

IV. Experimental Results

The experiments are made in MATLAB 7.14 environment by using IMAGE PROCESSING TOOLBOX. Some results, which illustrate the working of the proposed algorithm, are presented in the next figures below.

In Fig. 4 is presented the original image of size 640x480 pixels obtained by the camera and in Fig. 5 is shown its enhancement modification.

Fig. 4. Original Image

Fig. 5. Enhancement Image

The computed histograms of these images are given in Fig. 6. The increased contrast in the processed image represents that the histogram now fills more room in the dynamic range.

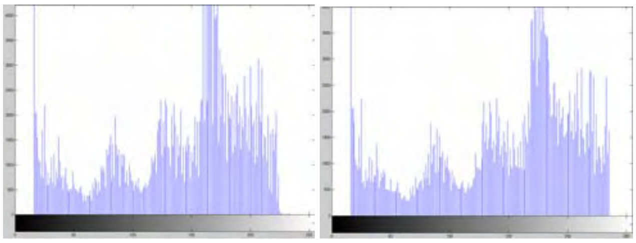

Fig. 6. Calculated histograms of the original and enhancement images

For edge detection was used a threshold value of 0.08, which provided good performance to thin the edges as well as avoid detection of non-circular shapes [7]. Fig.7 presents an edgemap image obtained via Sobel Operator.

Fig. 7. Edgemap image obtained via Sobel Operator.

The obtained result of the Circular Hough Transform is finding the coordinates of the center of the disk and its radius.

After the proposed image processing techniques is applied, we can identify the location of the disk in the original image, as shown in Fig.8.

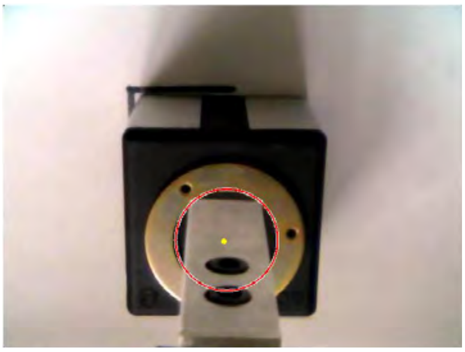

Fig. 8. Processed Image with detected position of the object

Sensitivity factor is an important parameter and specifies the sensitivity for the Circular Hough transform accumulator array [4]. Its value is in the range [0, 1]. By increasing of the sensitivity factor, can be detected more circular objects, including weak and partially obscured circles. Higher sensitivity values also increase the risk of false detection. It was used a sensitivity factor value of 0.92.

The obtained results for the computed coordinates of center of the circular object and its radius are more precise than the results obtained on the base of weighed centroids.

V. Conclusion

In this paper, an approach for position detection of industrial objects by using a camera mounted on a pick-and-place manipulator has been presented. The proposed algorithm is based on Circular Hough transform. The camera-manipulator configuration is described in order to obtain information for the relative position of an object with respect to the end-effector. Based on the proposed algorithm, when the manipulator is moving consecutively from one position to another over the different objects placed in the operational space, it is possible to detect an object with a specific feature (a circular element in our experiment), and to take it with the gripper. Future work will include the design of visual servoing of the pick-and-place manipulator.

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