Approach to Accurate Circle Detection:Circular Hough Transform and Local Maxima Concept

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Abstract—**Detecting circular objects over digital images have received considerable attention from industries for applications such as detection of pellets in pelletization plant, target detection, inspection of manufactured products etc. Several algorithms were proposed in past few years to detect circular features. One powerful approach for circle detection is the Circular Hough Transform and its variants. This article presents an algorithm which is based on CHT and Local Maxima concept. Finding one or several maxima considering different accumulators simultaneously and mapping the found parameters corresponding to the maxima back to the original image is key concept of proposed algorithm. Experiments were performed on real industrial images to validate the efficiency of proposed algorithm regarding good accuracy of detection.**

Keywords—Circular Hough Transform; local maxima; Distance Threshold; Safe House; Edge Map;

I. INTRODUCTION

In everyday experience, we encounter many objects which contain circular features in it. Detection of circular objects in digital images is important for image analysis in various computer vision applications such as detection of pellets in pelletization plant, inspection of manufactured products, target detection, aided vectorisation of drawings etc. This domain has been researched using various methods in past few years.

W.C.Y. Lam and S.Y. Yuen proposed one such scheme of detection with point triplets possessing right angle property. According to author propose scheme will reduce the enumerations to ${}^{n}C_2$ from ${}^{n}C_3$ [1]. Ten-Chuan Chen and Kuo-Liang Chung presented concept of randomized algorithm (RCD) which is not based on the Hough Transform [2]. Concept of RCD is that we select four edge pixels in the image and define distance criterion. If possible circle is found, apply an evidence-collecting process to determine whether possible circle is true or not. A two-step circle detection algorithm shows how a pair of two intersecting chords locates the center of the circle [3]. A Goneid, S.EI-Gindi, A. Sewisy proposed a method that proceeds on two stages: first, detect N edge points in an M x M image in both horizontal and vertical scan to construct symmetrical axes using two 1-dimensional arrays. The axes cross point determines the object center [4]. Contribution to this domain still continues. Emanuel E. Zelniker and I. Vaughan L. Clarkson presented an interpretation of the maximum-likehood estimator (MLE) and the Delogne-Kasa estimator (DKE) for circle center and radius estimator in terms of convolution of an image [5]. In September 2007, SLIDE (Subspace-based line detection) method proposed to estimate the center and radius of a single circle [6]. Concept of right triangles inscribed in a circle to detect circle in an image which is basis of Semi Random Detection (SRD) approach is presented by Fei SHANG, Jinwei LIU, Xiao ZHANG, Di TIAN [7].

Most common technique for circle detection which is used mostly by scientific community is Circular Hough Transform (CHT) and its variants. The Hough transform can be described as transformation to the parameter space from X, Y-plane [8]. Mathematically equation of circle in x, y-plane is given by

$$r^2 = (x-a)^2 - (y-b)^2 \tag{1}$$

Where r is the radius of the circle and a, b are the center of the circle. Equation 2 and 3 are parametric representation of the circle.

$$x = a + r \cos \Theta \tag{2}$$
$$y = b + r \sin \Theta \tag{3}$$

The circle has three parameter r, a and b, hence the parameter space will belong to R^3.

When we applied traditional CHT technique to industrial images which is obtained from Pelletization plant, the results obtained contains many false circles which may be due to pellets which looks similar to circle but not exactly the circle. For such type of real industrial images we extended the concept of local maxima to different accumulators. Concept of Safe House is also proposed to obtain more accurate results. This paper presents an algorithm which works for this type of real images with enhanced accuracy of detection.

The remainder of this paper is organized as follows. Section 2 contains the concept of proposed work. Section 3 contains proposed algorithm. Section 4 and section 5 contains the experimental results and conclusion respectively.

II. PROPOSED WORK CONCEPT

Variants of the CHT have been widely implemented, which more commonly reduce its computational complexity or to increase the detection rate of the algorithm. In this section we have proposed the concept which will increase the detection rate of the algorithm.

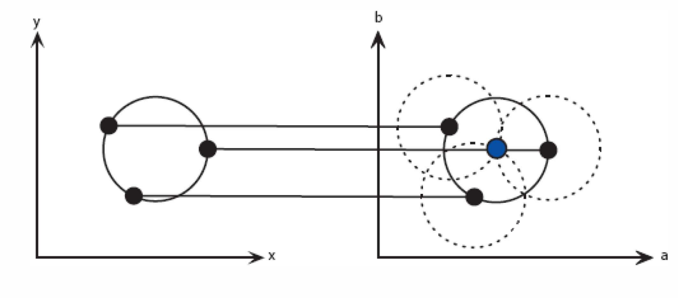

Figure 1. Parametric space representation of a constant radius circle[8]

First we find all edges using any of the edge detection technique in the image. In this paper we have used canny edge detection technique. The radius range is either given by the user of the application or already defined in program. Suppose radius range defined in program is (R_i, R_j). Then R_j - R_i will give the number of accumulators to be made and searched out in order to carry out desired task of detection. Accumulator matrix will have the same size as the parameter space.

Now consider each edge pixel obtained as result after applying canny edge detection technique. For each edge pixel draw a circle having radius equal to R_i (R_i lie within the radius range).The circle is drawn in parameter space (figure1). Here a-value corresponds to x-axis (eq.1) and b-value corresponds to y-axis (eq.2) while the z-axis is the radii. For this radius R_i we have one distinct accumulator. Initially all the cell values in the accumulator are set to zero. At the coordinates which lie on the perimeter of the drawn circle in parametric space, increment the value in accumulator matrix. Sweep every edge point in the input image and increment the cell values in the accumulator matrix.

This process is repeated for all desired radii which belong to radius range. If radius range is (R_i, R_j) then total number of accumulators needed is R_j-R_i.

A_1=

64	2	3	61	60	6	7	57
9	55	54	12	13	51	50	16
17	47	46	20	21	43	42	24
40	26	27	37	36	30	31	33
32	34	35	29	28	38	39	25
41	23	22	44	45	19	18	48
49	15	14	52	53	11	10	56
8	58	59	5	4	62	63	1

Figure 2. Accumulator matrix sample

Each accumulator which is made for particular radius will contain numbers also called votes or cuts. The number in any cell of accumulator matrix indicates the number of circles passing through that individual coordinates. First apply the concept of local maxima within the same accumulator. For each row of accumulator matrix, find out the local maxima. Figure shown above contain one sample of accumulator matrix of order 8 x 8 (figure 2). Consider first row of A_1.

$$A_1\,(1, 1{:}8) = \{64, 2, 3, 61, 60, 6, 7, 57\}$$

First row of A_1 contains 8 elements. Taking window size equals to five, slide this window to entire row over each element to find the local maxima.

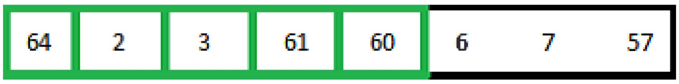

Figure 3. Sliding window on first row of A_1 (Maxima found = 0)

Figure 4. Sliding window on first row of A_1 (Maxima found = 1(61))

Figure 5. Sliding window on first row of A_1 (Maxima found = 0)

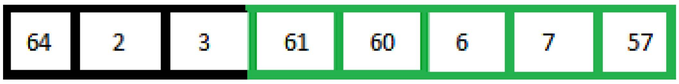

Figure 6. Sliding window on first row of A_1 (Maxima found = 0)

From the above figure 3-6, only one maxima found at the first row and fourth column. Corresponding coordinates (1, 4) is temporary elected as center candidate. This elected candidate has to pass through one addition tests to confirm the election for center candidate.

Extend the concept of local maxima to the different accumulator. Suppose coordinate P_k (x, y) is confirmed first test and elected. Consider four coordinates P_{k-1}(x, y-1), P_{k-2}(x, y-2), P_{k+1}(x, y+1) and P_{k+2}(x, y+2) which belongs to accumulators P_2, P_1, P_4 and P_5 respectively if k equals to three. These four coordinates along with the elected coordinate is searched for local maxima. If elected coordinate again got selected, then this candidate can be thought of real candidate for center coordinate otherwise discard the coordinate. Figure shown below will explain this concept more clearly (figure 7).

In the above example, coordinate (1, 4) which has cell value equals to 64 is selected. Let this coordinate belongs to accumulator P_3. This value 64 is compared with the values 55, 33, 51 and 39 which belongs to accumulator P_2, P_1, P_4 and P_5 respectively. The Value 64 passes this test also, so the coordinates (1, 4) is the real candidate for center coordinate. The result of this concept will contains more accuracy in detection than traditional Circular Hough Transform. After applying this concept on some of images may have more accurate results and some images results only reduction in false circles. This is due to nature of the image and source of the image through which image is obtained. To remove false circles completely or detecting the real circles only, two things were needed, center coordinate and cell value. (generally called votes). Suppose initial result of one of the image contains forty two circles.

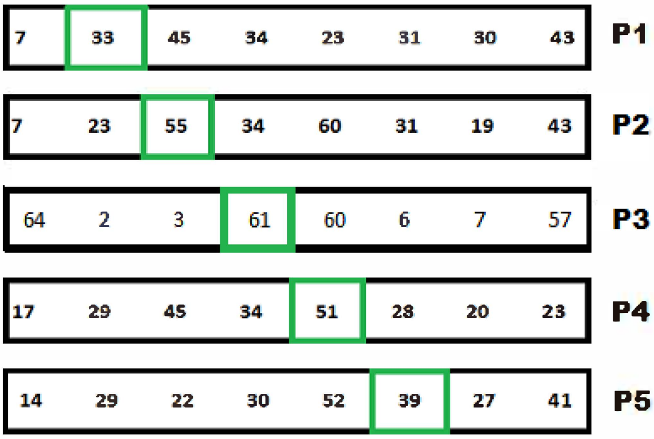

Figure 7. Sliding window on Different accumulators

After applying above concept the result contains twenty one circles. If our original image contains only seventeen circles, so still there are four false circles. To remove these false circles we store one of the center coordinates and its cell values to some place call it as a safe house. Take another center coordinate and apply distance threshold. If distance between coordinate which is in the safe house and coordinate which is under consideration is greater than distance threshold, then move the coordinates under consideration to safe house along with the corresponding cell value. If distance calculated is found less than threshold then the coordinate having greater cell values is considered to survive, coordinate having less cell values need to be discarded. Safe house will contain the much more accurate result.

III. PROPOSED ALGORITHM

Based on the concept in section II, proposed algorithm to detect centers and radii is as follows:

(1) Get the edge map of the image using canny edge detector technique.

(2) For each edge point

Taking edge point as center with radius r (r € radius range), draw a circle. At the coordinates which lie on the perimeter of the drawn circle in parametric space, increment the value in accumulator matrix.

// collecting votes in accumulator (cell values)

(3) Repeat step-2 for all edge points and all radii defined in radius range.

(4) For each maxima found

Compare maxima of that accumulator to their consecutive previous and next accumulators.

// confirmation of candidature

(5) Found parameters (r, a, b) corresponding to local maxima in step-4, map these to original image.

IV. EXPERIMENTAL RESULTS

The proposed algorithm is tested on several images. Some of them have shown in figure 8(a), figure 9(a), and figure 10(a). Figure 9(a) and figure 10(a) shows positive results. Only figure 8(a) has to put for Safe House test. Implementation of proposed algorithm shows reduction in number of false circles but still false circles exists (figure 8(d)). After implementing Safe House test, result of image (multipellet.jpg) is more accurate (figure 8(e)).

The reason may be image contains object that are not exact circles but may contain circular feature to some extent. Table I. shown below simplifies the picture of results more clearly.

TABLE I.

S. No.	**Results on Industrial Images**			
	Image Name	***CHT***	***Proposed Concept***	***Safe House***
1	Multipellet.jpg	Contains too many false circles	Reduction in false circle (more accurate than traditional CHT)	Accurate result (approx.)
2	Manypellet.jpg	Contains false circles	Accurate result	Needed
3.	Coins.png	Accurate results	Accurate results	Not needed

V. CONCLUSION AND FUTURE RESEARCH DIRECTION

The proposed work extends the concept of local maxima. This extension of concept will refine the result and increase in accuracy is assured. This works fine for all images. Implementation of proposed algorithm sometime over some images will show reduction in false circles. The result obtained after implementation of traditional CHT will have surely the number of false circle greater than the result which is obtained after the implementation of proposed work. Algorithm result sometime contains false circles which are due to nature of the image under consideration or the objects in the images have circular features to some extent but they are not exact circles.

Accurate detection of circular objects simultaneously reducing the complexity of algorithm is still the main domain of research.

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Figure 8(a). Original figure (multipellet.jpg)

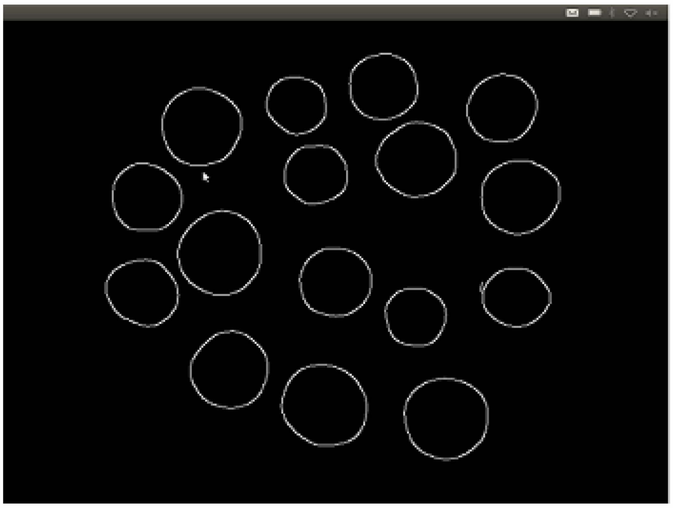

Figure 8(b). Figure after canny edge detection implementation

Figure 8(c). Figure after CHT implementation

Figure 8(d). Result of proposed concept

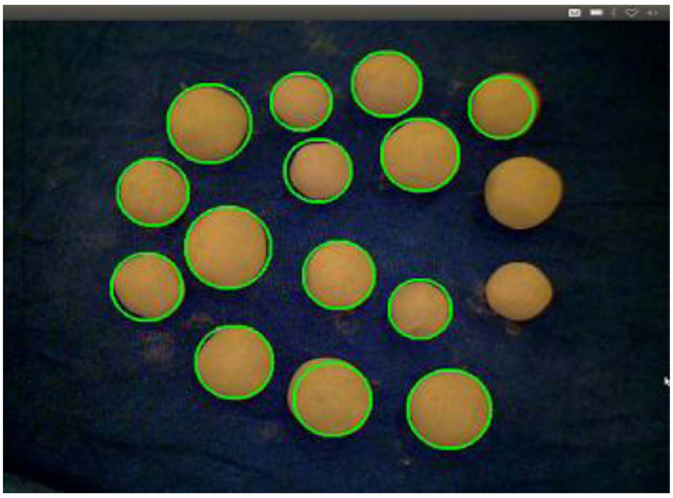

Figure 8(e). Safe House result (multipellet.jpg)

Figure 9(a). Original figure (manypellet.jpg)

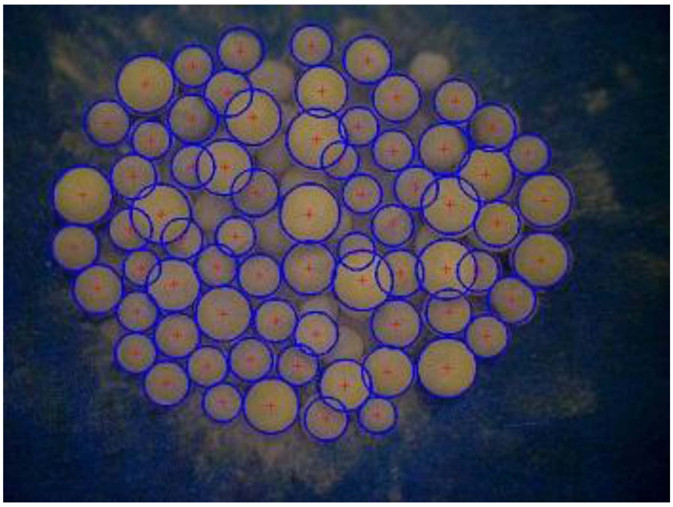

Figure 9(b). Result of proposed concept

Figure 10(a). Original figure (coins.png)

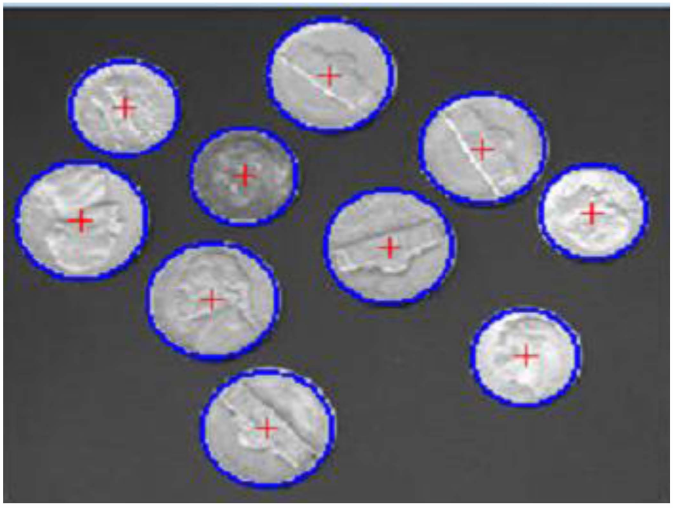

Figure 10(b). Result of proposed concept

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