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# CIRCULAR HOUGH TRANSFORM FOR DETECTING AND MEASURING CIRCLES OF AN OBJECT

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**Abstract** – This article proposes a method to detect circular shapes of any given image. The Circular Hough transform is one of the methods to find circles in an object especially the objects used in various industrial applications. This paper presents a modified method in order to improve the computational performance for a good accuracy of circle detection in a binary image. The purpose of the technique is to detect circles and calculate diameter of circle. At first basic transformation is applied to clear the noise in image and after this process Edge detection Algorithm is used to detect edges, then the characteristic point of circles are determined, after this process pattern of circle is extracted and then with the help of extraction parameter, the diameter can be calculated of an object. The proposed work makes use of openCV-python framework.

**Keywords** – Circular Hough Transform (CHT), edge detection, image transformation, contour extraction.

## I. INTRODUCTION

One of the most challenging tasks in Computer Vision is feature extraction in images. Usually objects of interest may come in different sizes and shapes, not pre-defined in an arbitrary object detection program. A solution to this problem is to provide an algorithm that can be used to find any shape within an image then classify the objects accordingly to parameters needed to describe the shapes. A commonly used technique to achieve this is the Hough Transform. Invented by Richard Duda and Peter Hart in 1992, the HT was originally meant to detect arbitrary shapes of for different objects. The Hough Transform was later extended to only identify circular objects in low-contrast noisy images, often referred to as Circular Hough Transform. This method highly depends on converting gray-scale images to binary images using edge detection techniques such as Sobel or Canny.

In everyday experience circular features are commonly sought in digital image processing. The problem of detecting circular features is very important for image analysis, in particular for industrial applications such as automatic inspection of manufactured products and components, aided vectorisation of drawings, target detection, mechanical parts[2], and particle trajectories[3,4] etc.

Object detection and recognition in noisy and cluttered images is a challenging problem in computer vision. First, the target object is obscured due to the presence of the other object which can interfere with recognition process. Second, some of the objects are overlapping between each other that make the recognition process challenging. Third, the various object positions and finally, the images themselves contain noise that make the recognition process difficult without proper preprocessing and segmentation process. This paper gives a detailed approach towards detection and measurement of circles. Sobel Edge detection Algorithm is used.

Due to its complexity, there are failures of objects that occur in each production process. The failure of an object is found from the defect of an object which cannot be repaired and thus wastes the production cost. The Failure Analysis (FA) is to identify the failure of a defect on media and classify the pattern of defect. The FA helps technicians to access problems rapidly, which decreases the waste and the production cost. The goal of this research is to identify circular objects in an image and find its diameter. There are several problems in detecting and recognizing the circles from the image.

## II. RELATED WORK

The detection of circular and elliptic shapes is a common task in computer vision and image recognition. Some methods rely on converting gray-scale images to binary ones using edge detection techniques and calculating numerical shape descriptors. Simple shape descriptors are sorted out in [8]. One of them, known as elliptic variance, is especially useful for detecting ellipses. Rosin proposed other descriptors (moment invariants, Euclidean distances) that can be adapted to measure the ellipticity of shapes [5].

To present a direct method for fitting ellipses to a set of points in the least-squares sense. Their method is exploited in the segmentation algorithm presented in this work. Previous methods used a generic conic fitting or an iterative approach to recover elliptic solutions. A variety of 'fit-to-data' functions were discussed [6]. Low level edge detection operators do not guarantee continuous boundaries of objects. This makes many image analysis tasks difficult, especially for noisy images. The aim of contour grouping algorithms is to connect edges that are supposed to be sub-parts of the same object. Contour grouping techniques were concentrated mainly on detecting salient curves [7].

Their basic idea is to reshape an initial curve provided by any rough segmentation technique, subject to constraints from a given image. Initially, the current curve is set to the initial one. [2] Showed that active contours can also be employed for tracking moving objects. The energy function calculates the difference between object features and background features, so it is useful for removing smears.

A commonly faced problem in computer vision is determining the location, number or orientation of a particular object in an image. One problem could, for instance, be to determine the straight roads. This problem can be solved using Hough transform for lines. Often the objects of interest have other shapes than lines, it could be parabolas, circles or ellipses or any other arbitrary shape. The general Hough transform can be used on any kind of shape, although the complexity of the transformation increases with the number of parameters needed to describe the shape.

## III. IMAGE TRANSFORMATION

The image can be colour or gray. The colour image of an object is taken as input. The dimension of an image is an important aspect to reduce the memory consumption and decrease the time requirement for further calculations. The required dimension for high result is 365 x 352. Here we are taking an image of size 365 x 352. After the size transformation, the image is further passed to gray scale conversion.

### Grayscale conversion:

As we are using openCV-python, we also need Numpy package installed in python, as it supports high performance multi-dimensional array object.

The steps required to convert a colour image into gray scale image are given below.

1. Import the cv2 module, which will make available the functionalities needed to read the original image and to convert it to gray scale.
2. Receive the original image.  
To read the original image, simply call the imread function of the cv2 module, passing as input the path to the image, as a string.
3. Receive the colour space conversion code.  
We need to convert the image to gray scale. To do it, we need to call the cvtColor function, which allows converting the image from a color space to another.
4. Convert the original image from the RGB colour space to gray, code: COLOR\_BGR2GRAY.
5. Now, to display the images, we simply need to call the imshow function of the cv2 module. This function receives as first input a string with the name to assign to the window, and as second argument the image to show.



Fig1

Fig1. The original image of an Industrial object.



Fig2

Fig2. The image after grayscale Conversion.

#### IV. CIRCLE EDGE DETECTION

Circular edge detection is used to find the curves, lines of an object. It has certain advantages such as

1. Reduces unnecessary information in an image while preserving the structure of image.
2. Extract important features of image like curves, corners and lines.
3. Recognizes objects, boundaries and segmentation.
4. Plays a major role in computer vision and recognition

These features are used by higher-level computer vision algorithms (e.g., recognition). There mainly exists several edge detection methods (Sobel [9,10], Prewitt [11], Roberts [12], Canny [12]). These methods have been proposed for detecting transitions in images.

We will use sobel detection algorithm for detecting the edges in the circle.

The formula shows how a particular pixel in the output image would be calculated.

The Sobel operator

performs a 2-D spatial gradient measurement on images. It uses a pair of horizontal and vertical gradient matrices whose dimensions are 3x3 for edge detection operations. The gradient approximation which it produces is relatively crude, in particular for high frequency variations in the image.

The gradient magnitude is given by

$$|G| = \sqrt{G_x^2 + G_y^2}$$

Although typically, an approximate magnitude is computed using:

$$|G| = |G_x| + |G_y|$$

The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by:

$$\theta = \arctan\left(\frac{G_y}{G_x}\right) - \frac{3\pi}{4}$$

In this case, orientation 1 is taken to mean that the direction of maximum contrast from black to white runs from left to right on the image, and other angles are measured anticlockwise from this.

#### PSEUDO-CODE FOR SOBEL EDGE DETECTION

**Input:** A Sample Real Image.

**Output:** Detected Edges.

**Steps:**

- Step 1: Accept the input image.
- Step 2: Apply mask G<sub>x</sub>,G<sub>y</sub> to the input image.
- Step 3: Apply Sobel edge detection algorithm and the Gradient.
- Step 4: Manipulation of G<sub>x</sub>,G<sub>y</sub> separately on the Input image.
- Step 5: Results combined to find the absolute magnitude of the gradient.
- Step 6: The absolute magnitude is the output edges.

#### V. CONTOUR EXTRACTION

Contour tracing is a technique that is applied to digital images in order to extract their boundary. Contour tracing is one of many pre-processing techniques performed on digital images in order to extract information about their general shape.

The first two, namely the Square Tracing Algorithm and Moore-Neighbour Tracing are easy to implement and are therefore used frequently to trace the contour of a given pattern. Unfortunately, both of these algorithms have a number of weaknesses which cause them to fail in tracing the contour of a large class of patterns due to their special kind of connectivity.

The following algorithms will ignore any "holes" present in the pattern. For example, if we're given a pattern like that of Figure 3 below, the contour traced by the algorithms will be similar to the one shown in Figure 4 (the blue pixels represent the contour). This could be acceptable in some applications but in other applications, like character recognition, we would want to trace the interior of the pattern as well in order to capture any holes which identify a certain character. (Figure 5 below shows the "complete" contour of the pattern) As a result, a "hole searching" algorithm should be used to first extract the holes in a given pattern and then apply a contour tracing algorithm on each hole in order to extract the complete contour.

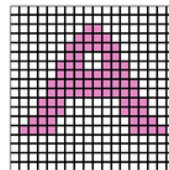


Fig 3

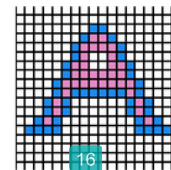


Fig 4

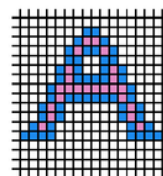


Fig 5

We can refer the two values for ease of implementation as 1, in which case we will consider it a "black" pixel and it will be part of the pattern,

0, in which case we will consider it a "white" pixel and it will be part of the background.

A black pixel is considered a 4-border pixel if it shares an edge with at least one white pixel. On the other hand, a black pixel is considered an 8-border pixel if it shares an edge or a vertex with at least one white pixel. (A 4-border pixel is also an 8-border pixel. An 8-border pixel may or may not be a 4-border pixel.)

## VI. CIRCULAR HOUGH TRANSFORM

1

The construction of real circle detection algorithm is one of the most challenging tasks because images are sensitive to noise and other complexities involved in processing. Various algorithms were proposed in this domain but Circular Hough Transform (CHT) has long been recognized as robust techniques for circle detection. The circle is actually simpler to represent in parameter space. The circle equation is

$$r^2 = (x-a)^2 + (y-b)^2 \quad (1)$$

As it can be seen the circle got three parameters a, b and r.

Centre of the circle in x and y direction is given by a, b and r is the radius. Circle parametric representation is given by

$$x = a + r \cos(\theta) \quad (2)$$

$$y = b + r \sin(\theta) \quad (3)$$

Thus the parametric space for a circle will belong to R. As the number of parameters needed to describe the shape increases as well as the dimensions of the parameter space R increases so do the complexity of the Hough Transform. So with the Circle Hough Transform, we expect to find triplets of (x, y, R) that are highly probably circles in the image. First find out the edges using Canny edge detection algorithm. For each edge point, draw a circle assuming that edge point as centre with the desired radius 1

The 'a' value is the x-axis, 'b' value is the y-axis while the z-axis is the radii in the parameter space of the circle drawn. At the coordinates which belong to the perimeter of the drawn circle we increment the value in accumulator matrix which essentially has the same size as the parameter space. In this way for each edge point in the input image drawing circles with the desired radii and incrementing the values in our accumulator. When completed with every edge point and every desired radius, turn attention to the accumulator. The numbers in the accumulator will represent the number of circles passing through the individual coordinates. Thus the highest numbers are taken into consideration.

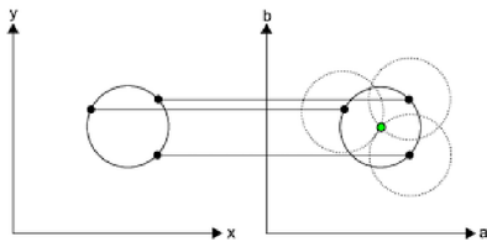


Fig6. Circular Hough Transform concept

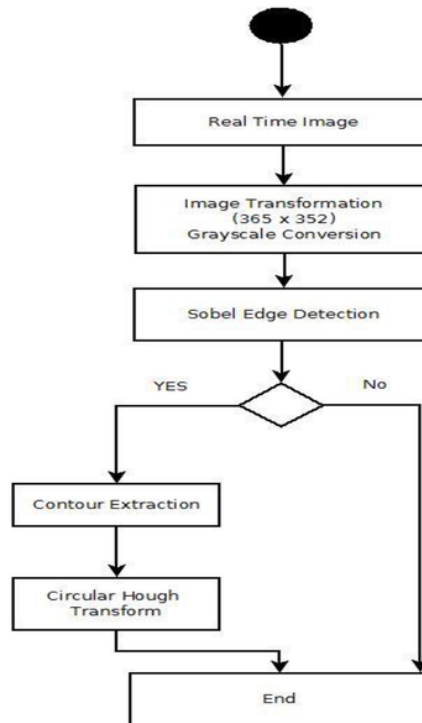


Fig7. Activity Flow of CHT

### Implementation:

So, the flow of events is something like this:

1. Load an image
2. Detect edges and generate a binary image
3. For every 'edge' pixel, generate a circle in the ab space
4. For every point on the circle in the ab space, cast 'votes' in the accumulator cells
5. The cells with greater number of votes are the centres



Fig8

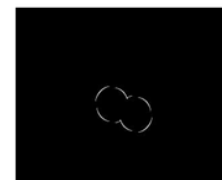


Fig9



Fig10



Fig11

Fig8 shows an image of detect edges.

Fig9 shows sobel operator generated image.

Fig10 shows for every white pixel in the above image, a circle is created in the ab-space.

The horizontal axis is the 'a' axis, the vertical axis is the 'b' axis. The brighter a spot, more the number of votes cast at the point. And more votes imply a greater probability of a point being centres. The above image, you can see the centres clearly. And these points can be easily extracted.

Fig11 shows three random points were chosen. Circles of radius  $r$  are drawn around them (the red, blue and green circles). And then, votes are cast at the pixels of these circles. Note that the technique worked even though the entire circle's perimeter was not visible. The two circles overlapped, and yet they were detected as separate circles.

When the radius is not known, the simplest solution is to just guess. Assume  $r = 1$ , and then run the same algorithm. Then assume  $r = 2$ , and run it again.

Assume  $r = 3$  and so on.

A safe limit would be the length of the diagonal of the image. No possible circle on the image can have a radius greater than or equal to the diagonal.

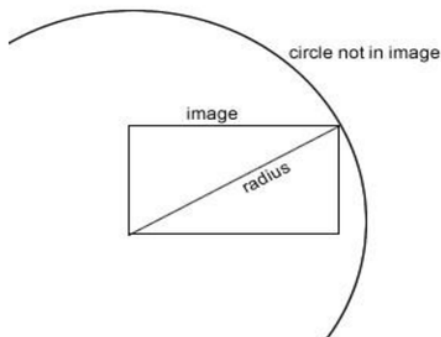


Fig12. Radius assumption for measurement of circle

So, you'll end up with a 3D parameter space. Each horizontal plane would be equivalent to a 2D parameter space where  $R$  is known.

By evaluating the centre of circle, measurement can be easily calculated by measuring the distance from centre to edge point.

The main drawback of Hough Transform is long computation times and large data storage requirement. A lot of research is going on and have been done to solve the mentioned drawbacks. These efforts range from software algorithmic changes like voting acceleration to hardware implementations like passing by parallel computing, and memory reduction. The Field Programmable Gate Array is among the most common hardware accelerators which is used in real-time implementations of the HT which an alternate solution for hardware acceleration to give tremendous computing performance.

## VI. CONCLUSION

In this paper we have proposed Circular Hough Transform to detect the circles in an object and also found an approach to measure the diameter of a circle. We also proposed to detect the edges by Sobel Detection method of a circular object for high accuracy. Circular Hough Transformation algorithm can be used along with the existing algorithms or concept can be applied in developing new algorithm. Future research domain include the areas such as algorithm optimization, reduction in complexity of algorithm, accurate circle detection etc.

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