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Circle Extraction Techniques-A Survey for Hole Diameter Measurement of Mechanical Components

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Abstract*— In Manufacturing industry before doing the assembly, all components needs to qualify for their dimension accuracy. Quality Control (QC) team performs this rigorous and time consuming task of manual inspection. For most of the components hole is basic engineering primitive and measuring the hole diameter is the main tasks as this insure the proper fitment of that component in the assembly. Currently this qualification of the hole diameter is done by QC team manually using different measurement gauges, this is tedious task and took the lots of man power. In this paper, the main aim is to survey the theory of edge detection and circle extraction technique for hole diameter measurement. This survey helps to solve this practical industrial problem and help the QC team to reduce their work load and improve their efficiency and accuracy.

***Keywords*— Edge detection, Circle Extraction, Fuzzy based approach, Hough Transform, R**

I. INTRODUCTION

Industrial application of image processing involves the detection of standard engineering shapes. Success rate of the shape detection depends on how well the edges get detected in image. Edge detection is very useful in a number of contexts. Edge detection find out object boundaries and therefore useful for segmentation, registration and identification of objects in surround scenes. The output of edge detection should be an edge image, in which the value of each pixel reflects how strong the corresponding pixels in the original image meet the requirement of being an edge pixel. This edge image is use for circle detection in digital image processing. Circle plays very important role in image analysis for industrial application such as automatic inspection of manufactured products and components, aided vectorization of drawing, target detection. Mmanufacturing industry manufactures various types of components which gets assembled in different assemblies which serves some function of human need. Circular hole is the basic shape of any mechanical component. So the correct measurement of this hole diameter is necessary. Manual hole diameter measurement of single hole is easy task but multiple holes diameter measurement that too for large number of component is tedious or even not particle sometime. When this task was done manually, it requires more time and manpower. Automated process of circle identification using image processing solve this problem. There are number of edge detection techniques and circle extraction techniques are available each with some advantages or disadvantages. To optimise the computational time required for circle detection proper choice has to be made among different available circle extraction techniques.

This paper is organized as follows. Section II is for the purpose of providing some information about edge detection for Image Segmentation. Section III is focused on showing the different circle extraction technique for hole diameter measurement and also focused on comparison of various circle extraction technique. Section IV presents the conclusion.

II. EDGE DETECTION TECHNIQUE

A. Edge Detection Technique

In edge detection is the process of identifying and locating sharp discontinuities in an image. The discontinuities are changes in pixels intensity which identify boundaries of objects in scene.

Discontinuities can be classified as:

1) Gradient discontinuity[1]

Here the gradient of the pixel value changes across a line

- Roof edges
- Ramp edges
- Step Edge
- Line edge

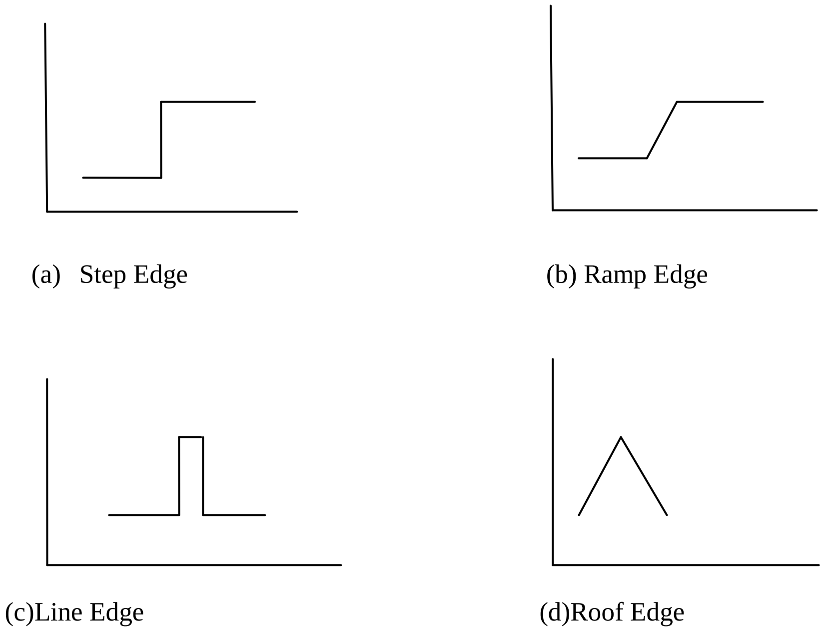

Fig.1. Type of Edges (a) Step Edge (b) Ramp Edge (c) Line Edge (d) Roof Edge

An Edge in an image is a significant local change in the image intensity, usually associated with a discontinuity in either the image intensity or the first derivative of the image intensity. Discontinuities in the image intensity can be either Step edge, where the image intensity abruptly changes from one value on one side of the discontinuity to a different value on the opposite side, or Line Edges, where the image intensity abruptly changes value but then returns to the starting value within some short distance[3]. However, Step and Line edges are rare in real images. Because of low frequency components or the smoothing introduced by most sensing devices, sharp discontinuities rarely exist in real signals. Step edges become Ramp Edges and Line Edges become Roof edges, where intensity changes are not instantaneous but occur over a finite distance. Illustrations of these edge shapes are shown in Fig.1.

2) Jump or Step discontinuity

Here pixel values change suddenly across some line. The step edge defines a perfect transition from one segment to another.

3) Bar Discontinuity

Here pixel values rapidly increase then decrease again across some line

B. **Steps in Edge Detection**

1) Filtering: Images are often corrupted by random variations in intensity values, called noise. Some common types of noise are salt and pepper noise, impulse noise and Gaussian noise. Salt and pepper noise contains random occurrences of both black and white intensity values. However, there is a trade-off between edge strength and noise reduction. More filtering to reduce noise results in a loss of edge strength[3].

2) Enhancement: In order to facilitate the detection of edges, it is essential to determine changes in intensity in the neighborhood of a point. Enhancement emphasizes pixels where there is a significant change in local intensity values and is usually performed by computing the gradient magnitude[1].

3) Detection: Many points in an image have a nonzero value for the gradient, and not all of these points are edges for a particular application. Therefore, some method should be used to determine which points are edge points. Frequently, thresholding provides the criterion used for detection[1].

C. **Edge Detection Methods**

A huge number of methods are available in the literature to segment images . This task is hard and very important, since the output of an image segmentation algorithm can be fed as input to higher-level processing tasks, such as model-based object recognition systems.

1) **Classical Edge detectors Approach**

a) The Roberts Detection

The Roberts Cross operator is simple and quick to compute, 2-D spatial gradient measurement on an image. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point. The operator consists of a pair of 2×2 convolution kernels as shown in Fig . One kernel is simply the other rotated by 90°[1].

+1	0
0	-1

Gx

0	+1
-1	0

Gy

Fig 2 Masks used for Robert operator.

These kernels are designed to respond maximally to edges running at 45° to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these Gx and Gy). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient .

b) Prewitt's operator

Prewitt operator is same as sobel operator and is used for detecting vertical and horizontal edges in images.

-1	0	+1
-1	0	+1
-1	0	+1

Gx

+1	+1	+1
0	0	0
-1	-1	-1

Gy

Fig 3: Masks for the Prewitt gradient edge detector

- Advantages

  It is simple to implement and for detection of edges and their orientations.

- Disadvantages

It is more sensitivity to noise and sometimes give inaccurate result

c) Sobel Operator

The operator consists of a pair of 3×3 convolution kernels as shown in Fig. Kernel is simply the other rotated by 90°.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Fig4 Masks used by Sobel Operator

These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these Gx and Gy). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient

d) The Laplacian of Gaussian method

e) The Laplacian of Gaussian method of highlights regions of image with rapid intensity change . The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian Smoothing filter in order to reduce its sensitivity to noise. The operator normally takes a single gray level image as input and produces another gray level image as output [1].

The commonly used small kernels are shown in Fig

1	1	1
1	-8	1
1	1	1

Gx

1	2	-1
2	-4	2
-1	2	-1

Gy

Fig 5. Discrete approximations to the Laplacian filter.

Because these kernels are approximating a second derivative measurement on the image, they are very sensitive to noise. So that the image is often Gaussian Smoothed before applying the Laplacian filter. This pre-processing step reduces the high frequency noise components before to the differentiation step.

- Advantages

Finding the correct places of edges and testing wider area around the pixel.

- Disadvantages

Malfunctioning at the corners, curves and where the gray level intensity function varies.

Not finding the orientation of edge because of using the Laplacian filter.

2) Soft Computing Approaches

Three different soft computing approaches to edge detection for image segmentation are most frequently used. These are as follows

a) Fuzzy based Approach[1]

There are different possibilities for development of fuzzy logic based edge detections. One method is to define a membership function indicating the degree of edginess in each neighbourhood. This approach can only be regarded as a true fuzzy approach if fuzzy concepts are additionally used to modify the membership values . The membership function is determined heuristically. It is fast but the performance is limited.

b) Genetic Algorithm based approach[3] .

Basically, a genetic algorithm consists of three major operations: selection, crossover, and mutation. The selection evaluates each individual and keeps only the fittest ones in the population. In addition to those fittest individuals, some less fit ones could be selected according to a small probability. The others are removed from the current population. The crossover recombines two individuals to have new ones which might be better. The mutation operator induces changes in a small number of chromosomes units. Its purpose is to maintain the population diversified enough during the optimization process.

III. CIRCLE EXTRACTION TECHNIQUE

A .Circle Extraction technique

Extracting circles from images has received much attention for several decades because an extracted circle can be used to find the location of circular object in industrial application. Fast and accurate detection of circles is important in the field of image processing and computer vision. Many circle-extraction methods have been developed. The brief discussions of this technique are as follows.

1) Hough Transform(HT)
2) Randomized Hough Transform(RHT)
3) Randomized Circle Detection(RCD)
4) Least square technique
5) Kalman Filter

1) Hough Transform (HT)

It is one of the best known algorithms. It transform a circle into histogram with three parameter(x, y and r) where x and y are coordinate of the circle and r is the radius. HT has a basic method to detect circle, has its advantages in insensitivity to noise in images and easiness in parallel computing.HT has advantages of small storage and high speed if the parameter space is limited to two dimensions. But it is not useful in three dimensions and so that it not applicable due to the sharp increase of computing time and storage[5].

2) Randomized Hough Transform (RHT)

The Randomized Hough Transform (RHT) in which computing time and storage requirements are reduced by random sampling in the edge image and establishing a link-list data structure for the parameters. In the RHT, three points are firstly picked randomly in the edge image to determine a circle and then judge whether its parameters are approximately equal to some parameters in the link-list. If no qualified parameters are found in the link-list, a new unit for the parameter, a new unit for the parameters will be defined and appropriately inserted into the link-list; otherwise, the score of the qualified parameters will be increased by one. If the resultant score is not smaller than a given threshold value, then a candidate circle is found and will be further affirmed for a true circle by evidence-collecting process. Excellent performance of RHT can be showed in simple image detection, but when it is apply on multicircle complex images it will demand a huge amount of computation and storage[4].

To solve this problem new method is invented called as randomised circle detection (RCD)

3) Randomised Circle Detection (RCD)

Randomised circle detection method is used to avoid the massive memory and computing time requirements caused by parameter accumulation. In RCD, four points are randomly picked from the edge image and the parameters of a circle can be calculated by any three points. If the fourth point is also on the circle, then the circle is declared as a true circle.

Here use of the multiple-evidence-based sampling strategy and refinement strategy to improve both the execution-time performance and the detection accuracy for RCD, but the robustness of the detection was also affected as a result of the gradient information use[4].

4) Least square technique

The least squares technique is based on adapting an earlier method developed for ellipse extraction which has been modified not only for circle estimation but also to reduce sensitivity in parameter estimation[6].

5) Kalman filter

Kalman filter algorithm is an extended version arranged to estimate the circle's parameters. A Kalman filter formulation required extension to handle the measurement nonlinearity and can be used to estimate circle parameters in a point-iterative manner[6].

B. Comparison of existing system

Comparison of curve fitting technique:

The comparisons are done on the basis of experiment was taken. The original image with 1034 points with seven circles .In order to test the robustness add noise to the image from 30% to 210%.The time requires for Randomized Hough Transform and Randomized Circle Detection algorithm are as follows.

Table 1: Time Performance Comparison [7]

Noise ratio%	RHT/s	RCD/s
0	0.0050	0.0056
30	0.0337	0.0591
60	0.3241	0.3178
90	1.1159	1.1791
120	2.9181	3.9959
150	11.1306	9.7959
180	27.0338	17.2028
210	49.7949	34.2179

For the first experiment the synthetic image is created by adding noise to a 256×256 original image. The original synthetic image with 1 034 points, which consists of seven circles with different radii. In order to test the robustness, randomly add different levels of noise to the original image. Here, the levels range from 30% (310 noises) to 210% (2 171 noises). The resulting images with 1241 and 2 171 noise. The execution time required in each algorithm is obtained from the average of 50 simulations and illustrated in table 1. These two algorithms can correctly detect the seven circles

IV. CONCLUSION

The purpose of this paper is to present a survey of various approaches of edge detection and circle extraction technique for hole diameter measurement. In future, we plan to design a novel approach for edge detection and Circle extraction for measurement of hole diameter .

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