



Review of two dimension geometric shape detection methods

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Abstract—Geometric shapes and geometric features are indeed involved in a wide variety of digital images. Much of these features carry within itself useful information that can be exploited for a broad range of real-world applications. Circle, rectangle and triangle features found in man-made environment frequently. Most approach developed for regular geometric shapes are based on synthetic images. Basically geometric shape detection methods broadly classified in three groups- based on Hough transform, detection by intelligent methods and detection by geometric property. A review of some geometric shape detection methods are collected and presented here.

Key words: geometric shape detection, Hough transform, intelligent methods, review of methods.

I. INTRODUCTION

Digital images generally contain repeating features or patterns that can be translated into meaningful data. This led to the development of a field in image processing known as feature extraction. Simple features that can be detected are like edges, blobs, corners, lines, curvatures and ridges. More complex algorithms are there to extract shapes such as rectangles, triangles and circles. Extracted dataset is transformed into a meaningful real-world application or sent for further processing. A review of some geometric shape detection methods are collected and presented here. Most approach developed for regular geometric shapes are based on synthetic images. Basically geometric shape detection methods broadly classified in three groups- based on Hough transform, detection by intelligent methods and detection by geometric property.

II. APPLICATIONS

In order to create a robust regular shape detection system, it is important to have a broad understanding of how a certain feature detection technique can be applied in real-world scenarios. In the field of pattern recognition, circle and ellipse detection has been studied and applied in various areas rather than other basic shapes, such as in manufacturing industries, in astronomical studies[32], and medical images processing in the past decades. Rectangular shape detection has more applications in aerial image analysis such as vehicle detection and building detection. Some examples of previously found geometric shape detection applications are listed as follow:

- Surveillance and Monitoring- In transportation department and for security reasons license plate detection [1], vehicle detection [31] is most primary requirement. Rectangle fitting is most general approach for these two applications. Road sign detection [25] methods use the circle, rectangle and triangle [29, 30] shape recognition.
- Spatial Surveying - Man-made buildings on earth [31] are application of rectangle detection from aerial image. Various circular features, such as impact craters, volcanoes, geological domes, and man-made structures/symbols, are found in terrestrial images [32].

- Agricultural Application - Aside from size measurement and comparison, mango fruit [25, 33] segmentation include circle and ellipse detection with color information of fruit.
- Automatic inspection and assembly[5]
- Biological objects are usually circular which requires circle detection[23]
- Human exercises: some human exercise i.e. soccer ball [9,10,22], Vehicle tire detection[15,18,20], Street ball detection [18,19], video inspection, requires geometric shape detection.
- Industrial applications: PhC microscopy [23], pattern recognition, machine vision [12], automatic inspection and assembly [17,40], automatic inspection of manufactured products and components, target detection [11,41], Robotics vision and modeling objects in scenes [41].

III. GEOMETRIC SHAPE DETECTION ALGORITHMS

One of the challenges of automated digital image analysis is shape detection, which is an important part of object recognition. Unfortunately, direct searching and detection of a class of even simple geometric patterns like straight lines, circles and ellipses in an image are very computation intensive. Geometric shape detection algorithms developed till date can mainly be categorized based on their architecture into three groups.

a. *Hough transform*

Since Duda and Hart extended original Hough transform [4] for arbitrary curves in synthetic images, it is used widely for line, circle, and rectangle detection. However, high computational cost and high memory requirement does not allow this method applicable for real time application. This cost and memory requirement becomes more when dimension of search space is high. The time complexity grows exponentially with the number of parameters used to characterize the shape. For circles this gives rise to a complexity of $O(n^3)$. For ellipse, the complexity, in general, is of $O(n^5)$. Consequently, in many simple real time applications this method often turns out to be far from practical [5]. To use the concept of HT while limiting its requirement of memory demand to low extent some new transformative were proposed. In RHT [24], edge pixels are randomly sampled and mapped into one point, which reduces the storage requirement and the computing time. However, RHT accumulates in the parameter space, which results comparatively large computation and memory.

Moreover, the accuracy of the detection results is directly related with the level of the parameter space quantized. For this reason, circles are hardly located well in an image. Chen proposed the randomized circle detection (RCD) [14]. Typical Hough-based approach employs an edge detector and uses edge information to infer locations and radii values. Peak detection is then performed by averaging, filtering and by histogram within the transform space. However, such approach to detect circle requires a large storage space as the 3-D cells include parameters (x, y, r) , augmenting the computational complexity and yielding a low processing speed. (x, y) are the center coordinates and r is radius of circle of edge image.

For rectangle even more 5 parameters - center location (two parameters), length, width and orientation required to extract arbitrary located rectangular objects. The accuracy of the extracted parameters for the detected- circle and rectangle is poor, particularly in presence of noise [11].

Different from RHT, RCD detects the potential circles by making use of hypothesis-verification algorithm. The efficiency and accuracy of the detection results are enhanced compared with RHT for it does not need an accumulator in the parameter space. However, sampling for RCD randomly happens on all edge pixels of the whole image, and verification of the hypothetical circles also uses all the edge pixels, which both occupy a mass of time. To solve these problems, a fast randomized circle detection algorithm is proposed in the paper [3].

The main concept used in the proposed RCD is that first randomly select four edge pixels in the image and define a distance criterion to determine whether there is a possible circle in the image; after finding a possible circle, we apply an evidence-collecting process to further determine whether the possible circle is a true circle or not[14]. Instead of using an accumulator for saving the information of the related parameters in the HT-based methods, the proposed RCD does not need an accumulator.

Every edge pixel in the image can be mapped into a conic surface in the 3-dimensional (3-D) (a, b, r) -parameter space.

Fast randomize method [3] is one more addition of methods to detect circle in image. Concept is first, the edge pixels with 8-adjacency connectivity are connected. Further, N edge pixels are randomly picked up in the same

connected curve which can exactly determine a possible circle with center and radius. The algorithm is faster than RCD for it samples only on the connected curve and also does not need evidence-collecting [3].

b. Detection by intelligent methods

Past few decades have seen a massive growth in the field of biologically inspired meta heuristics for search and optimization, Computational cost having been reduced almost dramatically; researchers from all corners are showing more interest in underlying principles of nature to solve nearly intractable optimization problems[9]. Alternative approaches for circle, triangle and rectangle shape detection include heuristic methods. For circle this is built over iterative optimization procedures which confine the search circle per optimization cycle yielding longer execution time [11].

In process of edge detection method by optimizing cost function starts with edge Image. Individuals for this evolution are computational representations of potential solutions for the problem to be solved. Genetic algorithm (GA), are used to optimize a fitness function by mimicking natural evolution for organisms. Each individual is represented as a binary string also known as a computational chromosome. The entire set of individuals examined at a time is called the population. This method detects only circle. Improved GA [16] is developed to detect plural shapes. Each chromosome represents plural kinds of shapes by interpreting each chromosome differently. This idea contributes to reduction of the number of chromosomes and to get better detection performance. Once a shape is detected, the shape is eliminated from the original image for efficient detection. Since the search space is high dimensional and very vast in general, initialization of chromosomes procedure exists in the method to give the chromosomes variety and for fast detection when the maximum fitness value does not change for a certain number of generations.

Bacterial foraging optimization for circle (BFOA) [9] tries to mimic the individual and grouped foraging behavior of *Escherichia coli*, a bacteria living in our intestines. The proposed algorithm is based on swarm intelligence technique, known as the bacterial foraging optimization (BFO) [9]. A new objective function has been derived to measure the resemblance of a candidate circle with an actual circle on the edge map of a given image based on the difference of their center locations and radii lengths. Guided by the values of this objective function (smaller means better), a set of encoded candidate circles are evolved using the BFO algorithm so that they can fit to the actual circles on the edge map of the image. The proposed method is able to detect single or multiple circles from a digital image through one shot of optimization.

Artificial Bee Colony Algorithm (ABC) works on same principle as BFOA and GA. Each individual bee here represents a trial circle and an objective function has been derived over domain of these trial circles. When the test circle represents a better approximation of the actual edge-circle, the value of the function becomes lesser. At last, minimizing the objective function using the ABC algorithm leads to fast and robust detection of circle in the given digital image. Another technique inspired by nature to detect circle is Artificial Immune system (AIS) [11]

AIS mimic the behavior of the natural immune system for solving complex optimization problems. The clonal selection algorithm (CSA) is arguably the most widely employed AIS approach. It is an effective search method which optimizes its response according to the relationship between patterns to be identified, i.e. antigens (Ags) and their feasible solutions also known as antibodies (Abs). The approach generates a fast sub-pixel detector which can effectively identify multiple circles in real images despite circular objects exhibiting a significant occluded portion.

Harmony Search Algorithm (HSA) introduced by Geem, Kim, and Loganathan [15] is one of the population-based evolutionary heuristics algorithms which are based on the metaphor of the improvisation process that occurs when a musician searches for a better state of harmony.

The approach is based on the Harmony Search Algorithm (HSA), a derivative free meta-heuristic optimization algorithm inspired by musicians improvising new harmonies while playing. The algorithm uses the encoding of three points as candidate circles (harmonies) over the edge-only image. An objective function evaluates (harmony quality) if such candidate circles are actually present in the edge image. Guided by the values of this objective function, the set of encoded candidate circles are evolved using the HSA so that they can fit into the actual circles on the edge map of the image (optimal harmony)

Neuro-fuzzy to detect triangle and rectangle [8] is presented by I. Z. Mihu and fella in 2003 to detect triangle and rectangle. This approach for geometric shape recognition uses a fuzzy classifier of angles and a multilayer neural

network for training and classifies the geometric shapes. Author states that this method examines the geometric shape as a whole in a way similar to human recognition process. The multilayer feed-forward neural network learns the internal angles of a triangle and rectangle and decides whether it is a triangle or rectangle. Figure 3 gives the idea behind this approach.

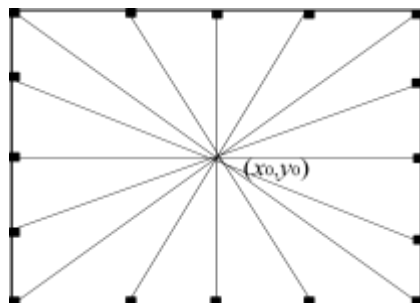


Figure 1 Extraction of sample points (black dots) to find internal angle of rectangle measured from center (x, y) of rectangle [8]

c. detection by geometric property

All geometric shape detection algorithms rely on the unique mathematical properties of that particular shape. For circle, we illustrated some of these properties using Figure 1.

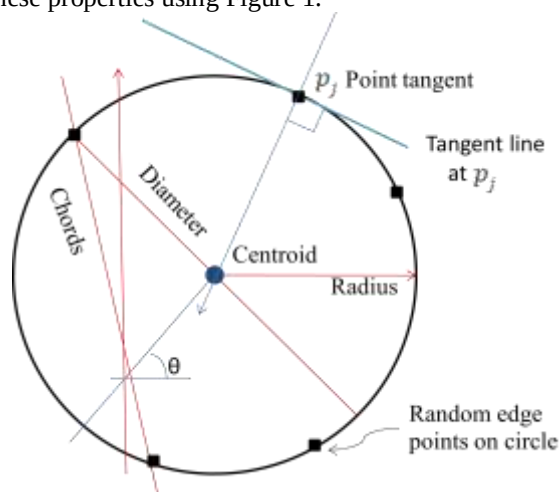


Figure 2 Figure highlight some useful parameter (red line) and geometric properties (blue colored) of circle

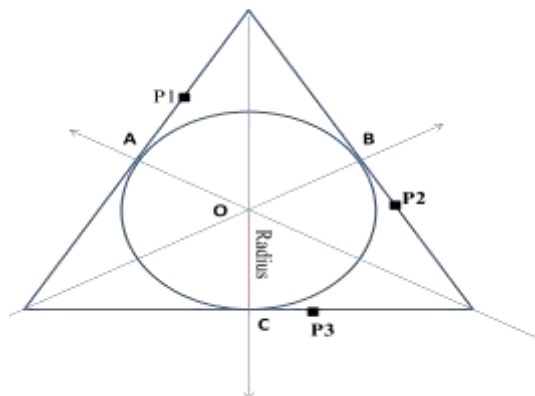


Figure 3 some useful parameters (edge point) and geometric properties (inscribed circle)

Some Method inspired by nature uses geometric property of shape to detect geometric shape. Ant System Algorithm [12] is one of them. This method build up on ant system which finds out closed loops in the image and then tests them for circles.

Method which directly uses the geometric property of circle is developed by some researchers in recent decade. Main concept of

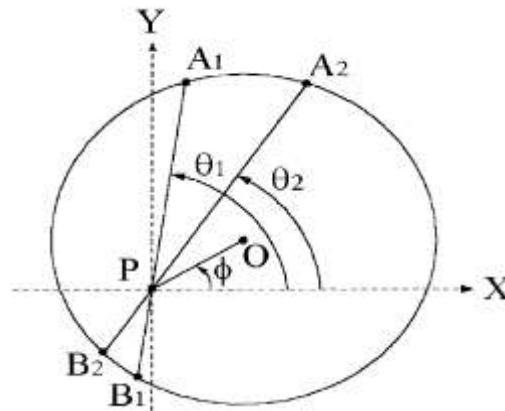


Figure 4 Figure represents two intersecting chords locates the center of circle

Circular Region Detection Algorithm based on the Geometric Characteristics [13] is find the two horizontal tangents (tangent d and f) and two vertical tangents (tangent a and c) of the round, then the radius of circle and the center of the circle can be determined. After the edge image and processing of vertical and horizontal scanning traversal, record the pixel number of the circular contour at the same time and store the information of the pixel number in the array.

According to the properties of pixels in digital images, in the location of the horizontal and vertical circular contour tangent, there will be a peak value of the pixel number inevitably. Another approach which uses geometric property to detect circle is a two-step circle detection algorithm [17], which uses pairs of chords. It is shown in figure 4 how a pair of two intersecting chords locates the center of the circle. Based on this idea, in the first step, a 2D Hough transform (HT) method is employed to find the centers of the circles in the image. In the second step, a 1D radius histogram is used to compute the radii. The proposed method does not use the edge direction information which is sensitive to noise.

IV. Conclusion

A review of some geometric shape detection methods are collected and presented here. Circle, rectangle and triangle features found in man-made environment frequently. Most approach developed for regular geometric shapes are based on synthetic images. Geometric shape detection methods based on Hough transform, based on intelligent approach and detection by geometric property reviewed. Initially hough transformed is proposed to detect geometric shapes.. Despite of its disadvantages of memory requirement, various alternates are researched by researchers after then. Many nature inspired techniques are proposed to optimize the results and accuracy in recent decade.

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