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Experimental Analysis of Boundary Approximation Models

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***Abstract*—** A human eye can differentiate between various objects by viewing at their shape, color and other features. To add this knowledge to the system we implement techniques for approximating boundary of a given object. The advantage of this boundary representation is that the compactness of the image is increased which helps in effective memory utilization. Boundary representation has various applications in the robotic vision system, in catastrophic collisions interpretation between geological tectonic plates, in performing various geometrical transformations, curve fitting, face recognition, detecting object in image and video, surface area calculation and many more. However, shape representation and description is a difficult task. Problem becomes more complex when shape or image is often corrupted with noise and other defects. Different boundary representation techniques are studied to understand boundary approximation of a given symmetric or non symmetric object. In this paper three selected methods-chain codes, signature method and splitting method have been implemented with different parametric variations and modifications for boundary approximation of a given symmetric or non symmetric object. The chain code of the surface boundary obtained has been compressed for effective memory utilization and time constraints. An important widely used boundary representation model called signature method has been experimentally analyzed for understanding the effect of boundary approximation with least number of reference points. A model has also been developed which uses the splitting method to approximate the boundary. This model has been modified to understand the effect of outcome on the number of selected reference points.

***Keywords*—** Canny edge detection; chain codes; dilation; erosion; morphology; signature method.

I. INTRODUCTION

Contour detection is an important area in image processing which deals with detecting various objects in an image. Contour can be defined as an outline or a boundary of an object. Contour detection along with different boundary representation techniques are studied to understand boundary approximation of a given symmetric or non symmetric object. Shape representation techniques can be broadly classified into two categories: (i) boundary based and (ii) region based shape representation techniques. In the boundary based techniques, objects are represented in terms of their external characteristics (boundary), while in region based technique, shape features are extracted from the whole shape region e.g. color, area. In comparison to region based shape representation, boundary based shape representation is generally more effective in cases where the objects have same color but different shapes. For example most plants have green or brown coloured leaves, but the leaves boundary shapes are different and thus they can be identified. Important boundary representation technique includes chain code, signature method and splitting method [1]. Chain codes are used to represent a boundary by a connected sequence of straight line segments of specified length and direction [2]. This representation is based on 4 or 8 connectivity of the segments The direction of each segment is coded by using a numbering scheme [3]. Fig.1 shows chain code representation where Fig.1(a) shows 8 direction numbering scheme and 076666553321212 is the derived chain code for Fig.1(b) with topmost left pixel is taken as starting pixel. Signature method is used to convert a two dimensional boundary into a representative one dimensional function. Here distance between centroid and boundary is calculated in terms of angle θ. In the splitting method initially two pixels that are at farthest distance from centroid are found. A line is drawn between these two pixels. Further, the threshold is defined. If the distance exceeds the defined threshold then divide the boundary segment into two parts. This procedure is followed recursively till the threshold condition fails [4]. The disadvantage of this method is that this procedure calculates all the distances and compares the maximum perpendicular distance with the threshold at each iteration which makes the system complex.

The main objective of this research work is to study and understand different techniques for boundary approximation of a given symmetric or non symmetric object. For this, the experimental work has been divided into three parts. Initially, different boundary approximation techniques have been studied and analyzed. Three selected methods:-chain codes, signature method and splitting method have been implemented with different parametric variations and modifications for boundary approximation of a given symmetric or non symmetric object. The chain code of the surface boundary obtained has been compressed for effective memory utilization and time constraints. Secondly, an important widely used boundary representation model called signature method has been experimentally analyzed for understanding the effect of boundary approximation with least number of reference points. Thirdly, a framework has been developed which uses the splitting method to approximate the boundary. This model has been modified to understand the effect of outcome on the number of selected reference points.

The rest of the paper is organized as follows: Section II addresses the details of different algorithms and techniques for

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approximating boundary. Section III presents the details of the proposed system. Section IV presents the experimental results and discussion of our proposed approach. Finally, in section V conclusions are drawn.

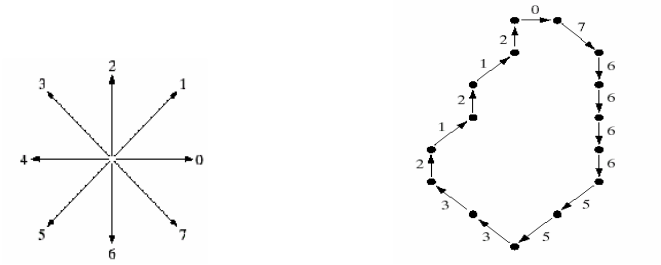

Fig. 1. Chain code representation (a) 8 direction numbering representation (b) generation of chain code.

II. LITERATURE REVIEW

Based on various boundary representation techniques, several approaches have been proposed for shape recognition. Broadly shapes can be classified as contour based technique and region based technique. Contour based technique includes chain code, signature method, splitting method and perimeter based, whereas region based technique my include area based, convex hull and geometric moments [5-6]. Features like color, area and perimeter for an object are calculated by various approaches [7-8]. In another work [9] initially the corners of the leaf are detected by 'Harris corner detection' method and the convex hull is determined by joining these corner points. The leaves are distinguished by finding out the difference between their internal angles at each control point. In another approach author [10] has proposed a two step approach of using a shape characterization function called centroid-contour distance curve and the object eccentricity for leaf image retrieval. Chain code technique is used to perform recognition for different types of fonts used in car plates [11]. Chain code can also be used to detect object in an image and video [12]. Chain code is translation invariant but can also be made rotation and scaling invariant. The author [13] has presented an algorithm to match the chain codes of two shapes after finding out scaling factor and rotation factor for two images, making chain code rotation and scaling invariant. In another application chain code is used for face recognition [14]. Chain code is used by the author for character recognition and then appropriate string matching look ahead branch and bound scheme is used to prune path which will make the approximation more accurate and efficient [15].

III. PROPOSED METHODOLOGY

The proposed methodology has been shown in Fig. 2. The framework consists of five phases- image acquisition, preprocessing and edge detection, boundary thickening, boundary representation algorithm, approximation and evaluation.

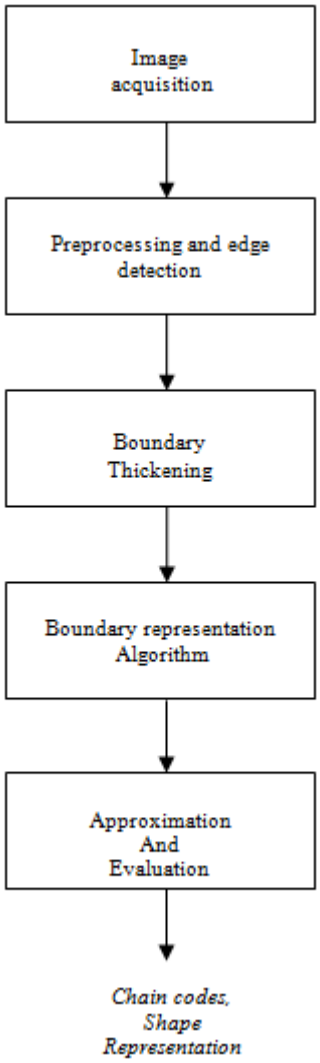

Fig. 2. Methodology of the proposed work.

Preprocessing involves enhancements of features that are important for further processing and to suppress information that is not relevant to the specific task . This phase involves the transformation from coloured image to gray scale so that suitable edge detection technique can be applied. The purpose of edge detection is to significantly reduce the amount of data in it, while preserving the structural properties to be used for further image processing. Here canny edge detection technique is used in this paper to detect the edge of an object. After applying edge detection method complexity of the image is reduced because we have only edges, so we get the shape of the boundary and rest of the pixels are discarded. Canny edge detection smoothes the image with a guassian filter to reduce noise and unwanted details [16-17]. Smoothed image is then filtered with a sobel kernel to get first derivative in both horizontal and vertical direction [18]. From these, we can find edge gradient and then edges are found by local maximum of the gradient of image. This edge detection uses two thresholds to detect strong and weak edges and includes the weak edges in the output only if they are connected to strong edges, so this

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technique is more likely to detect true weak edges. The requirement for boundary representation technique to be applied is that edges produced should be continuous but the problem with edge detection is that edges produced are not continuous. To make edges continuous, thickening algorithm is applied, where various morphological operations like dilation, erosion etc are used, the result of which is continuous boundary which is one pixel or at most two pixels thick [19-20]. In this proposed system three boundary representation techniques are used:- chain codes, signature method and modified splitting method one by one with different parametric variations and modifications for boundary approximation of a given symmetric or non symmetric object. In modified splitting method, let m be the count of the number of pixels with which the user wants to represent the boundary. Store all the boundary pixels in some set C and let its count be equal to n and then record the first element of the set C at index1in final set D. Count value is monitored and if it is more than one, then add n/2 pixel value at index 2 of set D and if the count value is more than two, then divide the set C into two subsets E and F Then start selecting pixel of position n/2 from each subset E and F recursively till its count becomes equal to m. In last, all the coordinate values of final set D are connected by using straight line segments. In the evaluation and approximation phase three different techniques have been analyzed with different parametric variations and modifications. Signature method has been experimentally analyzed for understanding the effect of boundary approximation with least number of reference points and the splitting method has been modified to understand the effect of outcome on the number of selected reference points.

IV. Results and Discussion

In this research work, three different boundary representation techniques:- chain codes, signature method and splitting method are tested on more than 50 images of symmetric regular shapes and non symmetric shapes like leaves [21] and characters. Chain code method is implemented on different leaves, shapes and characters. Fig 3 shows the GUI interface developed for chain code generation. Here Fig.4 shows generation of chain code. Fig. 4(b) is the transformed image for the corresponding input Fig. 4(a). The derived chain code is applied on the transformed image (Fig.4(c)). This is represented here in form of x:y implying x occurrences in y times continuation. This type of representation has compressed the size of chain code data. Fig. 4(d) is the regenerated image derived from the chain code. This shows that this representation is reversible. The results indicate that chain code works well for different leaves, regular shapes and characters (Fig. 4).

The advantage of signature method is that it can predict different shapes by viewing the shape of the graph. An interface has been developed for signature method (Fig.5). Fig. 6 shows relationship between the distance of boundary pixel from centroid and corresponding angle at n, n/2 and n/4 where Fig. 6(b), (c) and (d) are the graphs generated for n, n/2 and n/4 pixels respectively for the input Fig 6(a). The results show that in addition to n pixels, this method even works quite well for n/2 pixels which will further reduce the space complexity. For n/4 pixels, the graph does not give sufficient information. Moreover, the image quality is degraded when it is generated from these n/4 pixels. This method is reversible for n pixels. Further it can be concluded that this method works well for leaves and shapes but no useful information is extracted in case of characters.

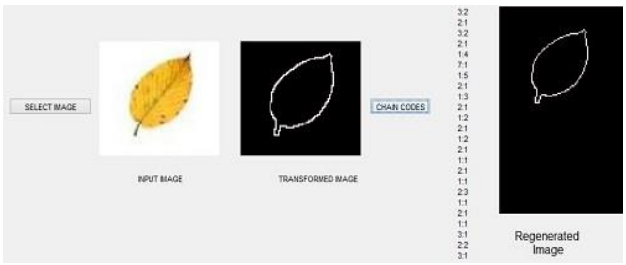
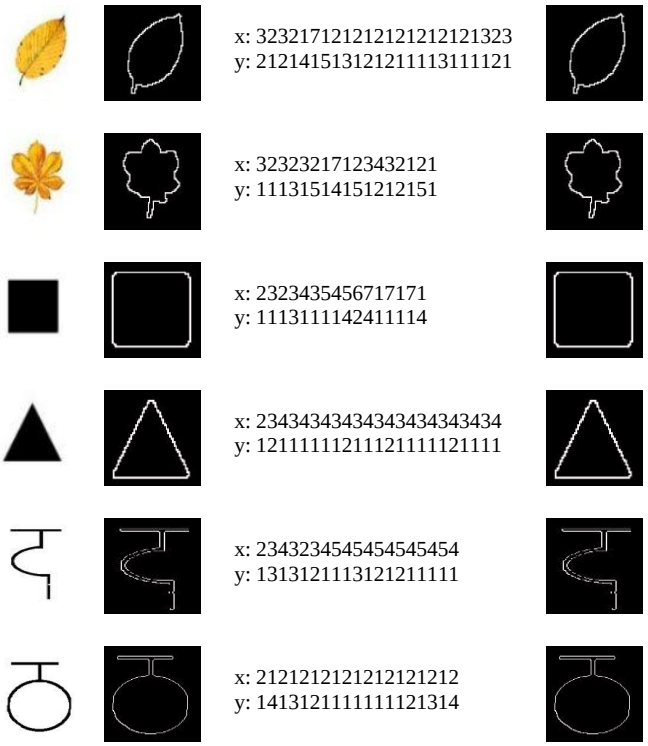


Fig. 3. Interface developed for chain code.



(a) (b) (c) (d)

Fig. 4. Generation of chain code where (a) input image (b) transformed image (c) represent chain code (d) represent regenerated image.

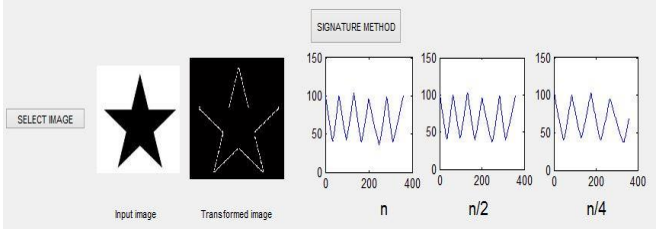


Fig. 5. Signature method interface.

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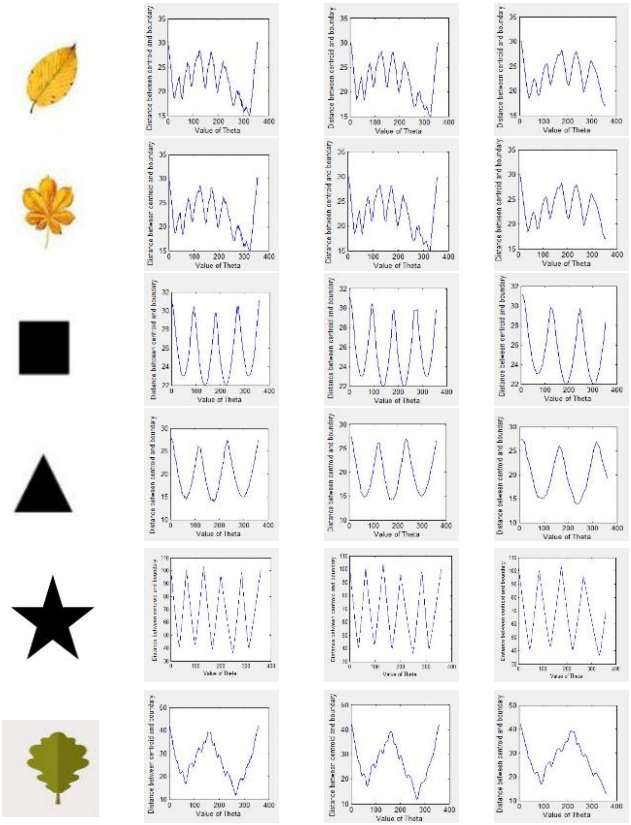

Fig. 6. Relationship between the distance of boundary pixel from centroid and corresponding angle at n, n/2 and n/4 where (a) input Image and (b), (c), (d) are the graphs for N, N/2 and N/4 pixels respectively

Different results confirm that modified splitting method works well for approximation of leaves and shapes. Another interface for modified splitting method has been developed (Fig.7). The coordinate values have been generated by modified splitting method as shown in Fig.8. Fig.8(b) shows the number of pixels with which the user wants the approximated boundary to be regenerated. Fig.8(c) shows the n+1 pixel coordinate values and the Fig. 8(d) is the regenerated image that is produced by connecting the n+1 pixel coordinates by using straight line segments. Here first rows represent x and y coordinate pixel values (Fig. 8(c)). Further Fig.9 shows the regenerated image optimized at different number of coordinates n equal to 3, 7 and 12 which indicates that on exceeding the n value, regenerated image begins to match original picture more accurately but at the cost of more space and time. The advantage of the modified splitting method over original splitting method is that this procedure does not calculate all the distances for comparison reducing the time and space complexity to a great extent. However, it does not generate required output when number of pixel coordinates is less than 3 or exceeds 13 due to recursion based redundant pixel coordinate values.

Fig. 7. Interface developed for splitting method interface.

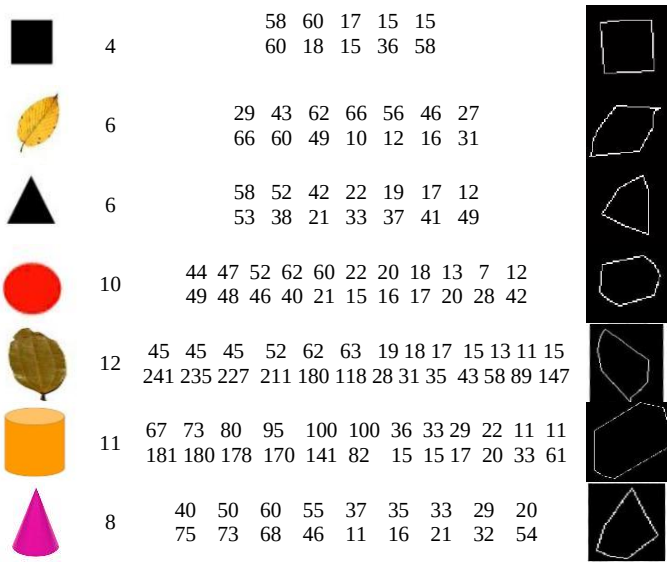

Fig. 8. Generation of coordinate values by modified splitting method, where (a) input image (b) number of pixels taken for boundary approximation (c) coordinate values for n+1 pixels (d) approximated Image

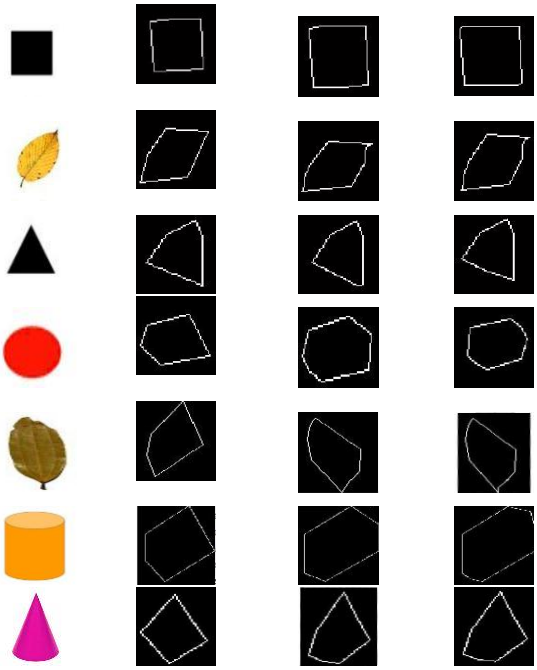

Fig. 9. Variation in approximated images by modified splitting method where (a) input Image and (b), (c), (d) are the approximated images for N=3, 7 and 12 pixel values respectively

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V. CONCLUSION

Contour detection along with boundary representation techniques plays a vital role in approximating boundary of a given symmetric or non symmetric object. In this research work three selected methods-chain codes, signature method and splitting method have been implemented with different parametric variations and modifications for boundary approximation of a given symmetric or non symmetric object. More than 50 images of different leaves, regular shapes and characters were tested. The chain code of the surface boundary obtained has been compressed for effective memory utilization and time constraints. Signature method has been experimentally analyzed for understanding the effect of boundary approximation with different number of reference points. This method generates output even with n/2 and n/4 pixels. Thirdly, a model has been developed which uses the splitting method to approximate the boundary. This model has been modified to understand the effect of outcome on a number of selected reference points. The min and max variable have been established and outputs are generated. However, this system has the limitation that the system does not generate output when max variable is beyond 13. This work may further be extended by taking large database, by including more number of pixels for getting more significant boundary representation. Further time constraints for boundary approximations may also be observed for evaluation of techniques.

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