Shape Approximation using Circular Grids

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Abstract: - Research in shape approximation has been motivated by object analysis, matching and recognition. Polygonal shape approximation is widely acceptable and gives reasonable reflection for the shape of the object. This paper presents an object shape approximation algorithm which generates polygons for closed objects. The algorithm is also capable of handling open objects as well as handwritten characters.
The proposed algorithm utilizes circular grids to generate the segments. The user can control the number of segments generated by adjusting the granularity of the grid. The outcome of the proposed algorithm is scale and rotation invariant.

Key-Words: - Polygon, Shape approximation, Circular grid, Rotation invariant, Scale invariant, Handwritten characters, Open shape, closed shape

1 Introduction

Image representation is an essential step that follows the segmentation process of the image and is required for the recognition process. Computational requirements for shape matching are typically more efficient when performed on represented data rather than the original raw data [1, 4, 5]. There are two types of image representation; namely: external and internal representations [16]. Each of these representation types offers features used for further processing. When the primary focus of the application is on regional properties, such as texture and color, an internal representation is selected. However, if the focus of the application is on shape characteristics, an external representation is chosen. In the second case, the boundary is described by certain features, such as length, orientation of the straight lines joining extreme points, and the number of concavities on the boundary [6, 7].

Chain coding is a succinct way of representing a shape as a list of points. Only a starting point is represented by its location while the other points are represented by successive displacements from point to point along a certain path. Typically, this representation is based on 4 or 8 connectivity of segments to give a direction weight to concatenate between the neighboring coordinates. The concatenation is done in a clockwise direction. Eventually, we get an approximate representation of the external boundary of the original shape that can be used for further processing. The chain coding approach has several drawbacks. The resulting chain of codes tends to be quite long and any small disturbances along the boundary due to noise or imperfect segmentation causes changes in the code that may not be related to shape boundary [8]. It also depends on the scale of the shape and gives different results to the same shape with different scales.

Many techniques have been designed to approximate shapes using geometric features. Regular geometric shapes can be used to approximate the dimensions of a pictorial object. Along with other features, the dimensions and location of the bounding geometric shape can be utilized to identify the object. The minimum bounding rectangle (i.e. MBR) of an object is one of the simple techniques which gives a rough shape approximation [2, 3]. There are various other approaches used to compact the data into external representation. Each approach attempts to get the most accurate result of the representation in comparison with the original image under processing.

The external boundary of a shape can be more accurately described using a polygon consisting of segments which connect the coordinates of selected points on the boundary of the original image. Each pair of adjacent points defines a segment in the polygon. The goal of the polygonal approximation is to capture the boundary shape using as fewest possible polygonal segments as possible [9]. In the minimum perimeter polygons technique, the polygonal approximation is gathered by taking the shrink of concatenated cells in the grid that contains the original external boundary of the image [10, 11]. Then, a polygon of minimum perimeter that fits the geometry is produced. This method is called a rubber band approximation as it considers the boundary of the shape as a rubber counter within the concatenated shrink cells.

Splitting technique is another method that depends on partitioning the shape into segments and detecting new coordinates that lie over the boundary of the segments depending on some criteria and threshold [12]. The main drawback of the splitting technique is that it lacks accuracy as it gives a general approximation and skips details that may be important in the recognition process. However, this algorithm is efficient when treating regular and general shapes that don't have much detail and can be recognized easily.

Section 2 of this article presents an adaptive shape approximation algorithm using circular grids. Section 3 discusses experimental results for running the algorithm for various types of shapes. The article concludes by section 4.

2 Proposed Algorithm for Shape Approximation using Circles

A number of polygon shape approximation algorithms to obtain accurate external boundary with minimum number of segments have been proposed. Polygons tend to yield acceptable reflection for the external boundaries of the original objects [13, 14, 15, 17]. This section presents an adaptive algorithm to find the polygon approximation of the external boundary of a shape using circles. The algorithm identifies selected points on the boundary by utilizing co-centered circles which intersect with the boundary of the shape. Clockwise concatenation between adjacent detected pair of points is conducted to generate the polygon approximation for the shape. It is worth mentioning that a larger number of circles in the grid produces more intersection points with the boundary which generates a more accurate polygon shape approximation. The following steps outline the details of the algorithm:

Step 1: Obtain the original segmented boundary.

Step 2: Identify the farthest two points on the boundary of the shape. The midpoint between the two points is designated by CA. Draw a line LA between CA and one of the farthest points and LB between CA and the other point.

Step 3: Identify the nearest boundary point to CA and draw a line between them, denoted as LC.

Step 4: Draw a circle centered at CA and radius LC. The circle will touch the boundary of the shape at the nearest point to CA.

Step 5: Draw additional co-centered circles at CA and radii increments of Δr until a circle is drawn which touches the farthest point identified in step 2.

Step 6: Identify all intersection points between the circles drawn in step 4 and 5 and the boundary of the shape. Then, perform a clockwise line concatenation between the points to generate the desired polygon approximation.

The behavior of the previous algorithm clearly depends on the value of Δr. It is clear that a smaller Δr brings about a closer approximation for the original shape of the object. Fig. 1 describes an example that demonstrates the proposed algorithm.

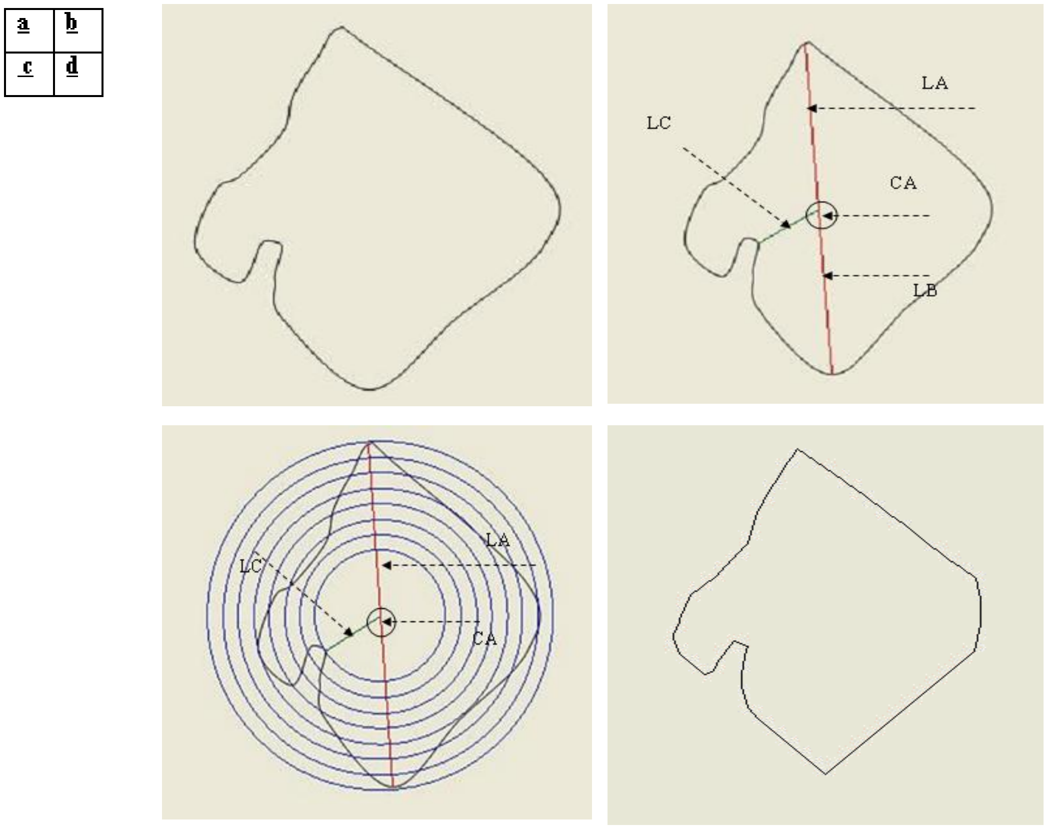
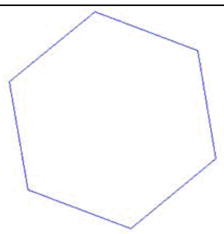
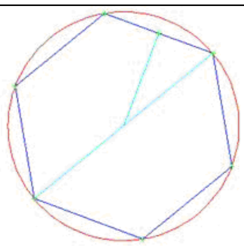
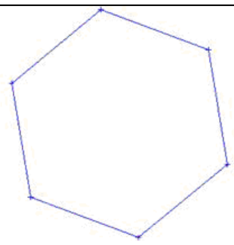
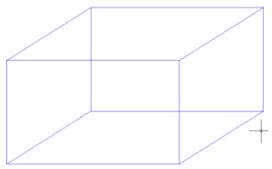
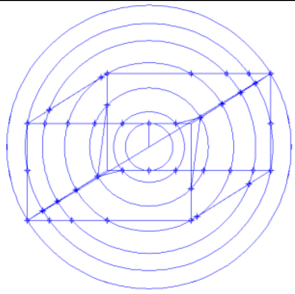
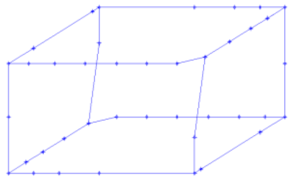
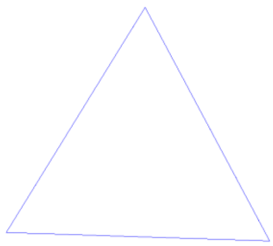
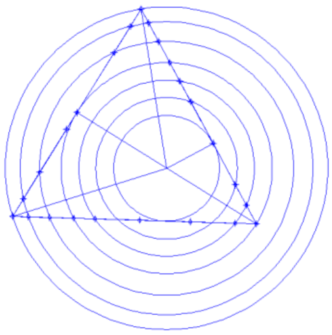
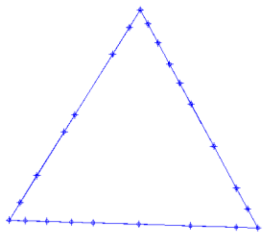


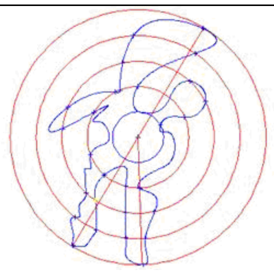
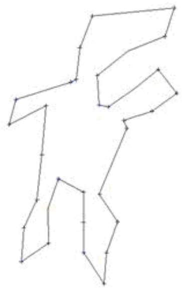
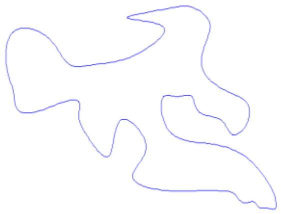
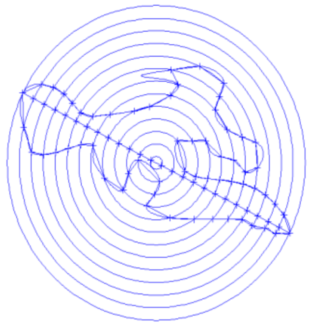
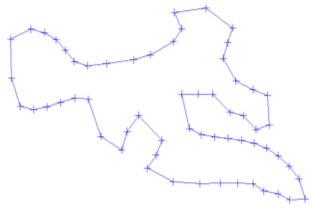
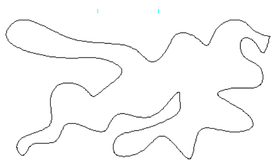
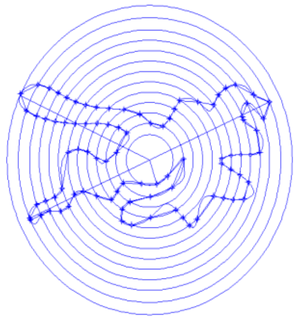
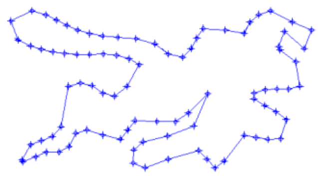
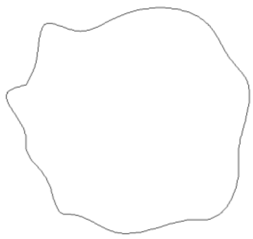
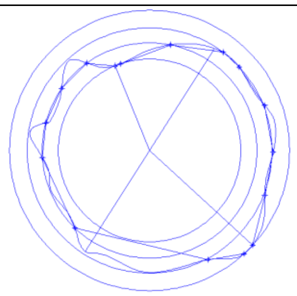
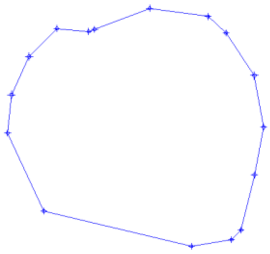
Fig 1. (a) A segmented object boundary (b) Steps 2 and 3 (c) Co-centered circles at point CA (d) Resulting polygon**.**

It is worth noting that rotating the object will not impact the segments generated by the algorithm. This is due to the fact that the farthest two points on the boundary of the shape and the nearest point to CA will remain the same. Moreover, the algorithm will generate scale invariant results by selecting Δr which is proportional to the scaling ratio. Additionally, the algorithm confines it computations to the circular grid bound from inside by the circle that touches the nearest boundary point from CA and from outside by the circle that touches the furthest boundary point from CA.

3 Experimental Results

We implemented the adaptive shape approximation algorithm using MATLAB in order to investigate its behavior with respect to various segmented regular, irregular, and complicated objects. Fig. 2(a) illustrates the outcome of the algorithm when applied on hexagon, cube and triangle. Similarly, the algorithm performs well for irregular and complicated shapes as shown in Figure 2(b) and 2(c), respectively. The algorithm clearly handles closed shapes as well as open shapes and discontinued boundaries as shown in the mentioned figures.

(a) Regular Shapes		
Original segmented shape	***Circular grid***	***Result***
1 		
2 		
3 		

(b) Irregular Shapes		
Original segmented shape	***Circular grid***	***Result***
1 		
2 		
3 		
4 		

(C) Complicated Shapes		
Original segmented shape	***Circular grid***	***Result***

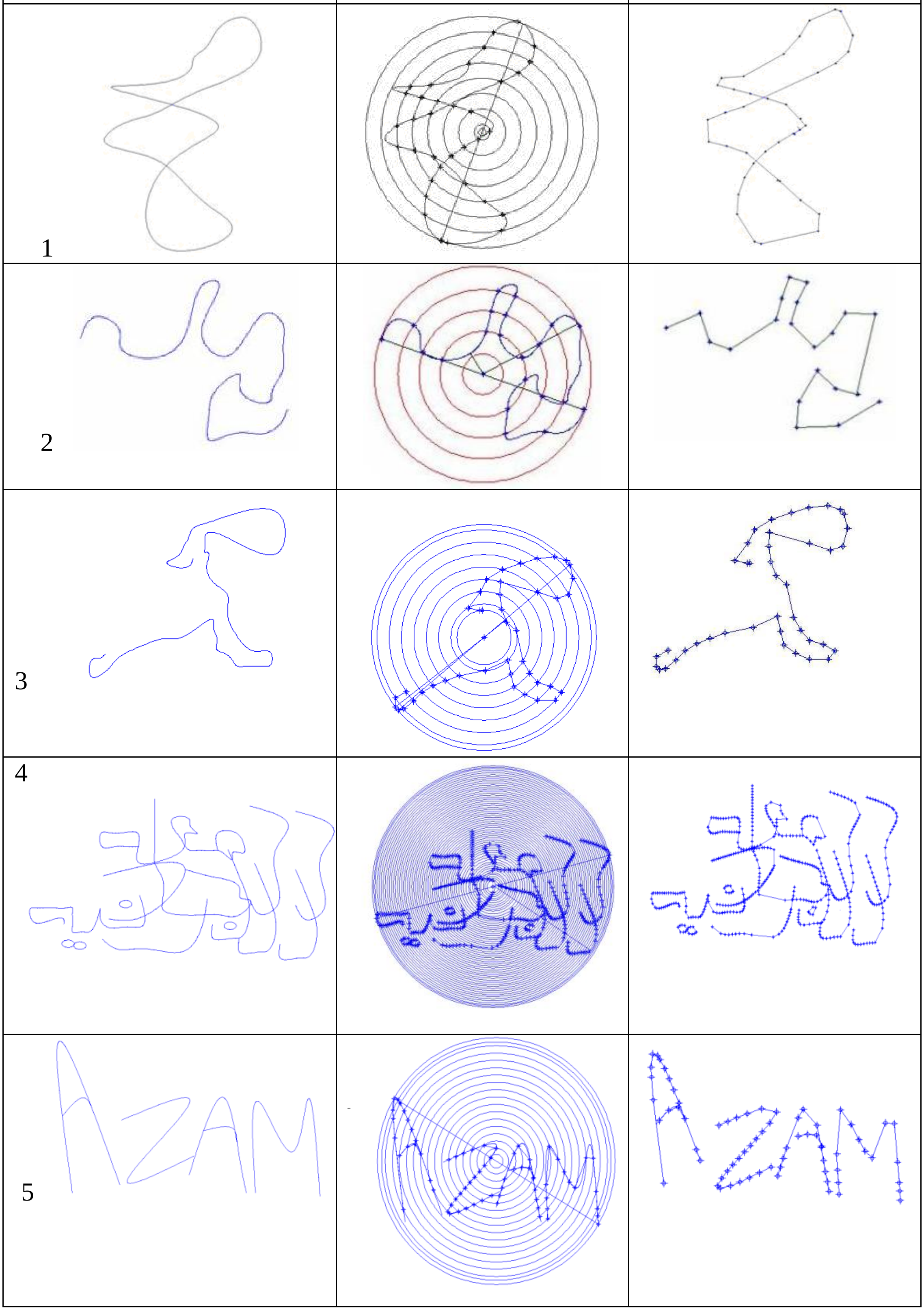


Fig. 2. Experimental results (a) Regular shape (b) Irregular shapes (c) Complicated shapes

As mentioned before, the proposed algorithm enables the user to select the degree of accuracy of the final result by increasing or decreasing the number of circles in the circular grid (i.e. selecting a value for Δr). Fig. 3 illustrates an example of the relationship between the number of circles and achieved approximation accuracy for a complicated shape. It is worth mentioning that the selection of Δr is domain specific and may require limited user interaction.

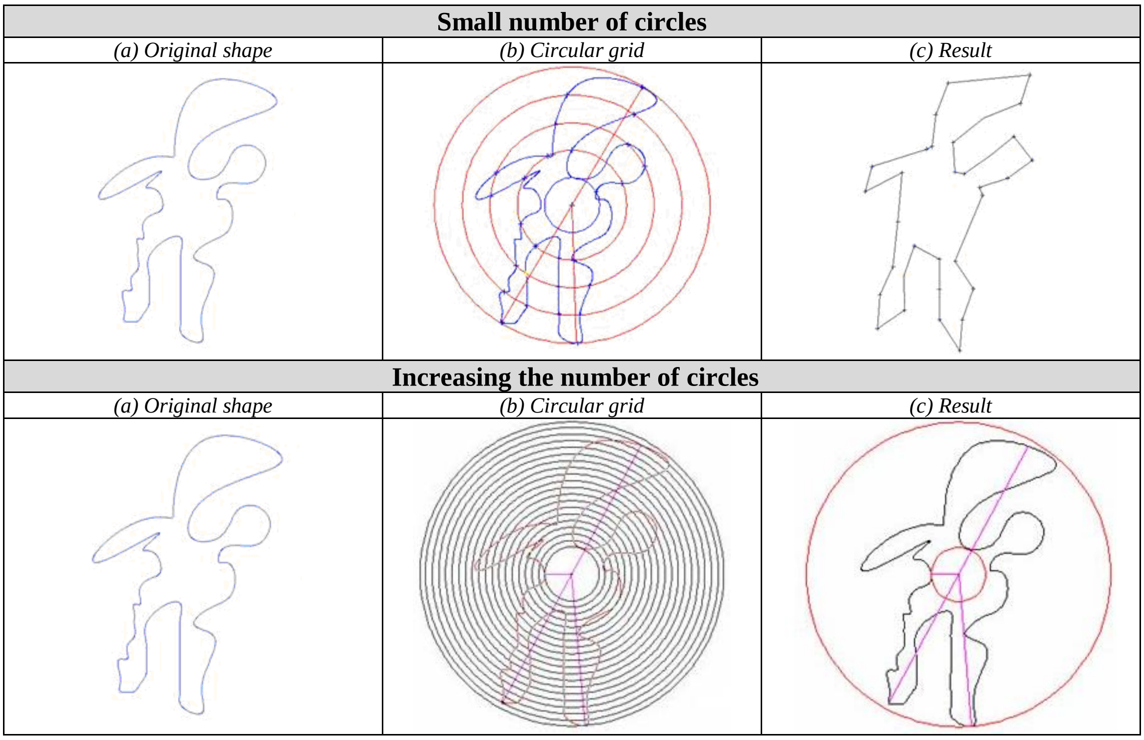


Fig. 3. Relationship between Δr and achieved approximation accuracy

We have also investigated the behavior of the algorithm for handwritten characters. The algorithm produced acceptable polygon approximation results as shown in Fig. 4. We argue that the algorithm can produce feature vectors which may be utilized in optical character recognition for various languages. This will be further investigated as a future study for Arabic optical character recognition.

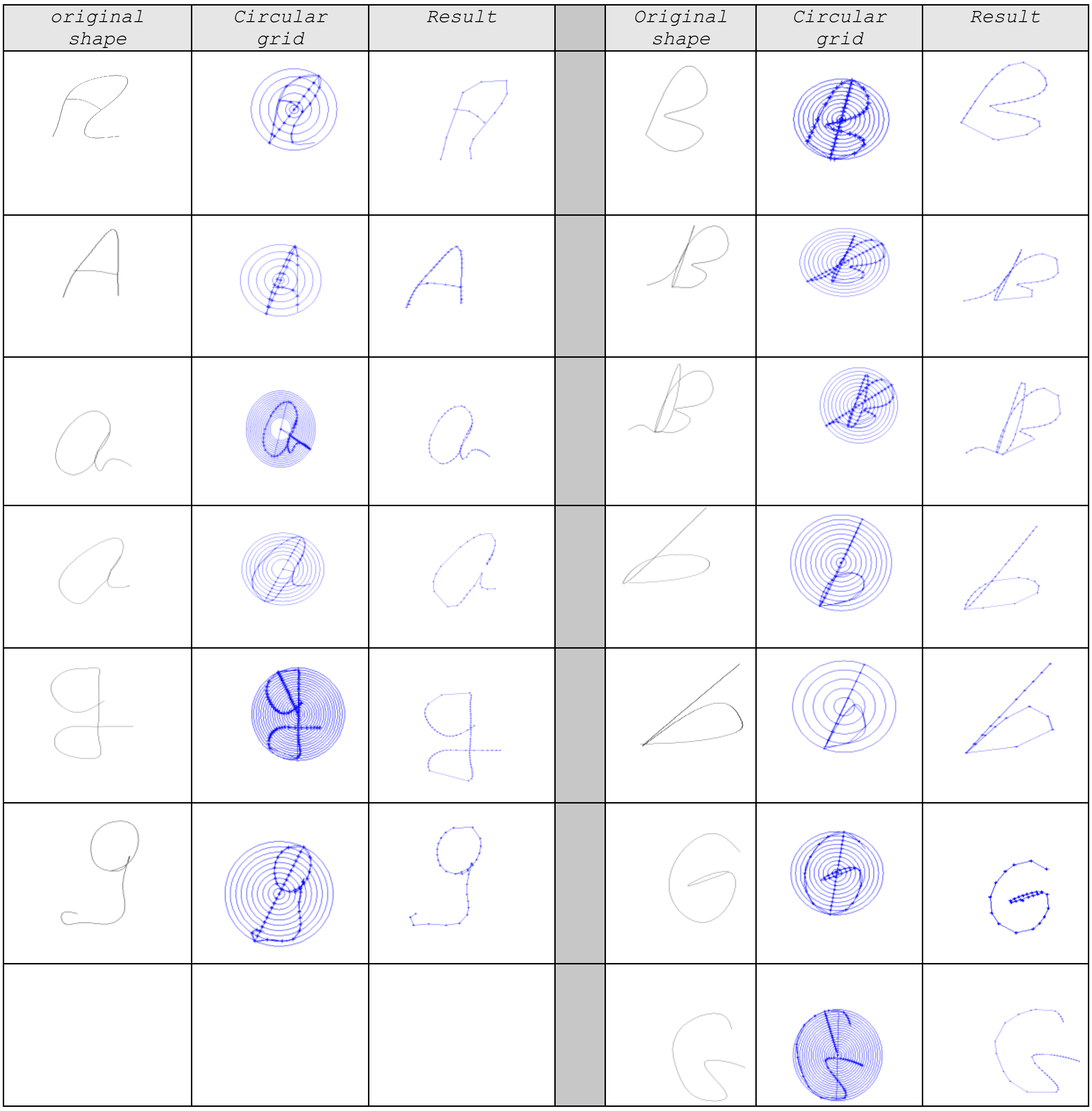


Fig. 4. Polygon approximation using circular grids for handwritten characters

4 Conclusion

In this paper, we presented an adaptive polygon shape approximation algorithm which can be applied on various kinds of shapes. The accuracy of the approximation result can be controlled by increasing or decreasing the granularity of the circular grid. The algorithm is scale invariant as the same number of segments is generated by selecting proportional grid granularity. Likewise, it is rotation invariant using the same grid granularity. The algorithm confines its computations to the circular area between the smallest and largest circles surrounding the concerned shape. It is worth noting that the outcome of the algorithm for handwritten characters can be utilized as a preprocessing step to produce feature vectors which may be the basis for optical character recognition. Investigating this hypothesis for Arabic character recognition will be a future research avenue.

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