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AN ADAPTIVE-TRIANGLE METHOD FOR BINARY IMAGE CONTOUR DATA APPROXIMATION

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ABSTRACT

This paper presents a new efficient algorithm for contour approximation and compression. The single step parallel contour extraction (SSPCE) method will be used in this work to achieve Cartesian representation of the object. We also discuss the main idea of the analyzed approach to obtain contour approximation and we will compare it with the Ramer and Trapezoid methods of contour approximation. For comparison, we are going to use the mean square error and signal-to-noise ratio criterions. Experimental results are obtained both in terms of image quality, compression ratios and speed. The main advantages of the analyzed algorithm are the short computational time of operations and good quality of approximation.

Keywords: *Contour Representation, Contour Compression, Polygonal Approximation, Ramer, Triangle and Trapezoid Methods*

1. INTRODUCTION

Edge detection and contour-tracing techniques produce contour lines. Contours play an important role in processing medical images, image compression, etc. Contour processing is also required in computer vision e.g. robot guidance or non-contact visual inspection. However, some methods of edge detection and contour approximation may have good image quality of approximation and compression ratios but they need longer computational time of operation. Hence, we present a new efficient algorithm called Adaptive-Triangle approach to address the problem of speed in time of operations.

The Cartesian representations are mostly used for the contour approximation procedures. (In this paper we use the method known as single step parallel contour extraction method "SSPCE" to extract contours from binary image [1]). Polar or Freeman's (also generalized) chain coding representations are usually desirable in many applications [2] & [11].

The fundamental goal of the digital signal compression is to reduce the bit rate for transmission and storage without significant loss of information. The well-known algorithm in spatial domain is Ramer [3] who has presented repeated end points that suit the algorithm. Connecting a number of points by joining all the line end points give the approximation of such data and that is the basic idea of this algorithm. The analyzed method corresponds to a family of polygonal methods in image and signal data processing. A. Dziech and others introduced new algorithm for contour compression using triangle & tangent methods [4], [7] & [9]. The Triangle method uses the ratio between the height and length, triangle distances for each segment as the fit criterion of the algorithm. The Tangent method uses the tangent of an angle between two straight lines called opening and closing lines as the fit criterion.

Contour compression can be applied in such common areas as topographic or weather maps preparation, character recognition like the algorithms introduced by Sirjani [5]. Later Ali Ukasha and others introduced a new algorithm for contour compression using Trapezoid method [6], [8] & [10] which uses segmentation of the contour points to get trapezoid shapes consisting four points.

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2. RELATED STUDIES

2.1 Single Step Parallel Contour Extraction (SSPCE) Method

In this paper, the contour data for the analyzed algorithm is extracted from black-white images using a well-known method of contour extraction called (SSPCE) with 3x3 pixels window structure. By using the central pixel the object contours are extracted and all possible edge direction is found which connects the central pixel with one of the remaining pixels surrounding it [1].

2.2 Ramer Method

Ramer presented an iterative method which starts with an initial segmentation and splits the segment at the point which has the farthest distance from the corresponding segment unless the approximation error is no more than the pre-specified tolerance as shown in Figure 1 [3].

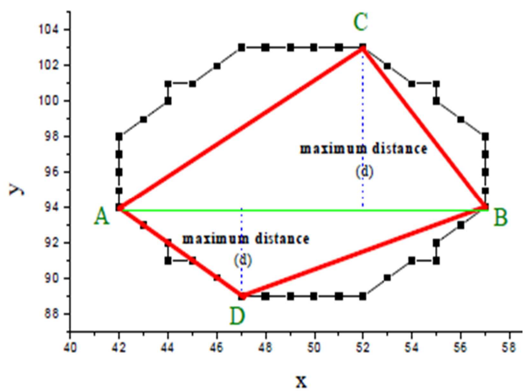

Figure 1: Curve Approximation By Ramer Method.

2.3 Triangle Method

The idea of this method consists in segmentation of the contour points to get a triangle shape (SP, B, and EP points) as shown in Figure 2 [4].

The ratio between height of the triangle h and length of the base of the triangle b is compared with a given threshold value using formula 1.

$$(h / b) < th \qquad (1)$$

If the ratio value is smaller than the threshold, the EP of the triangle is stored and SP is shifted to the EP, then a new segment is drawn. Otherwise the second point (B) is stored and the SP is shifted to the B point of the triangle. Then a new segment is drawn. The stored points determine the vertices of an edge of the approximating polygon.

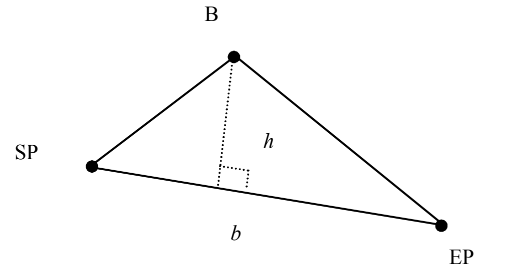

Figure 2: Curve Approximation By Trapezoid Method.

2.4 Trapezoid Method

The proposed algorithm belongs to a family of polygonal methods of approximation. The idea of this method consists in segmentation of the contour points to get trapezoid shapes (points of SP, B, C, and EP). The first and last points of each segment are called starting point (SP) and ending point (EP) respectively. The fit criterion of the Trapezoid method (referred here as algorithm I) [6] & [8] is the ratio between the perpendicular distance (dB) from point B to the line (SP – C) to the perpendicular distance (dC) from point C to the line (B – EP) as illustrated in Fig. 2 and is defined by formula 2

$$(dBC \,/\, dCEP\,) < th \qquad (2)$$

Where *th* is the given threshold value, *dBC* is the distance between B and C points and *dCEP* is distance between C and EP points. Fitting the curve of closed contour by the line segment using Trapezoid method is shown in Figure 3.

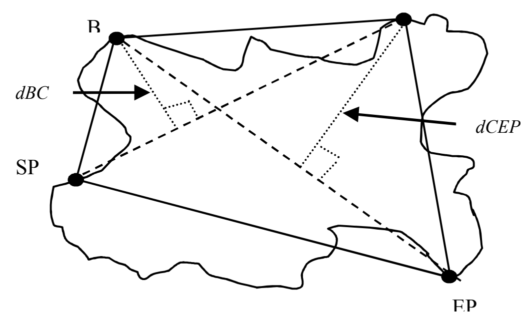

Figure 3: Curve Approximation By Trapezoid Method.

3. THE PROPOSED SCHEME

The idea of the analyzed method is referred to as Adaptive-Triangle method which consists in choosing two points on the contour curve and computes the maximum distance from contour curve to the straight line that connects them as shown in Figure 4. This distance is compared

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with a given threshold by using formula 3. Flowchart of the analyzed algorithm is depicted in Figure 5.

$$d_{max} > th_1 \qquad (3)$$

Where *VA* is the sequence of indices of the final vertices, CC is the sequence of the input for the contour, Sp is starting point, Ep is ending point, d_{max} maximum distance from (Sp-Ep) line to the contour curve, *L* is the input contour length and *f* is the length between each two points

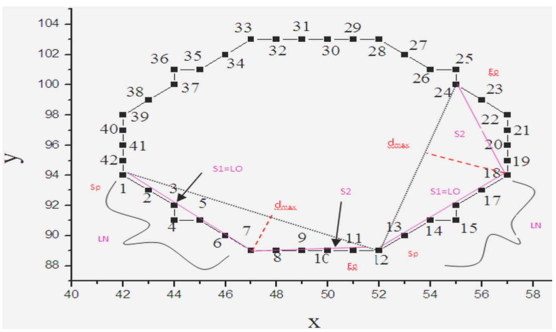


Figure 4: Curve Approximation By Adaptive-Triangle Method.

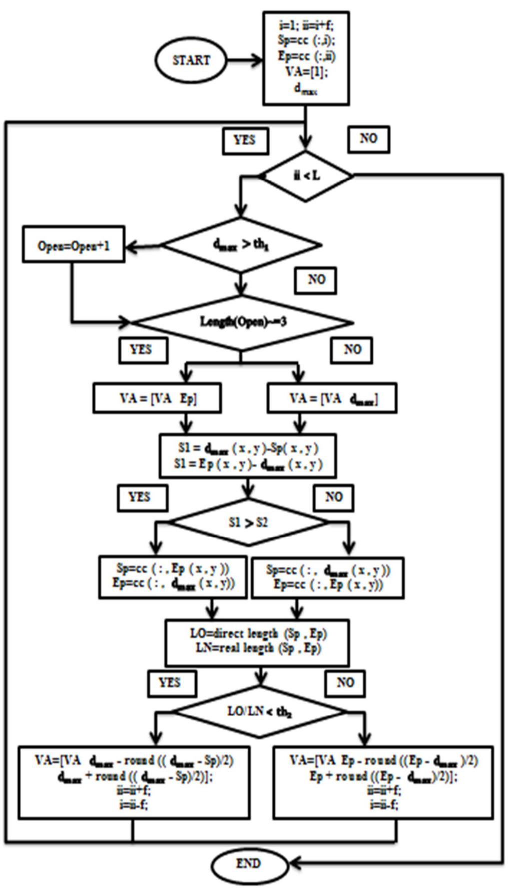


Figure 5: Flowchart Of The Adaptive-Triangle method (Proposed Algorithm).

4. MEASURES USED

The compression ratio of the analyzed method is measured using formula 4.

$$CR = \frac{(L_{CC} - L_{AC})}{L_{CC}} \cdot 100\ \% \qquad (4)$$

Quality measuring of an approximation during the approximating procedure uses mean square error (MSE) and signal-to-noise ratio (SNR) criterions by formulas 5 and 6 respectively.

$$MSE = \frac{1}{L_{CC}} \sum_{i=1}^{L_{CC}} d_i^2 \qquad (5)$$

where d_i is the perpendicular distance between i point on the curve segment and straight line between each two successive vertices of that segment.

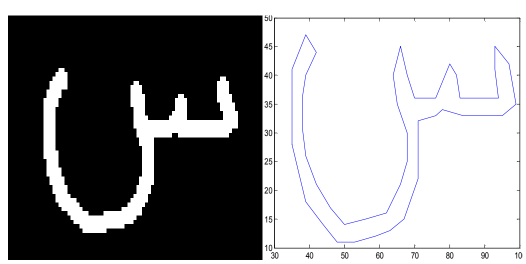
$$SNR = -10 * \log_{10}\left(\frac{MSE}{VAR}\right) \qquad (6)$$

where *VAR* is the variance of the input sequence.

Performed analysis and experiments show that SNR should be greater than 30 dB for some contours and less than this value for others to obtain the expected compromise between compression ratio and quality of reconstruction. In the case of high threshold level, the contour details are eliminated and the level of the introduced distortion cannot be accepted.

5. THE EXPERIMENTAL RESULTS

It can be seen that the proposed method for the Arabic letter shown in Figure 6.a gives high compression and good quality as shown in Figure 6.b. The related results are in Table 1.



(a) (b)

Figure 6: Results Of Approximation For Arabic Letter Image Using An Adaptive-Triangle Method (Proposed Algorithm): a) Binary Image, b) Contour Approximation After Using SSPCE Method.

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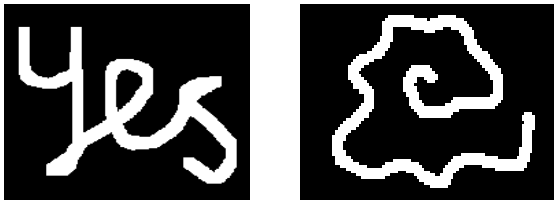
To visualize the experimental results, a set of two tested images (black & white level) were selected as shown in Figure 7.



(a) (b)

Figure 7: Test Binary Images: a) Yes, b) Serpent.

Table 1: Contour Approximation For Arabic Letter Image

	MSE	SNR	CR[%]	elapsed time (s)
b)	0.34	33.65	79.59	0

Some selected results of the compression for the text (Yes word) & Serpent contours are illustrated in Figure 8 & Figure 9 (related results are in Table 2 & Table 3) respectively.

Table 2: Contour Approximation For Yes word Image

	MSE	SNR	CR[%]	elapsed time (s)
a)	0.44	39.65	90.33	0.015
b)	1.006	35.97	91.88	0.016
c)	1.63	33.87	92.60	0
d)	1.98	33.03	94.55	0

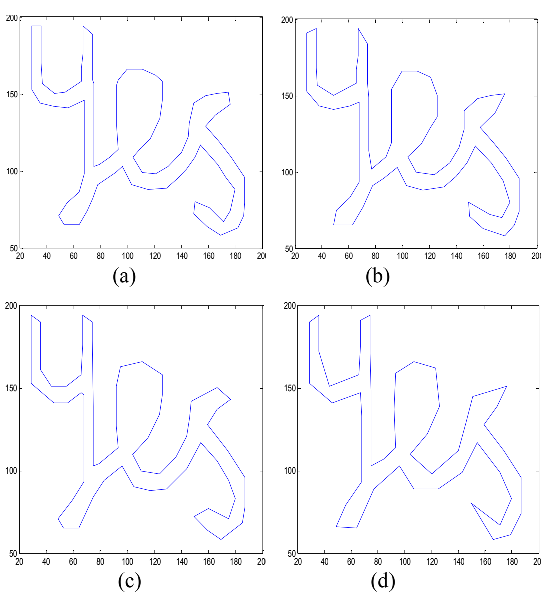


Figure 8: Results Approximation For Yes Word Contour.

Table 3: Contour Approximation For Serpent Image

	MSE	SNR	CR[%]	elapsed time (s)
a)	0.28	36.25	81.11	0.013
b)	0.35	35.28	82.34	0.0156
c)	0.43	34.38	83.57	0.0156
d)	0.51	33.67	84.80	0.0156

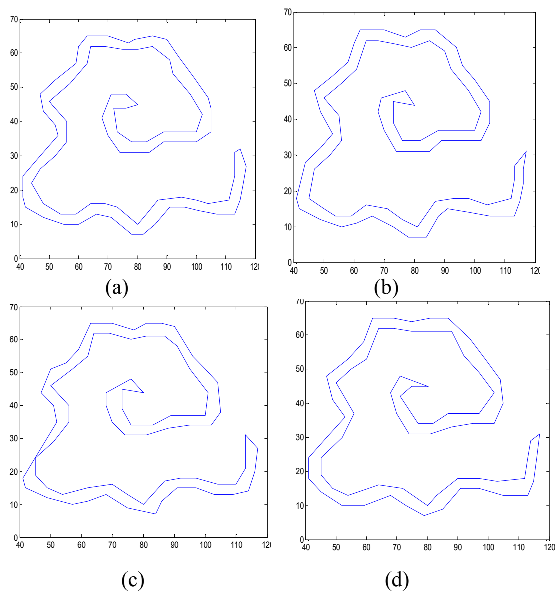


Figure 9: Results Approximation For Serpent contour.

The results presented in Figures 8 and 9 shows that the proposed method has good compression abilities for such type of contours and that the compression ratio can be even greater than or equal to 94%. The approximated yes word contour using Ramer, Trapezoid and the proposed method for CR = 92% is shown in Figure 10 (related results are in Table 4).

Table 4: Contour Approximation Using Different Methods For Yes Image.

Method	MSE	SNR	CR[%]	elapsed time (s)
Ramer	0.27	41.75	92.29	0.031
Trapezoid	1.77	33.52	92.70	0
Proposed	1.63	33.87	92.60	0

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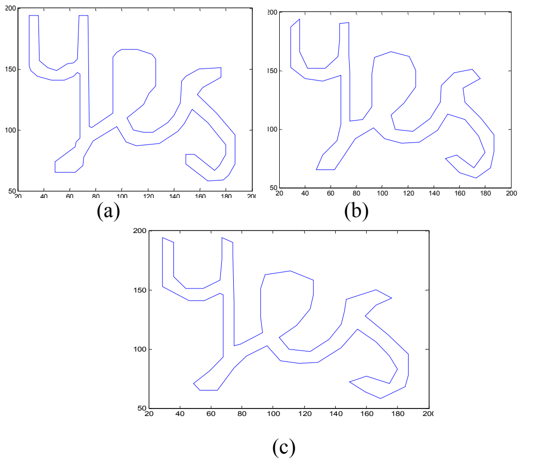

Figure 10: Results Approximation For Yes Word Contour Using: a) Ramer Method, b) Trapezoid Method, c) Analyzed Method.

The comparison of the analysed method with Ramer and Trapezoid methods has also been performed. The plots of MSE and SNR versus CR are shown in Figure 11 and Figure 12 respectively

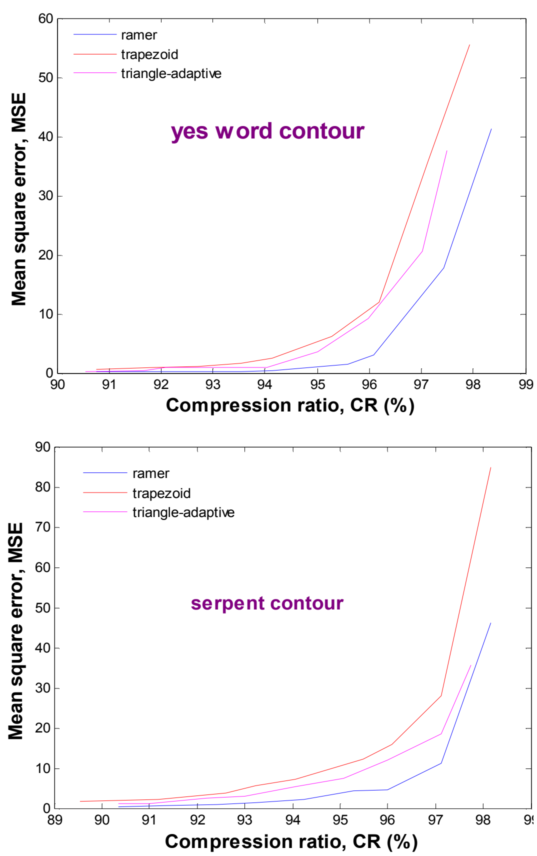

Figure 11: Comparison Of The Analyzed Method With Ramer And Trapezoid Methods For MSE Versus CR For The Tested Contours.

The plots show that SNR using analyzed algorithms is less than Ramer and better than Trapezoid method by about 2 decibel for higher compression of contours. But the time required in operation execution using Ramer method is higher than the analyzed method and very near to trapezoid algorithm. So, we can say that the proposed method is located between Ramer and Trapezoid algorithms in time required (speed), SNR and MSE.

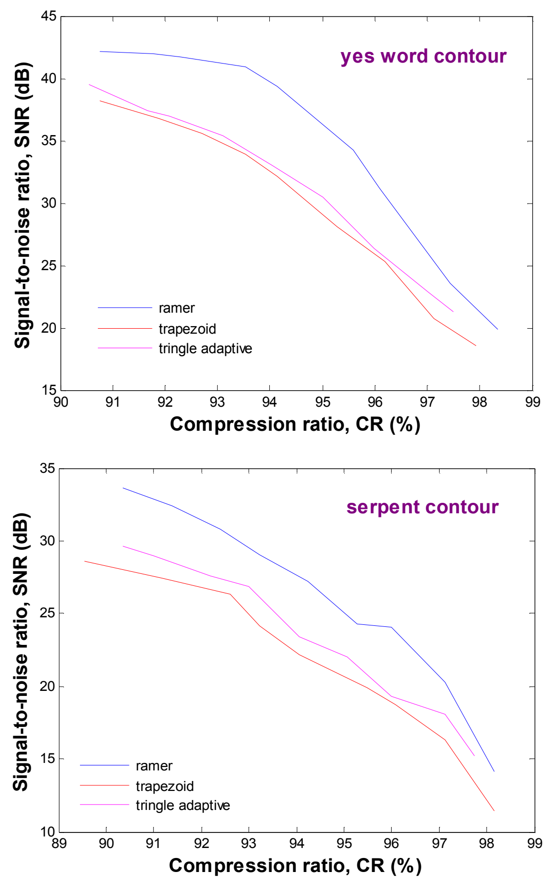

Figure 12: Comparison Of The Analyzed Method With Ramer And Trapezoid Methods For SNR Versus CR For The Tested Contours.

6. CONCLUSION

In this paper, we have presented a new scheme of contour compression called Adaptive – Triangle method. In this work, some of the spatial methods of contour compression (Ramer and Trapezoid) are discussed and compared with the analyzed method. The short computational time of operations and good quality of approximation are the main advantages of the proposed algorithm. Therefore it gives the analyzed algorithm usefulness in a wide application for contours where

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the speed is necessary. The presented results show that the proposed algorithm for contour approximation is faster than that of Ramer method and very close to trapezoid method. However, the quality of the Ramer method is the best among the two other methods but the analyzed algorithm has a better quality than Trapezoid method. The high compression can be performed and obtained without any significant losses of the approximation quality. The compression ratio obtained by this method can be greater than or equal to 94% (as shown in Fig. 8. d) without significant visible distortion. The simplicity of implementation is also an important advantage of the analyzed method both in terms of memory requirement and fit criterion complication.

For future work, this work can be improved by finding a better result of the image quality of the contour approximation, maintaining the advantage of its speed value.

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