New Approach Of Contour Approximation

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Abstract

This study introduced new algorithm of a method known as Trapezoid method for the contour compression. The analysed algorithm is able to approximate efficiently a set of straight segments in a near optimal way in terms of contour quality. Representations of the input contour points are in Cartesian co-ordinates which are processed in such way to obtain vertices and which some of them are chosen as the vertices of the contour polygon. The analysed algorithm has some main advantage compared to the existing methods, it is faster on implementation. The proposed algorithm is compared with Ramer method because it has best quality among well known algorithms; and with Triangle method because it's high speedity in implementation; in addition to the Trapezoid method (I algorithm) of contour approximation. Computational time of analysed method is estimated depending on a number of numerical operations. This paper shows that the simplicity is additional distinct feature of the proposed algorithm. This work gives an overview of the system architecture, describe the compression technique, and discuss implementation aspects. Experimental results for single and multi-contours images are obtained in terms of image quality, compression ratios, and image retrieval timings. It was concluded that the proposed algorithm have high compression efficiency with accepted quality for different type of contours from different languages such as Arabic and English.

Key Words

Polygonal approximation, contour representation, and contour compression

1. Introduction

Contours analysis in digital images has attracted and continues to attract great interest in the computer vision community. For this purpose, a number of features can be obtained like corners, inflection points, etc. that offer useful information for object identification and modeling tasks.

Contour representation and compression are required in many applications such as computer vision, topographic or weather maps preparation, medical images and moreover in image compression. Each contour can be determined by expliciting its grey-level of x and y co-ordinates of the initiating point and also a sequence of the external limits of the contour.

The contour approximation and compression require the existing procedures concentrate on the coding schemes in the time domain. Some of the existing approaches are for solving the problem of contour compression in spatial domain which mostly is based on the polygonal approximation scheme. They search for polygon with the minimum number of sides that best fits the curve, for a given criterion. The well known algorithm is introduced by Ramer, who has presented repeated end points that suit the algorithm [1].

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Joining all line end points which are obtained by connecting number of points gives the approximation of such data (i.e.

Later A. Dziech and others introduced new algorithm for contour compression using triangle method [11], which uses the ratio between the height and length triangle distances for each segment as the fit criterion of the algorithm. New algorithms have been introduced for contour compression known as Tangent [4], and Centeriod [7] methods.

The Cartesian representations are mostly used for the contour approximation procedures. Polar or Freeman's (also generalised) chain coding representations are usually desirable in many applications [5], [6]. In this paper the Trapezoid method (algorithm I) for contour approximation and compression is presented, compared and developed by this proposed algorithm. Figure 1 shows the main steps of contour compression procedure.

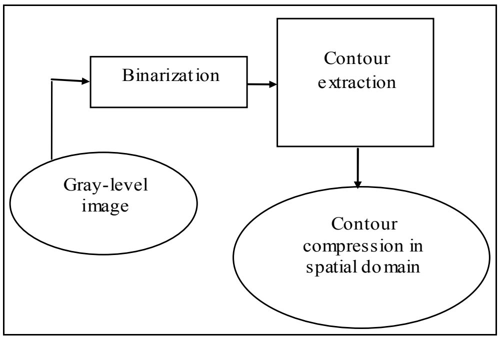


Fig. 1. Block diagram of contour compression

2. Description of the Algorithm

The important step to obtain some features of object recognition is by using the contour extraction from a given 2D-digital images. By means of tracing, edges points are connected and then contour points are coded using for instance Freeman chain coding. There exist two main fields of research for the 2D-object is the basic idea of this algorithm). Other algorithm existing proposed are available in [2], [3], [16], and [17].

contour extraction problem: The object contour following (OCF) [8], [9] or sequential methods and the multiple step contour extraction (MSCE) [10] or parallel methods. Later, an object-oriented contour extraction algorithm (OCE) was developed [10], [12]. This paper uses other algorithm which initiated a third class of contour extraction algorithms, single step parallel contour extraction (SSPCE) [13]. In many applications of image and contour processing and analysis it is desirable to obtain a polygonal approximation of an object under consideration, which is the analysed method belongs to. Contour points segmentation is the main idea of the Trapezoid method which is referred in this paper as (algorithm I) as was explained in [16] and [17]. We do that to obtained trapezoid shapes (points of *SP*, *B*, *C*, and *EP*). The first point of each segment is called starting point (*SP*) and the last one is called the ending point (*EP*). The fit criterion of the algorithm 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. To eleminate some points from the contour, the ratio is compared with threshold value using the following equation [16] and [17]:

$$(dB \;/\; dC) < th \qquad (1)$$

where *th* is given threshold value.

To calculate these values the simple trigonometric formula is used. If equation (1) is not valid the second, third and ending points are stored as vertices of the edge of the approximating polygon for the contour and the *SP* is shifted to the *EP* of the trapezoid, then a new segment is drawn.

Otherwise the third and ending points of the trapezoid are stored as vertices of the edge of the approximating polygon for the contour and the *SP* is shifted to the *EP*. Then a new segment is drawn. The idea of the Trapezoid method (algorithm I) is illustrated in Fig. 2 [16] and [17].

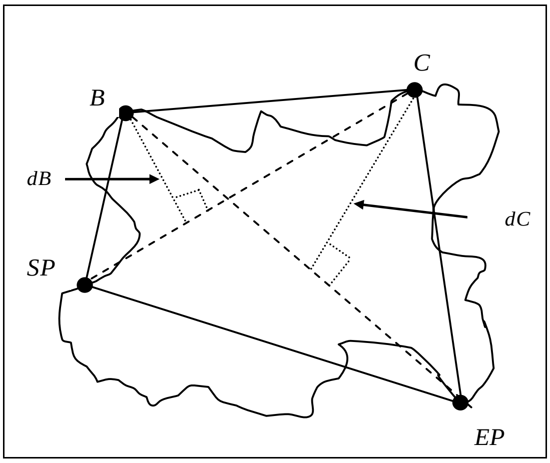


Fig. 2. Illustration of the basic trapezoid for the Trapezoid method (algorithm I)

The algorithm scans contour points only once i.e. it does not require the storage of the analysed contour points. The original points of the contour are discarded as soon as they are processed. Only the co-ordinates of the starting point of the contour segment, and the last processed point are stored.

The analysed criterion can be modified depending on methods of contour representation. The contours can be described in Cartesian representation, the x and y co-ordinates, or polar representation, using a length of the line *l* from one point to the next in sequence and the angle α between every two lines [14] and [15]. The most popular contour representation method is Freeman chain coding [6] and [8] which is used to determine all possible connections for both 8-connectivity and 4-connectivity schemes.

Flowchart of the analysed algorithm is depicted in Fig. 3.

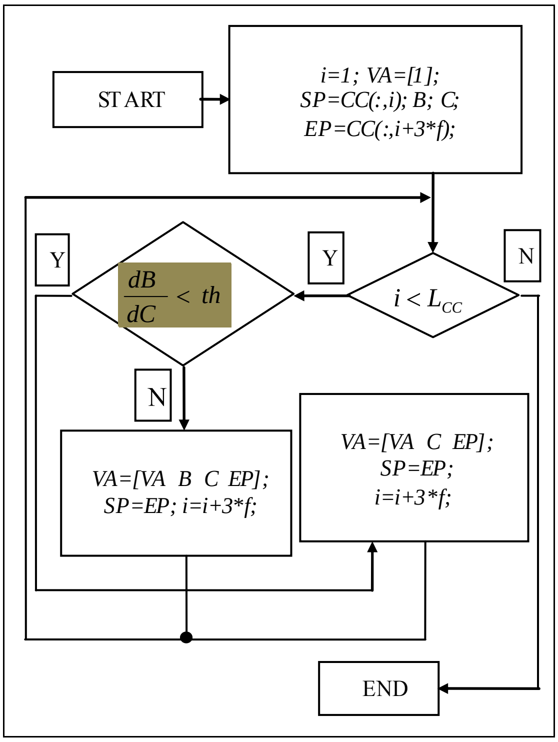


Fig. 3. Flowchart of the Trapezoid I algorithm

Where *VA* is sequence of indices of the final vertices, *CC* is sequence of the contour input, *SP* is starting point, *EP* is ending point, *dB*, *dC* and *th* are as mentioned before (see Fig.2 and Eq. 1), L_{CC} is the input contour length, and *f* is the length between each two points of the trapezoid.

The basic idea and the flowchart of the proposed Trapezoid method (algorithm II) is identical to the previous one (algorithm I) but the fit criterion here used the equation

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

Where *dBC* is distance between *B* and *C* points, and *dCEP* is distance between *C* and *EP* points. This means that the shadowed region in Fig. 3 is changed by equation (2). The goal by using this equation is to eleminate more points than using equation (1) for algorithm I.

The idea of the analyzed (algorithm II) of the Trapezoid method is illustrated in Fig. 4.

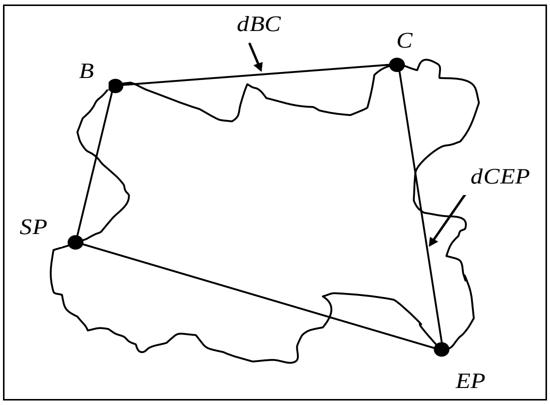


Fig. 4. Illustration of the basic trapezoid for the Trapezoid algorithm I

The analysed algorithm uses (SSPCE) contour extraction procedure with 3x3 pixels window structure to extract the object contours by using the central pixel to find the possible edge direction which connects the central pixel with one of the remaining pixels surrounding it.

3. Ramer Algorithm

This algorithm has been introduced for polygonal approximation of extracted contours by Ramer [1]. The contour segment can be approximated with few numbers of edges (two dimensional curves) to obtain the polygons shapes. The algorithm is based on the maximum distance of the curve from the approximating polygon, and this distance is used as the fit criterion. Finally by drawing the lines between these vertices the polygonal approximating contour is obtained. Fitting the curve of closed contour by the line segment using Ramer method is shown in Fig. 5.

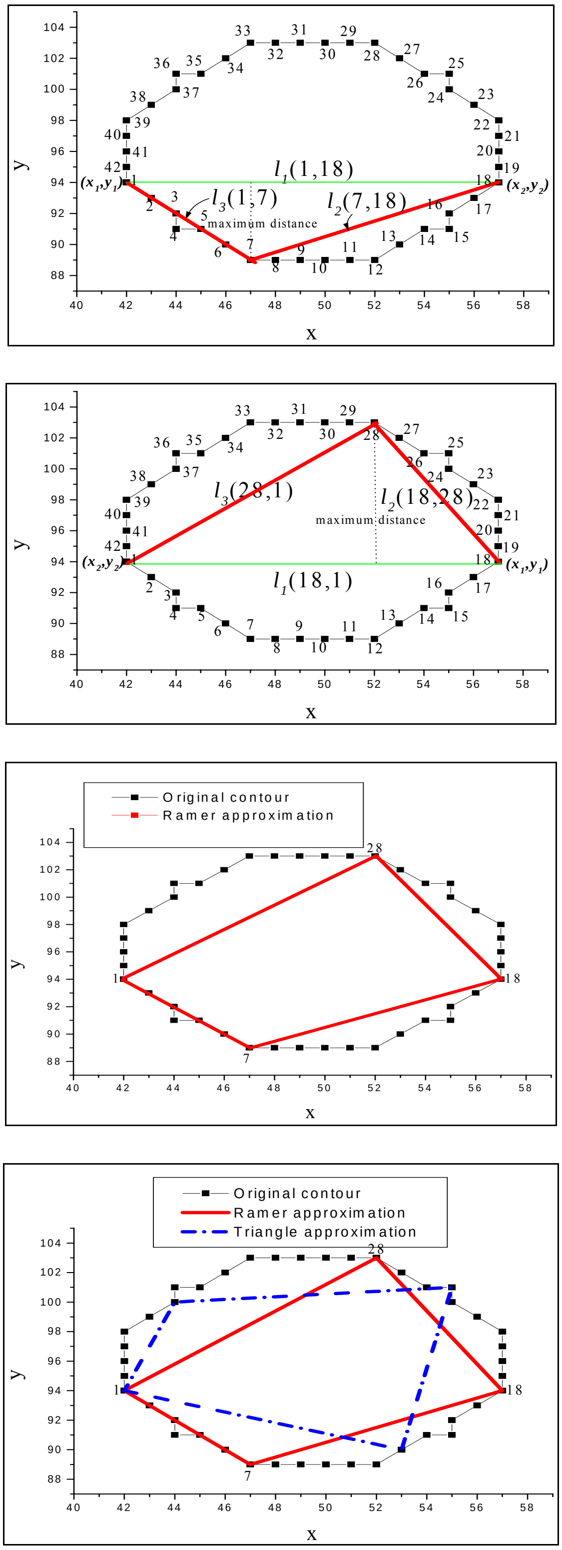


Fig. 5. Curve approximation by Ramer algorithm

4. Triangle Method

The idea of this method consists in segmentation of the contour points to get triangle shape (SP, B, and EP points) as shown in Fig. 6 [11]. The ratio between height of the triangle h and length of the base of the triangle b is compared with the given threshold value by the following equation

$$h \,/\, b \;<\; th \qquad (3)$$

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.

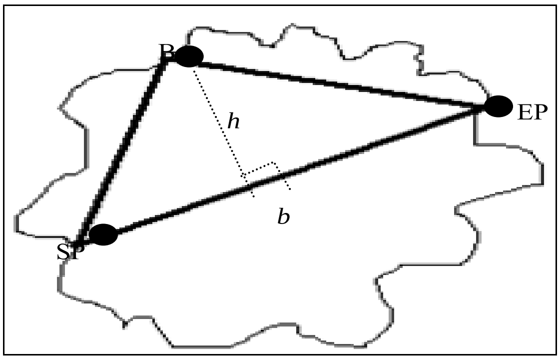


Fig. 6. Contour approximation by Triangle algorithm

5. Applied Measures

The presented method is deals with the compression ability. The following equation can used to evaluate the compression ratio (CR):

$$CR \;=\; [(\,L_{CC} \;-\; L_{AC}\,)\,/\,L_{CC}\,] \cdot 100\;\% \qquad (4)$$

where L_{CC} is the input contour length, and L_{AC} is the approximating polygon length.

Evaluation the distortion produced during the approximating procedure is done using the mean square error (*MSE*) and signal-to-noise ratio (*SNR*) criterions which has the following formulas respectively:

$$MSE \;=\; (1\,/\,L_{CC}\,) \cdot \sum_{i=1}^{L_{CC}} d_i^{\,2} \qquad (5)$$

where d_i is the distance between i point of the curve segment and straight line between starting and ending points (vertices) of that segment.

$$SNR = -10 \cdot \log_{10}(MSE \,/ VAR) \qquad (6)$$

where *VAR* is the input sequence variance.

From the practical point of view, the value of *SNR* should be greater than 33 dB for some contours and less than this value for others to obtain the expected compromise between compression ratio and quality of reconstruction. When the threshold level is high the contour details of contours are eliminated and level of introduced distortion can not be accepted.

6. Results of the Experiments

Fig. 7b shows Arabic name contour approximation with high compression and good quality of reconstruction (related results are in Table 1). Where NO is number of operations (i.e. number of arithmetic operations which are performed such as addition, multiplication, division,…, and so on).

a) b)

Figure 7. Results of approximation for Arabic name contour

Table 1

	MSE	*SNR*	*CR* [%]	NO
b)	9.67	32.55	96.09	1517

To analyse the experimental results a set of two test contours was selected. Selected contours are shown in Fig. 8.

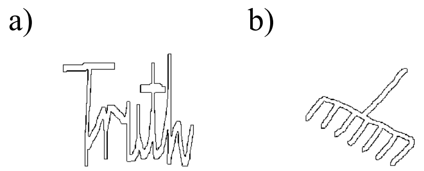


Fig. 8. Test contours: a) Text, and b) Forke

Some selected results of the compression for the Text contour, are illustrated in Fig. 9 (related results are in Table 2). Some selected results of Forke contour are shown in Fig. 10 (related results are in Table 3).

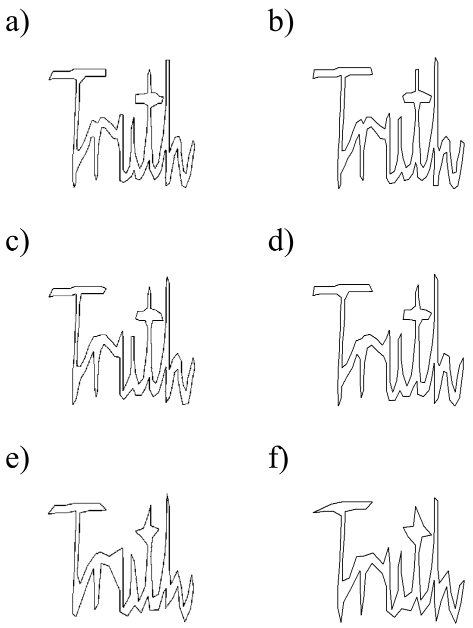


Fig. 9. Results of approximation for Text contour

Table 2

	MSE	*SNR*	*CR* [%]	NO
a) Trapezoid I	1.08	40.14	89.86	3086
b) Trapezoid II	0.75	41.76	89.90	1763
c) Trapezoid I	1.63	38.36	92.20	2320
d) Trapezoid II	1.69	38.21	92.20	1358
e) Trapezoid I	8.50	31.20	95.41	1378
f) Trapezoid II	5.28	33.26	95.41	791

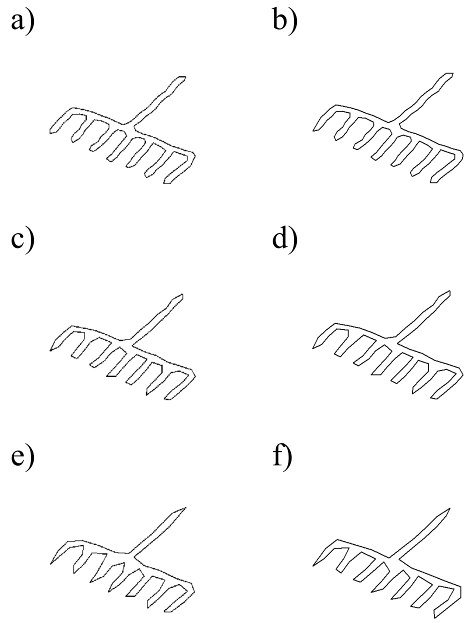


Fig. 10. Results of approximation for Forke contour

Table 3

	MSE	*SNR*	*CR* [%]	NO
a) Trapezoid I	0.81	40.90	90.00	1903
b) Trapezoid II	0.76	41.19	90.00	1196
c) Trapezoid I	3.20	34.94	94.07	1127
d) Trapezoid II	3.44	34.62	94.07	711
e) Trapezoid I	6.79	31.67	95.78	864
f) Trapezoid II	6.21	32.06	95.78	524

Both algorithms gives good quality with higher compression ratio with some little significant losses for single and for multi-contours as shown in Fig. 11 and

Fig. 12 (related results are in Table 4 and Table 5 respectively).

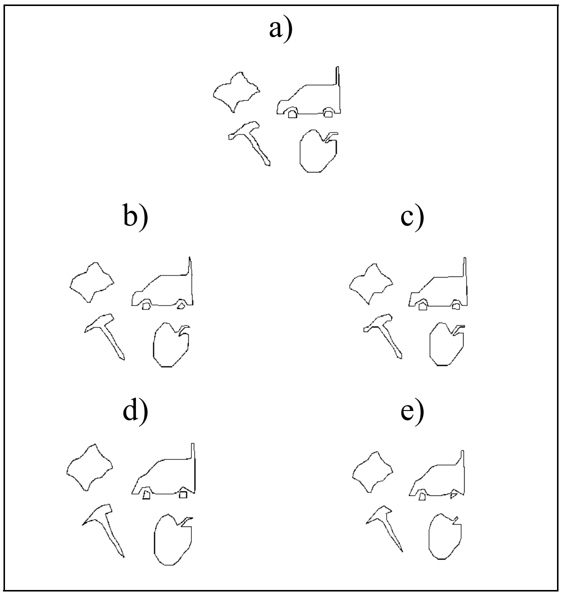


Fig. 11. Results of approximation for Different shapes contours

Table 4

	MSE	***SNR***	***CR*[%]**	**NO**
b) Triangle	0.80	36.91	89.60	28874
c) Ramer	0.22	42.73	89.60	67193
d) Trapezoid I	1.30	34.89	89.60	26816
e) Trapezoid II	4.13	30.80	89.60	26566

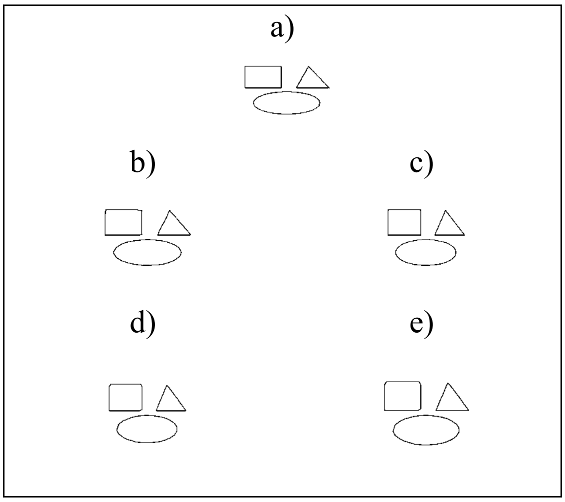


Fig. 12. Results of approximation for Geometric shapes contours

Table 5

	MSE	***SNR***	***CR* [%]**	**NO**
b) Triangle	0.13	45.63	89.25	21027
c) Ramer	0.04	50.31	89.29	89723
d) Trapezoid I	0.17	44.78	89.11	19834
e) Trapezoid II	0.15	45.37	89.10	19044

The analysed algorithm can be used to compress Text of letters in Arabic languages as shown in Fig. 13 and Fig. 14. (The word depicted in Fig. 13a means "The Teacher" in English Language). The related results are in Table 6 and Table 7 respectively.

Fig. 13. Results of approximation for Teacher contour

Table 6

	MSE	***SNR***	***CR* [%]**	**NO**
b)	7.25	30.62	95.71	827

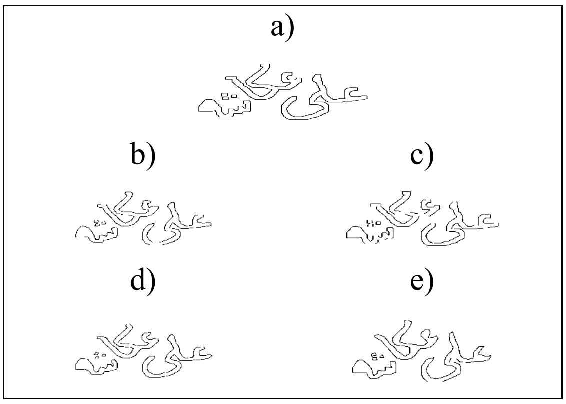


Fig. 14. Results of approximation for Arabic name contour

Table 7

	MSE	***SNR***	***CR* [%]**	**NO**
b) Triangle	0.84	39.34	88.30	57917
c) Ramer	0.09	49.13	88.32	176965
d) Trapezoid I	1.04	38.80	88.30	55550
e) Trapezoid II	2.74	34.75	88.30	54672

The approximated Rose contour using analysed algorithm compared with Triangle, Ramer and Trapezoid (algorithm I) methods for CR = 93.40% is shown in Fig. 15 (related results are in Table 8).

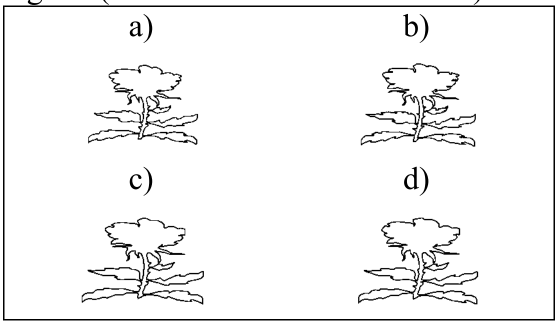


Fig. 15. Approximated Rose contour: a) Triangle method, b) Ramer method, c) Trapezoid method (algorithm I), and d) Analysed method (algorithm II)

Table 8

Method	*MSE*	*SNR*	*CR* [%]	NO
a) Triangle	1.87	40.21	93.41	8713
b) Ramer	0.64	44.88	93.36	387,718
c) Trapezoid I	3.34	37.69	93.36	4392
d) Trapezoid II	3.52	37.47	93.39	2767

The presented results show that the proposed method has good compression abilities; especially for the contours that have small waves (i.e. approximately no ripple). By these results both of Trapezoid method (algorithm I) and proposed method (algorithm II) can be given high compression for single contours more than for multi-contours. However the proposed method is faster than the previous one. It is seen that the compression ratio for such type of contours can be even greater than or equal to 96%. Comparison of the compression abilities versus number of operations, MSE and SNR of the analysed method and the Ramer, Tangent and Trapezoid (algorithm I) methods is presented in Figs. 16, and 17 respectively for the Text and Rose contours. It is shown that the analysed algorithm is much faster than those comparing methods for many different shapes of contours.

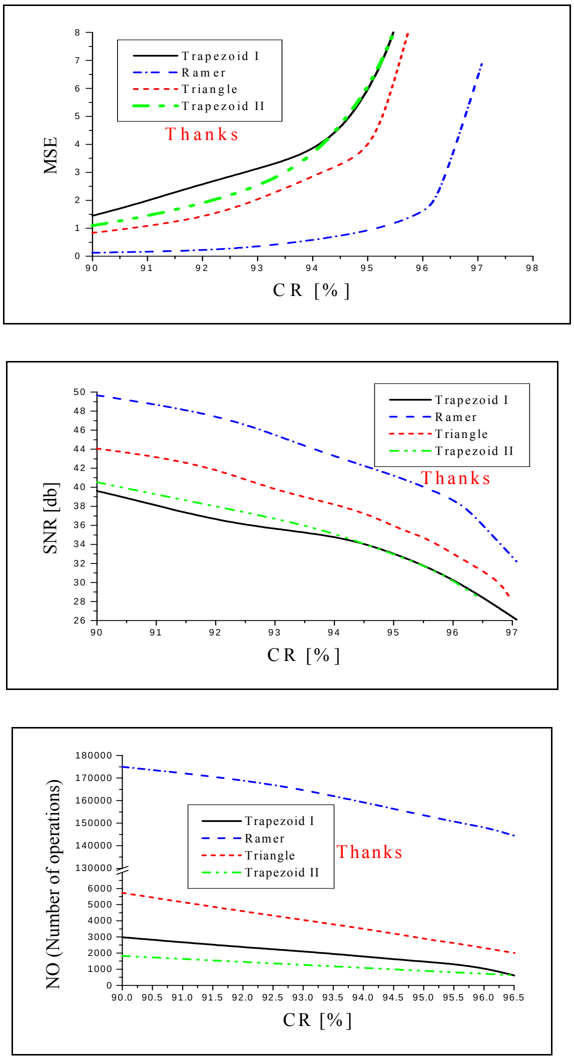
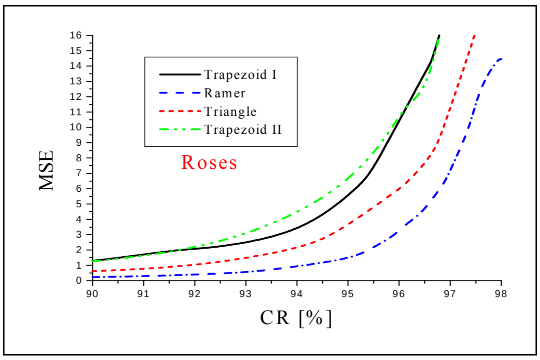


Fig. 16. Comparison of the analysed method with Ramer and Triangle methods for MSE, SNR, and NO versus CR for the Text contour



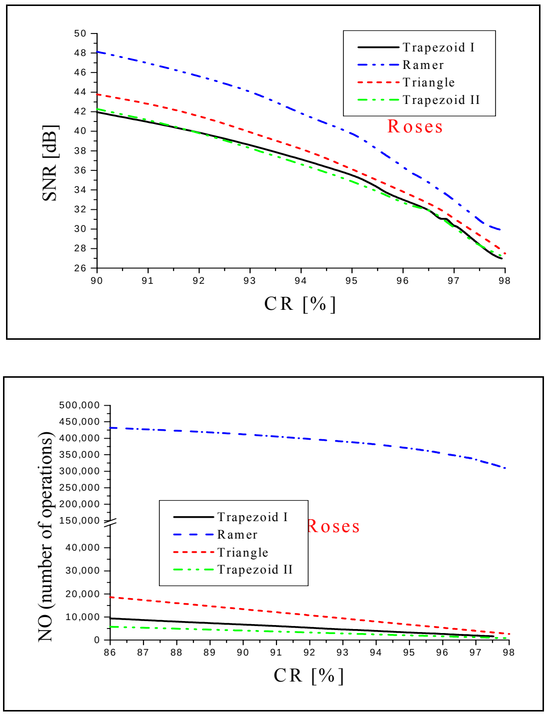


Fig. 17. Comparison of the analysed method with Ramer and Triangle methods for MSE, SNR, and NO versus CR for the Rose contour

The presented results show that the analysed method is much faster than that of comparing methods in all analysed cases. However, the SNR using the Ramer algorithm gives much better approximation quality than Triangle, Trapezoid (algorithm I) as well as the analysed method (algorithm II); but the proposed algorithm II is much faster than the others. Large number of operations is obtained using Ramer method because it searches for the maximum distance from all points in the curve segment and straight line between the starting and ending points of contour segment.

7. Conclusion

The very small number of operations and accepted quality of approximation are the main advantages of the proposed algorithm. Therefore the computational time is much less and it allows the analysed algorithm to be used in a wide application for contours where the speed is necessary. The presented results show that the analysed algorithm for contour approximation is many times faster than that of Ramer, Triangle and Trapezoid (algorithm I) methods. The high compression can be obtained with little significant loses of approximation quality. The compression ratio obtained by this method can be greater than or equal to 96% (as shown in Fig. 7). To obtain higher compression ratio with small significant visible distortion in the reconstruction quality; the accepted level of the reconstruction quality is determined. The threshold which has maximum number of points between each two points in the trapezoid shape with the conservation of the accepted level of the reconstruction quality is the optimum value within range (0.1 - 0.2). The results concluded that both algorithms (I & II) of Trapezoid method has higher compression efficiency for single contour than multi-contours but the proposed algorithm (II) is much faster. The simplicity of implementation is also an important advantage of the analysed method both in terms of memory requirement and fit criterion complication.

طريقة جديدة لضغط المحيط

علي عبد الرحمن عكاشة *

المـلخص

تقدم هذه الدراسة لوغاريثم جديد لطريقة تسمى بشبه المنحرف لضغط المحيطي. اللوغاريثم المحلل يمكن بفعالية من تقريب فئة من الأجزاء المستقيمة بطريقة مثلى في حدود كفاءة المحيط. يتم تمثيل نقاط دخل المحيط في الإحداثيات الكارتيزية والتي تعالج بطريقة ما لإنتاج مجموعة نقاط لكي يتسنى إختيار بعضها لمضلع المحيط. اللوغاريثم المقترح له بعض الميزات الرئيسية مقارنة مع اللوغاريثمات الموجودة سلفا وهى سرعتها في التمثيل.
اللوغاريثم المقترح سيقارن مع طريقة رامر لأن لها جودة أفضل من بين اللوغاريثمات المعروفة ومع الطريقة المثلثية لأن لها سرعة فى التمثيل وبجودة عالية بالأضافة الى طريقة شبه المنحرف (اللوغاريثم الأول I) لتقريب المحيط. حساب الزمن اللازم للطريقة المحللة يخمن إعتمادا على عدد العمليات الحسابية. هذه الورقة توضح أن البساطة هي سمة إضافية مهمة للطريقة المقترحة. هذا العمل يعطي مقدمة عامة على التركيب البنائي للمنظومة ووصف تقنية الضغط وتناقش كيفية تمثيلها.
نتائج التجارب لصور ذات محيط واحد أو لعدة محيطات يتم الحصول عليها في حدود جودة الصورة، نسبة الضغط وزمن إستعادة الصورة.
الدراسة خلصت إلى أن للطريقة المحللة كفاءة ضغط محيط عالية وبجودة مقبولة لأنواع مختلفة من المحيطات من لغات مختلفة كالعربية والإنجليزية .

8. References

1. Ramer U.: 1972, An iterative procedure for the polygonal approximation of plane curves, *Computer Graphics and Image Processing, Academic Press, 1*, 244.
2. Sirjani A., & Cross Dixon G. R., 1984, An algorithm for polygonal approximation of digitized object, *Pattern Recognition,7*, 5, 299.
3. Montanari U., 1970, A note on minimum length polygonal approximation to a digitized contour, *Comm. of ACM, 13*, 1, 41.
4. Baran R., & Dziech A., 2005, Tangent method and the other efficient methods of contour compression, *WSEAS Transactions on Computers*, *4*, 7, 805.
5. Freeman H., 1961, Techniques for the digital computer analysis of chain-encoded arbitrary plane curves. *Proc. of the National Electrician Conference,* Chicago Illinois, 421.
6. Jain A. K., 1989, *Fundamentals of digital image processing* (Englewood Cliffs, NJ: Prentice-Hall).
7. Dziech A., Baran R., & Ukasha A., 2005, Contour compression using centroid method. *WSEAS Int. Conf. on Electronics, Signal Processing and Control (ESPOCO),* Copacabana, Rio de Janeiro, Brazil, 225.
8. Duda R. O., & Hart P. E., 1973, *Pattern classification and scene analysis* (NY: John Wiley & Sons).
9. Heijden F., 1995, *Image Based Measurement Systems* (NY: John Wiley & Sons).

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10. Nabout A., & Nour Eldin H. A., 1993, The topological contour closure requirement for object extraction from 2D-digital images. *Proc. IEEE Conf. on Systems, Man and Cybernetics, Le Touquet, France*, 120.
11. Dziech A., Ukasha A., & Baran R., 2006, Fast method for contour approximation and compression, *WSEAS Transactions on communications, 5*, 1, 49.
12. Nabout A., Su B., & Nour Eldin H. A., 1995, A novel closed contour extractor, principle and algorithm. *Proc. of the IEEE/ISCAS Conf. on Circuits and Systems*, Seattle, USA, 445.
13. Dziech A., Besbas W. S., Nabout A., & Nour Eldin H. A., 1997, Fast algorithm for closed contour extraction. *Proc. of the 4th International Workshop on Systems, Signals and Image Processing*, Poznań, Poland, 203.
14. Batchelor B. G., & Laing S. G., Polar-vector representations of edges in Pictures, *Electronics Letters, 13*, 24, 1977, 727-729.
15. Freeman H., Boundary Encoding and processing, 1970, *picture Processing and Psychopictorics, Academic Press*, 241.
16. Ukasha A., Saffor E., & Hassan M., 2008, Contour compression using trapezoid method. *International Symposium Computer and Information Sciences (IEEE/ISCIS),* Istanbul, Turkey.
17. Ukasha A., Dziech A., Elsherif E. & Baran R., 2009, An efficient method of contour compression. *International Conference on Visualization, Imaging and Image Processing (IASTED/VIIP),* Cambridge, United Kingdom, 213.