An Efficient Spatial Domain Methods & Wavelet Transform for Contour Compression

Ali Ukasha and Fathi Alwafie

Abstract— This paper presents a method of contour extraction and compression from grey level image. The proposed algorithm is applied in spectral domain using single-level wavelet transform (WT). Single step parallel contour extraction (SSPCE) method is used for the binary image after inverse wavelet transform is applied to the details images. Then the contours are compressed using either ramer, tangent, triangle, or trapezoid methods in spatial domain. Effectiveness of the contour extraction and compression for different classes of images is evaluated. In the paper the main idea of the analyzed procedure for both contour extraction and image compression are performed. To compare the results, the mean square error, signal-to-noise ratio criterions, and compression ratio (or bit per pixel) were used. The simplicity to obtain compressed image and extracted contours with accepted level of the reconstruction is the main advantage of the proposed algorithm.

Keywords— Wavelet transform, image compression, ramer, tangent, triangle and trapezoid methods.

I. INTRODUCTION

Contour representation and compression are required in many applications e.g. computer vision, topographic or weather maps preparation, medical images and moreover in image compression. The transform coding method compresses image data by representing the original signal with a small number of transform coefficients. It exploits the fact that for typical images a large amount of signal energy is concentrated in a small number of coefficients. The goal of transform coding is to minimize the number of retained transform coefficients while keeping distortion at an acceptable level. Transform coding is an integral part of one of the most widely known standards for lossy image compression, the JPEG (Joint Photographic Experts Group) standard. Contour extraction and image compression can be obtained using transforms such as fourier [1], walsh [10], dct [3], wavelet [6] and periodic haar piecewise-linear (PHL) which is based on the integration of haar functions [4]. In this paper the discrete wavelet transform will be used. To obtain the compressed image and binary image, inverse wavelet transform is applied to the approximation coefficients image and details coefficients images respectively. The contours are extracted from binary image using single step parallel contour extraction (SSPCE) method [2]. Finally the compressed contours are obtained using either ramer, tangent, triangle, or trapezoid methods.

Flowchart of the algorithm for image compression and contour extraction is depicted in Fig.1.

![Flowchart of the proposed algorithm for image compression and contour compression](image)

Fig. 1. Flowchart of the proposed algorithm for image compression and contour compression

II. DISCRETE WAVELET TRANSFORM (DWT)

The Wavelet analysis is an exciting new method for solving difficult problems in mathematics, physics, and engineering, with modern applications as diverse as wave propagation, data
compression, signal processing, image processing, pattern recognition, computer graphics, the detection of aircraft and submarines and other medical image technology [6]. Wavelets allow complex information such as music, speech, images and patterns to be decomposed into elementary forms at different positions and scales and subsequently reconstructed with high precision.

Wavelets are obtained from a single prototype wavelet called mother wavelet by dilations and shifting using the equation (1).

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}} \Psi\left(\frac{t-b}{a}\right)$$  \hspace{1cm} (1)

III. 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 [7]. Fitting the curve of closed contour by the line segment using ramer method is shown in Fig. 2.

![Fig. 2. Curve approximation by ramer method](image)

IV. 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. 3 [5].

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 equation (2).

$$\frac{h}{b} < \text{th}$$  \hspace{1cm} (2)

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. 3. Curve approximation by triangle method](image)

V. TRAPEZOID METHOD

The algorithm is belongs to a family of polygonal methods of approximation. The idea of the algorithm consists in segmentation of the contour points to get trapezoid shapes (points of SP, B, C, and EP) [8] & [9]. 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; 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. 4, and is defined by equation (3).

$$\frac{dB}{dC} < \text{th}$$  \hspace{1cm} (3)

where th is given threshold value.

Trigonometric formula is used to calculate these values. If equation (3) is not valid the second, third and ending points are stored 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 and the SP is shifted to the EP; then a new segment is drawn. The vertices of an edge of the approximating polygon are determined by these stored points.
VI. TANGENT METHOD

This method uses tangent of an angle between two straight lines called opening line which is constant for all of the segment points and closing line as the fit criterion [11]. These two lines determine the width of analyzed segment as set of input sequence points which is going to be replaced by an edge of the approximating polygon. Fig. 5 shows the fit criterion of the algorithm.

![Diagram of tangent method](image)

Fig. 5. Curve approximation by tangent method

The analyzed criterion of the ramer, tangent, triangle, and trapezoid algorithms can be modified depending on methods of contour representation. The contour uses chain coding schemes of contour representations to determine all possible connections for both 8-connectivity and 4-connectivity schemes such as Cartesian representation, or polar representation, or generalized [6].

VII. APPLIED MEASURES

The proposed image compression and contour extraction method is related to the data compression and extraction problems. To evaluate its compression ability, the following compression ratio (or bit per pixel) was introduced if each pixel is implemented by eight bits, and is defined by equations (4) and (5) respectively.

\[ CR = \frac{\text{NOZ}}{(n \times m)} \times 100\% \]  

where: NOZ is number of zero coefficients in the spectral domain; \( n \times m \) is size of the image

\[ \text{bpp} = \frac{\text{ZS} \times 8}{(n \times m)} \]  

where: ZS is coefficients number in the desired zonal

The mean square error (MSE) and peak signal-to-noise ratio (PSNR) criterions were used to evaluate the distortion introduced during the image compression and contour extraction procedures, and is defined by equations (6) and (7) respectively.

\[ \text{MSE}(I, \tilde{I}) = \frac{1}{(n \times m)} \sum_{i=0}^{n} \sum_{j=0}^{m} (I(i,j) - (\tilde{I}(i,j)))^2 \]  

\[ \text{PSNR}(I, \tilde{I}) = 10 \log_{10} \left( \frac{(L - 1)^2}{\text{MSE}(I, \tilde{I})} \right) \]  

where \( I \) is the original image, \( \tilde{I} \) is the reconstructed image, and \( L \) is the grey-level number.

VIII. RESULTS OF THE EXPERIMENTS

To visualize the experimental results a test grey level image were selected. Selected image is shown in Fig. 6.
The decomposition of Tools image using first level of DWT is shown in Fig. 7.

The compressed Tools image can be obtained using approximation coefficients only as shown in Fig. 8 (related results are shown in the Table 1).

<table>
<thead>
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<th>Table 1</th>
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<td>MSE</td>
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<td>b)</td>
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The extracted contours using SSPCE method for contour extraction of Tools image are obtained using horizontal, vertical, and diagonal coefficients as shown in Fig. 9.

![Fig. 9. Tools image: (a) Binary image from details coefficients, and (b) Contours extraction using SSPCE method](image)

The compressed contours for Tools image are obtained using ramer, tangent, triangle, and trapezoid methods are shown in Fig. 10 (related results are shown in the Table 2).

<table>
<thead>
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<th>Table 2</th>
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<td>Measures Method (Compression)</td>
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<td>a) Tangent</td>
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<td>b) Ramer</td>
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<td>c) Triangle</td>
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<td>d) Trapezoid</td>
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The proposed algorithm is compared with binary image which is obtained using suitable threshold criteria as shown in Fig. 11 (related results are shown in Fig. 12 and in Table 3).

![Fig. 11. Tools image: (a) Binary image using threshold, and (b) Contours extraction using SSPCE method](image)

![Fig. 6. Test image: Tools (256x256) ![Image 124x646 to 223x727](image)

![Fig. 7. Tools image decomposition using first level of DWT ![Image 79x235 to 267x443](image)

![Fig. 8. Tools image reconstruction using approximation coefficients: a) Original image, and b) Compressed image ![Image 64x118 to 163x199](image)

![Fig. 9. Tools image: (a) Binary image from details coefficients, and (b) Contours extraction using SSPCE method](image)

![Fig. 10. Tools image: (a) Binary image from details coefficients, and (b) Contours extraction using SSPCE method](image)

![Fig. 11. Tools image: (a) Binary image using threshold, and (b) Contours extraction using SSPCE method](image)
with accepted quality compared with the binary image using threshold value. It is seen that ramer algorithm takes more time than the tangent, triangle, and trapezoid algorithms in the analyzed method for tested image. The presented results show that the proposed method using triangle method is much faster than that others for tools image. The results show that SNR is improved by the proposed algorithm compared to binary image using suitable threshold value by about 0.2 decibels for some images.

**IX. CONCLUSIONS**

The good quality of contour extraction and compression are the main advantage of the proposed algorithm compared with the binary image using suitable threshold value. By using single level of discrete wavelet transform the two sub-images are obtained (compressed image and extracted contour). Ramer, tangent, triangle, and trapezoid methods are used to compress the extracted contours without significant visible distortion. The reconstruction quality improvement of compressed contour compared to the binary image which is obtained by using of suitable threshold value is about 0.2 decibels. The contour compression using triangle and tangent methods is much faster than using of ramer and trapezoid method for all analyzed cases. Important advantage of the analyzed method is the simplicity of implementation both in terms of memory requirement and fit criterion complication.

**REFERENCES**


