COMPARISON OF SOME EFFICIENT METHODS OF CONTOUR COMPRESSION

REMIGIUSZ BARAN\textsuperscript{1} ANDRZEJ DZIECH\textsuperscript{2}
\textsuperscript{1}Department of Electronics and Intelligent Systems, Kielce University of Technology, POLAND
\textsuperscript{2}AGH University of Science and Technology, Świętokrzyska Academy in Kielce, POLAND

Abstract: - Effectiveness of the Tangent Method [4,5] for contour approximation is discussed in the paper. The compression abilities, level of introduced distortion, complexity (expressed by the computational time) of this algorithm are measured and compared with some other, appreciated methods. The mean square error, signal-to-noise ratio and number of required operations are used as the main criterions of this comparison. Finally, results of experiments and advantages and drawbacks of the Tangent Method (TM) are discussed.

Key-Words: - contour representation, contour compression, polygonal approximation, the Ramer method, the MMSE algorithm.

1 Introduction

Edge detection and contour-tracing techniques produce contour lines. Contours play an important role in image and signal data processing. Contour compression can be applied in such common areas as topographic or weather maps preparation, character recognition, processing of medical images, image compression etc. Contour processing is also required in computer vision e.g. robot guidance or non-contact visual inspection.

The fundamental goal of the digital signal compression is to reduce the bit rate for transmission and storage without significant loss of information. One of the main approaches solving this problem is the time domain approach. Most of the time domain methods for contour approximation and compression are based on the polygonal approximation scheme [6]. The mostly appreciated example of such scheme is the Ramer algorithm [1]. Also very efficient are the algorithms: the MMSE (Minimum Mean Square Error) [2], the MAE (Minimum Area Error) [3] and the recently developed TM algorithm [4,5] A quite new approach to the polygonal approximation, which is generally based on a gradient of the contour line, is used by the TM algorithm.

2 The TM Algorithm

The fit criterion of the discussed TM algorithm [5] is the tangent of an angle between two straight lines, called opening and closing lines. These two lines determine the width of analysed segment - a set of input sequence points which is going to be replaced by an edge of the approximating polygon.

The fit criterion of the TM algorithm is illustrated in Fig. 1.

![Fig. 1. Fit criterion of the TM algorithm.](image)

The opening line is passing through the first two points of a new segment under the investigation. The first point of each segment is the starting point SP. The SP point and the third point - the ending point EP - of the investigated segment determine the closing line. If the tangent of the $\phi$ angle is less than a given threshold $p$ then EP point is shifted to the next point and the new closing line is drawn. Otherwise, the SP and EP points determine vertices of an edge of the approximating polygon. Next the EP is marked as the SP point of a new segment.
The described TM algorithm can be applied for contours represented in different ways: by using polar, Cartesian or the \((θ, l)\) co-ordinates of the generalised chain coding [6]. The \((θ, l)\) representation is a case of the generalised chain coding scheme where the contour curvature is encoded as a function of a fitting segment length. Adequate equations for the fit criterion were derived for each of contour representation methods listed above [5].

2.1 Equations in Cartesian representation

The fit criterion in Cartesian representation can be obtained from the following equation

\[
tg \phi = \frac{m_2 - m_1}{1 + m_2 \cdot m_1}
\]

where:
- \(m_1\) - slope of the opening line;
- \(m_2\) - slope of the closing line.

Tangent of the \(φ\) angle is specified if \(m_2 \neq m_1\), or in other words, if the \(φ\) angle is in range \((-π/2, π/2)\).

2.2 Problem of the “cutting effect”

Such fit criterion leads to the undesirable “cutting effect”. The reason why this effect occurs is illustrated in Fig. 2.

Fig. 2. Illustration to the “cutting effect” problem.

Fig. 2 shows a situation where the EP point is not achieved. This is when the tangent of the \(φ\) angle is less than the threshold \(p\). To eliminate the disadvantage of the “cutting effect” a second input parameter - MWS, was introduced. The MWS parameter limits the maximum width of the analysed segment.

Flowchart of the TM algorithm for contours in Cartesian representation is depicted in Fig. 3.

3 Applied Measures and Test Contours

To evaluate the compression abilities of the algorithms a following compression factor was introduced

\[
η = \frac{(L_C - L_{AC})}{L_C} \cdot 100\% \tag{2}
\]

where:
- \(L_{AC}\) - length of the approximating polygon;
- \(L_C\) - length of the input sequence \(C\).

To evaluate level of the distortion introduced during the approximation procedure the mean square error (\(ε\)) and signal-to-noise ratio (SNR) criterions were used. The mean square error is defined as follows

\[
ε = \frac{1}{L_C} \sum_{i=1}^{L_C} d_i^2 \tag{3}
\]

where:
- \(d_i\) - distance between the input contour \(i\)-point and the edge of the approximating polygon; if the edge is a part of a straight line described by a common equation, then

\[
d_i = \frac{|A \cdot x_i + B \cdot y_i + C|}{\sqrt{A^2 + B^2}}
\]
The SNR criterion is defined by the following equation

\[ \text{SNR(dB)} = 10 \cdot \log \left( \frac{\sigma_C^2}{\epsilon} \right) \]  \hspace{1cm} (4)

where:

\[ \sigma_C^2 = \frac{1}{L_C} \sum_{i=1}^{L_C} (C_i - C_{\text{ave}})^2 \quad \text{- variance of sequence } C, \]

\[ C_{\text{ave}} = \frac{1}{L_C} \sum_{i=1}^{L_C} C_i \quad \text{- average of sequence } C. \]

Computational time of the TM procedure depends in general on used hardware parameters. In our analysis the following measure of number of operations is used

\[ NpL = \frac{\text{number of operations}}{L_C} \] \hspace{1cm} (5)

A set of two test contours was selected for purpose of better presentation. Selected contours are shown in Fig. 4.

Fig. 4. Selected test contours.

### 4 Selection of the MWS Parameter

Plots of \( \epsilon \) and SNR versus compression factor \( \eta \) for different values of MWS parameter are shown in Fig. 5.

The mean square error should not exceed the value of 3.5 and SNR should not be less than 31. Otherwise, all of the input contour details are eliminated and level of introduced distortion cannot be accepted. Therefore, it is reasonable to select the value of MWS equal to 20.

### 5 Experimental Results

Selected results of contour approximation performed with use of all the discussed algorithms (with different values of \( p \)) are shown in Figs. 6, 7, 8 and 9.

<table>
<thead>
<tr>
<th>Case</th>
<th>( p )</th>
<th>( \epsilon )</th>
<th>SNR</th>
<th>( NpL )</th>
<th>( \eta[%] )</th>
</tr>
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<tbody>
<tr>
<td>a)</td>
<td>4,0</td>
<td>1,22</td>
<td>37,86</td>
<td>57,24</td>
<td>96,00</td>
</tr>
<tr>
<td>b)</td>
<td>4,8</td>
<td>2,57</td>
<td>34,60</td>
<td>53,53</td>
<td>96,78</td>
</tr>
<tr>
<td>c)</td>
<td>3,8</td>
<td>1,44</td>
<td>34,50</td>
<td>69,30</td>
<td>95,97</td>
</tr>
<tr>
<td>d)</td>
<td>5,0</td>
<td>2,40</td>
<td>32,29</td>
<td>65,17</td>
<td>96,91</td>
</tr>
</tbody>
</table>

Fig. 5. Plots of \( \epsilon \) versus \( \eta \) (a) and SNR versus \( \eta \) (b) for different values of MWS parameter.

Fig. 6. Results obtained with use of the Ramer algorithm.
Presented results show that all the compared algorithms have good compression abilities. The compression factor for the Ramer, MMSE and MAE algorithms is even more than 96%. Compression abilities of the presented Tangent Method are slightly worst - maximum value of the compression factor was almost 95%.

However, the TM algorithm is much faster than the others. The $N_{pl}$ parameter shows that the computational time of TM is about 2 times shorter than that of the MAE, about 7 times shorter than that of the Ramer and even more than 20 times shorter than that of the MMSE.

The obtained results are presented in Figs. 10, 11 and 12.
Figs. 10 and 11 shows that the Ramer algorithm has the best compression abilities. The difference between the Ramer and the Tangent Method algorithms is about 2%. It is also noticeable that the compression factor for presented Tangent Method algorithm is limited (because of MWS).

Fig. 11. SNR versus compression factor $\eta$.

Fig. 12 confirms main advantage of the presented Tangent Method algorithm - the Tangent approximation procedure is a few times faster than the others. The fastest one is the Tangent Method algorithm for Cartesian method of contour representation. It is because of the fit criterion similarity. It can be also remarked that the computational time is rising when the compression factor is rising. Such dependence is true for the Tangent Method and MMSE algorithms. The contrary dependence is obligatory for the Ramer procedure.

6 Conclusions
- The main advantage of the Ramer method is its good compression abilities. Its main fault is a large complexity and a long computational time.
- The MMSE procedure has good compression abilities and a slow algorithm.
- The MAE algorithm shows good abilities of compression and short computational time.
- The main advantage of the Tangent Method in comparison with the Ramer, the MMSE and the MAE algorithms is a very short computational time of the approximation procedure. In addition, the TM algorithm shows that the decreasing of the computational time can be achieved without significant loss of approximation quality. The advantage of this method is also simplicity of implementation both in terms of memory requirement and fit criterion complication, what is especially noticeable for the algorithm for contours in Cartesian representation.

Acknowledgement
This work was supported by the Polish State Committee for Scientific Research (KBN) under the Grant No. 4T11D00525 (period of support: 2003-2005).

Reference: