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SEQUENTIAL DATA COMPRESSION WITH DOUBLE TRACING METHOD

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ABSTRACT

This paper introduces a double tracing method as one of the fast sequential methods to reduce the data of a contour.

A sequential structured double tracing data compression method is introduced and examined its properties. This double tracing method is developed to improve the line fittingness of the distance based sequential data compression. A weighting method to determine the significance of each vertex is discussed to remain the important local structures of a contour.

1. Introduction

There are many CAD/CAM or CIM systems with various input devices as camera or scanner. It is important to describe a contour with fewer descriptions with keeping the enough quality.

Various kinds of data compression methods have been introduced for each particular purpose or for the general purposes(1)(2)(3)(4)(5). These data compression methods can be classified for two major characteristics. One is sequential structured method, and the other is non sequential structured method. Generally, the better approximation and the better data compression ratio are realized by non sequential structured methods, and less time and memory consumption are realized by sequential structured methods.

This paper introduces two sequential structured methods. Both two methods in this paper require exact one pass of original data to select the neglectable data. In many sequential structured methods, some distortion may appear between original contour and compressed contour. These distortion may neglect the vertices even a clear corners as a corners of square.

The proposed method neglects on-line vertices with first trace, and sequentially followed second trace extracts the corners.

We also propose the weight function of each vertex at the second trace. This weight function of each vertex is measured during the first trace.

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2. Distance based sequential data compression

As the data compression, let us review previous methods in this section. At the next section, sequential data compression with keeping contour features will be examined.

Figure 1 shows one of the typical non sequential data compression method.

The procedure of this method can be described as follows.

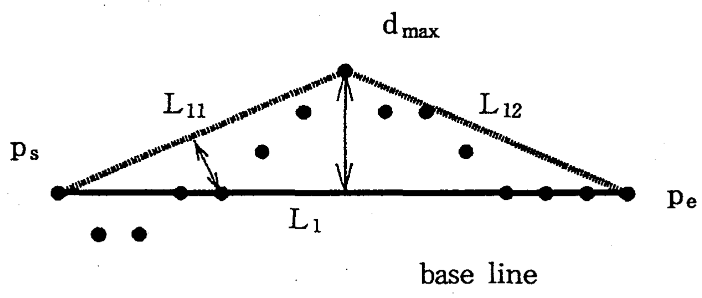


Fig.1 Non sequential method

Procedure A : non sequential method

1. Connect two end points of the contour S with straight line L_1.
2. Calculate distance d_{1j} to each point p_j from the line L_1.
3. If a point p_i with the maximum distance $d_{1i} = d_{1max}$ from the line L_1 is over the tolerance ε, divide the line L_1 into two parts L_{11} and L_{12} at the point p_i.
4. Re-calculate the distance to each point from the respected line.
5. Divide the line L_{qr} until all points of the contour locate within the tolerance ε from the respected line.

This procedure is quite easy to understand, implement and guarantees all neglected points are within the tolerance.

But the biggest disadvantage of this data compression method is the time consumption for recursive distance calculation.

In order to reduce the calculation time, we already proposed some sequential procedures for data compression without loosing the major features of original contour.

One of the sequential data compression procedure shown in Fig.2, can described with following procedure[6].

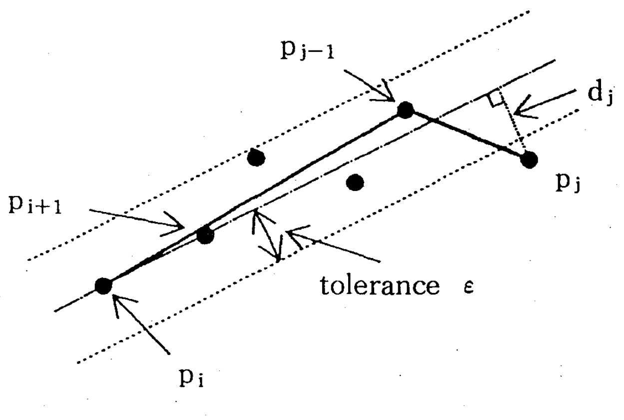


Fig.2 Sequential method

Procedure B : sequential method

1. Assume base line L_{ij} with two points p_i and p_j.
2. Calculate distance d_{j+1} of p_{j+1} from base line L_{ij}.
3. When d_{j+1} satisfies

$$d_{j+1} \geq \varepsilon \quad , \tag{1}$$

then point p_i is not reductive.
Renew the points for base line as $p_i = p_j$, $p_j = p_{j+1}$ and going back to procedure 1.

4. When d_{j+1} satisfies

$$d_{j+1} < \varepsilon \quad , \tag{2}$$

then p_{j+1} has possibility to be neglected.
Then calculate distance d_{j+2} at p_{j+2} from base line L_{ij}.

5. When d_{j+2} satisfies

$$d_{j+2} \geq \varepsilon \quad , \tag{3}$$

then p_{j+1} can not be neglected.
In this case, renew the points for base line L_{ij} as $p_i = p_j$, $p_j = p_{j+1}$ and going back to procedure 2.

6. When d_{j+2} satisfies

$$d_{j+2} < \varepsilon \quad , \tag{4}$$

then point p_{j+1} is proved as reductive point. Still the point p_{j+2} keeps possibility to be neglected.

Generally, when the points p_i, p_j are the points to define the base line L_{ij}, and the relation of distance $d_{j+n} \leq \varepsilon$ is assumed,

The line L_{jn} defined by p_j and p_n will be new base line with the assumption of following relation.

$$d_{j+n+1} > \varepsilon \qquad (n = 1,2,3,\cdots) \tag{5}$$

New base line is defined with renewed points $p_i = p_j$, $p_j = p_n$ as L_{ij}.

If equation (5) is satisfied with $n = 0$, that means $d_{j+1} > \varepsilon$ against base line L_{ij}.

There are two more exceptions to this procedure at start point and at end point. Both the start point p_1, and the end point p_e of the input should never be neglected.

All of these exceptions in this procedure have been done to keep the maximum distance d_{max} between input contour and output contour within the tolerance ε .

With this procedure, all neglected points are guaranteed to be within the tolerance ε .

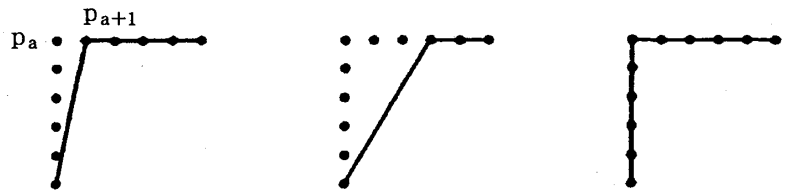
3. Definition of the procedure for double tracing data compression

With sequential procedure B shown in Section 2, enough ability was confirmed, but some problems are still remained.

As shown in Fig.3(a), when the tolerance has the relation of $2d > \varepsilon \geq d$, sequential procedure B selects the point p_{a+1} as a corner point of given contour, though the point p_a is the true corner points.

This is simply caused by the output points are selected as the last point that does not exceed the tolerance ε from baseline. As the result of this feature of sequential procedure B, when original contour has clock wise direction, output will be slightly rotated to clock wise. When original contour has counter clock wise direction, output will be slightly rotated to counter clock wise.

To eliminate this rotation of the contour, we introduced another procedure as sequential procedure C as follows.



(a) $\varepsilon=2$ (b) $\varepsilon=4$ (c) ideal

Fig.3 Distortion by single trace method

Procedure C : double trace sequential method

1. Select two points p_i and p_{i+1} as base line L_i, and set the straight line tolerance ε_s as

$$\frac{\sqrt{2}}{2}a < \varepsilon_s < a \quad , \tag{6}$$

where a is the minimum unit of this coordinates.

2. Calculate distance d_{ij} of the point p_j $(j=i+1, i+3, \ldots)$

$$d_{ij} = dist(L_{1i}, p_j) \quad , \tag{7}$$

where $\mathrm{dist}(L,p)$ calculates the distance between line L and point p.

3. When d_{ij} satisfies

$$d_{ij} \geq \varepsilon_s \quad , \tag{8}$$

the point p_{j-1} is selected as the output of this first process, because the point p_{j-1} is the last point that has the distance less than tolerance ε_s.

4. Renew the points $p_i = p_{j-1}$ and $p_{i+1} = p_j$, and continue procedures 2. and 3. These procedures neglect the on-line vertices.

5. When we get three output points q_{s-1}, q_s and q_{s+1} from previous procedure, calculate distance

$$d_{s-1,s+1} = dist\ (L_{q_{s\ 1}}, q_{s+1}) \quad . \tag{9}$$

6. When $d_{s-1,s+1}$ satisfies

$$d_{s-1,s+1} \geq \varepsilon_g \quad , \tag{10}$$

where ε_g is given global tolerance, point q_{s-1} and q_s becomes final output and renew base line by q_s and q_{s+1}, then continue procedure 2. to get the point q_{s+2}.

7. When $d_{s-1,s+1}$ satisfies

$$d_{s-1,s+1} < \varepsilon_g \quad , \tag{11}$$

point q_{s+1} may be neglected after examining next point q_{s+2}.
So, go back to procedure 2., and get the next output q_{s+2}.

8. When $d_{s-1,s+2}$ satisfies

$$d_{s-1,s+2} < \varepsilon_g \quad , \tag{12}$$

the point q_{s+1} will never be used as the final output points, then the next point q_{s+2} should be prepared.

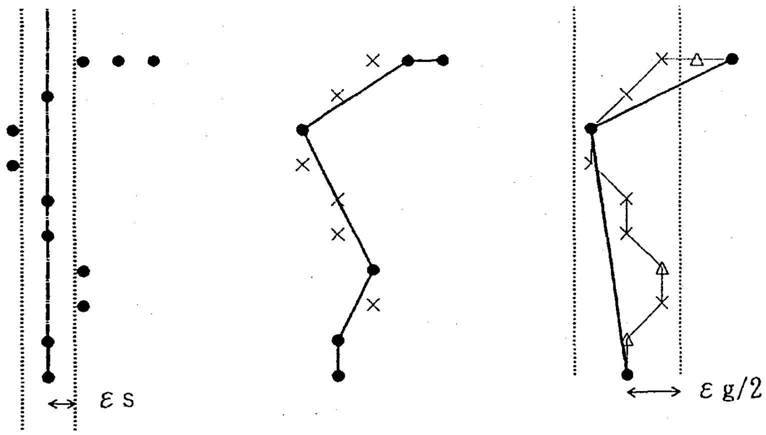
9. When $d_{s-1,s+2}$ satisfies

$$d_{s-1,s+2} \geq \varepsilon_g \quad , \tag{13}$$

the points q_{s-1} and q_{s+1} are used as the final output points.

10. Renew the all candidate points, and go back to procedure 1.

The flow of this method is shown in Fig.4.



● original data × reduced by 1st trace △ rduced by 2nd trace
(a) original (b) 1st trace (c) 2nd trace

Fig.4 Procedure of double trace method

The first trace is given by procedures 1. to 4. which neglect vertices on the base line. The second trace is given by procedures 5. to 9. which neglect vertices near the base line.

To prove the efficiency of the proposed sequential data compression procedure, some experiments have been done.

The contour in Fig.5 is digitized by the flat bed scanner. Tiny circles in each contour show the final output points of the proposed procedure.

Fig.6 shows the rotation invariability with the rotated contour of Fig.5.

Both Fig.5 and Fig.6 prove the accuracy of corner detection for feature extraction.

The proposed procedure also effective for more complexed contour as shown in Fig.7. The result of the data reduction with tolerance $\varepsilon_g = 6$ with Procedure B (single trace), ε_g

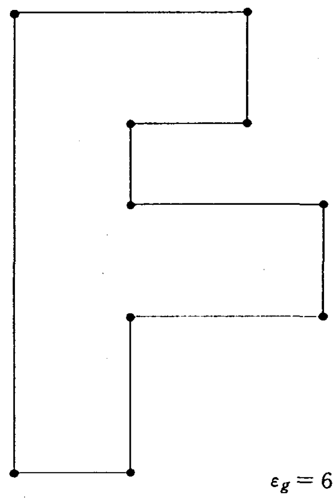


Fig.5 Example of double trace method

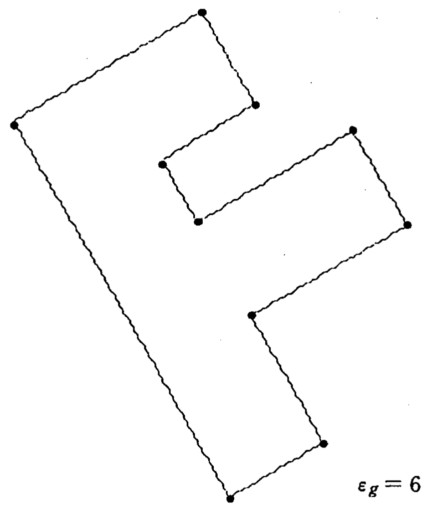


Fig.6 Example of rotation invariability

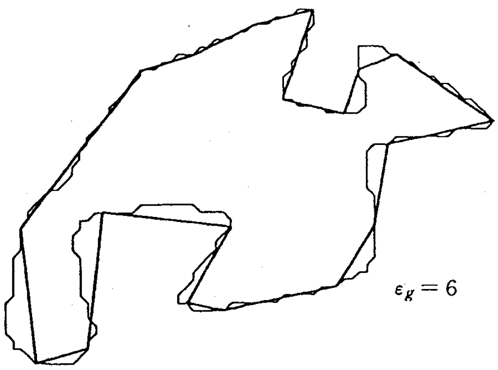


Fig.7(a) Example of complicated contour by single trace

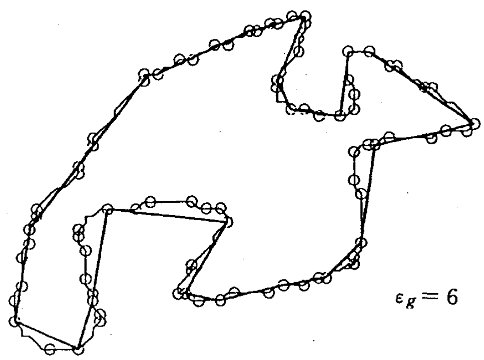
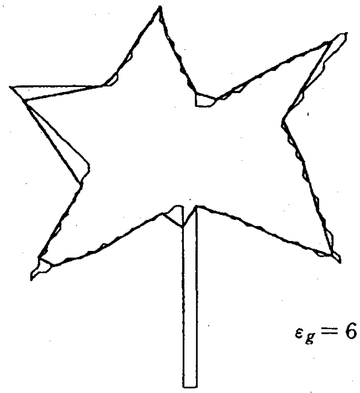


Fig.7(b) Example of complicated contour by double trace

= 6 with Procedure C (double trace) are shown in Fig.7(a) and Fig.7(b) respectively.

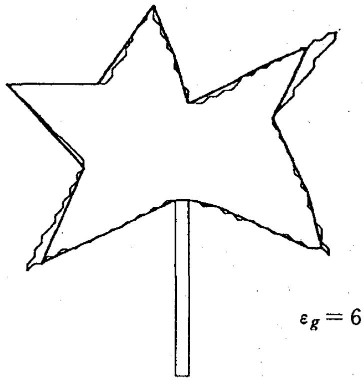
4. Weight function of point to keep the contour features

Even by the double tracing data compression method, the narrow channel shown in Fig.8 may be neglected from the output. Fig.8(a) shows the result by Procedure B with the tolerance $\varepsilon_g = 6$, and Fig.8(b) shows the result by Procedure C with the same tolerance. In both results, the vertices for narrow channel at the bottom of the original contour are neglected.



— output contour
— original contour

Fig.8(a) Neglected feature by single trace



— output contour
— original contour

Fig.8(b) neglected feature by double trace

To protect these important features of original contour from reduction, we added a definition of the weight function of a point.

The weight function w_i of a point p_i is calculated as total number of points between p_h (former selected point) and p_j (next selected point) as following,

$$w_i = (j - i) + (i - h) = j - h \tag{14}$$

where p_h, p_i, p_j are output data series as shown in Fig.9.

The weight function can be measured during the 1st trace in double tracing method as shown in Fig.10.

In the 2nd trace, if a point p_i has the weight w_i than a certain weight tolerance w_T, that point will be selected as non neglectable point.

Fig.10 clearly shows the effect of this double tracing method with weight function. (w_T = 10 and $\varepsilon_g = 6$)

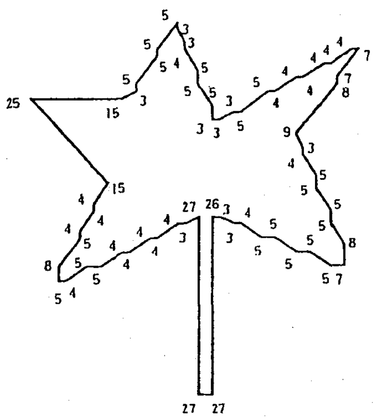
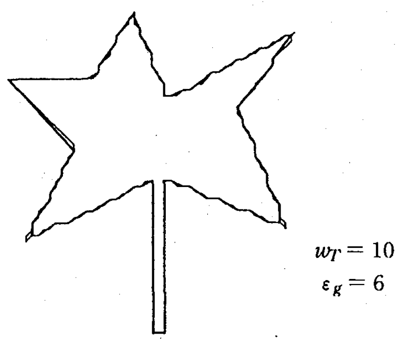


Fig.9 Weight function value after 1st trace



— output contour
— original contour

Fig.10 Feature protection by weight function

5. Conclusion

In this paper, we proposed a sequential data compression procedure with double tracing method.

This procedure requires less time than the procedure with recursive calculation structure. Because the proposed method has simple one pass structure to decide which point of the contour can be neglected or not.

One advantage of the proposed method includes the exact corner extraction from given contour with rotation invariability.

In addition, when the input contour is given by the freeman code, the first trace can be done only by additions and subtractions.

As the data reduction has a character as data smoother, small features of given contour are sometimes lost through .data reduction process. The weight function protect the important points, which shape the feature of original contour, from neglection.

Two methods described in this paper, have complete one pass sequential structure. This structure will reduce the computation load and is easy to implement to any CAD/CAM or CIM system.

Though the 2D contour was treated in this paper, these procedures can be easily extended to the 3D wire frames.

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