AN ENHANCED THINNING ALGORITHM USING PARALLEL PROCESSING

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ABSTRACT

A Thinning algorithm is a very important factor in order to recognize the character, figure, and drawing. Until comparatively lately, the thinning algorithm was proposed by various methods. In this paper, we ascertain the point at issue of ZS, LW and WHF algorithms that are the parallel thinning algorithms. The parallel thinning algorithm means the first processing doesn't have to influence to the second processing. ZS algorithm has a problem that loses pixels in slanting lines and LW algorithm doesn't have one pixel width in slanting lines. So we propose an enhanced parallel thinning algorithm that connects the pixels each other and preserves the end point.

I. INTRODUCTION

Until comparatively lately, many thinning algorithms were researched by various methods. In order to reduce the quantity of information minimally, a thinning algorithm play an important role in recognition of the character, figure, and drawing[1-2].

These thinning methods are classified into two categories. One is an algorithm based the pixel. It is repeatedly to exclude an outline-pixel from a boundary of object until slim lines with one-pixel width are remained. The other algorithm is not based the pixel. The pixel-based method is to find the centerline of object. This algorithm has an advantage of calculation, but it has a fundamental problem to makes noises in horizontal stroke at scan-time. It is not suitable in general applications[1-4].

The pixel-based algorithm is also classified into two categories. In excluding the boundary pixels, to influence the first process to the second process is the sequential method. On the other hand, the parallel processing method means the first process does not influence to the second process.

After ZS thinning algorithm[5] was introduced, many thinning algorithms were proposed by various methods. LW algorithm[6], WHF algorithm[7] and other algorithms are followed. ZS thinning algorithm, referred generally, has problems which does not preserve slanting lines with two-pixel width sometimes. LW algorithm can shrink the horizontal lines well, but has the two-pixel width in slanting lines. WHF algorithm can make the one-pixel width, but according to circumstances, it has a problem that makes needless trees. Those algorithm's results are shown in Fig. 1.

Missing the important information of original image and not having an 8-neighbor connectivity and one-pixel width are the very serious problems. Therefore, we propose a new parallel thinning algorithm. It can preserve information of objects in slanting lines, and has an 8-neighbor connectivity. An algorithm proposed, in this paper, makes the slanting lines with two-pixel width into the one-pixel width lines. And it preserves an 8-neighbor connectivity and makes slim lines with a perfect 1-pixel width. The previous algorithms are reviewed and a new parallel thinning algorithm is proposed in the second section. And we describe the detail and evaluate the performance. In the third section, the experimental results in previous algorithms are shown and compared with the performances by the proposed algorithm, and the problems are discussed. Finally, we conclude the new thinning algorithm and consider the further researches.

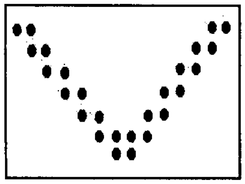
II. PARALLEL THINNING ALGORITHM

2.1 Previous parallel thinning algorithms

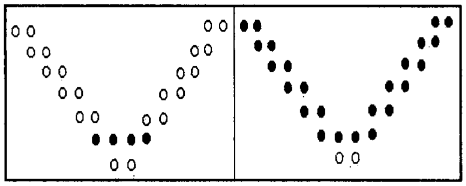
In the drawing and character recognition, the thinning algorithm plays a very important role. Creating the thinned image precisely and making the minimum data is to hold a key to recognize the object.

The study of thinning has been improved until lately. The well-proved thinning algorithms are ZS algorithm, LW algorithm and WHF algorithm, etc. As shown in Fig. 1, ZS algorithm has a problem that the slanting lines are erased. LW algorithm has the problem which slanting lines with two-pixel width were remained. And WHF algorithm has a weak point that makes needless trees.

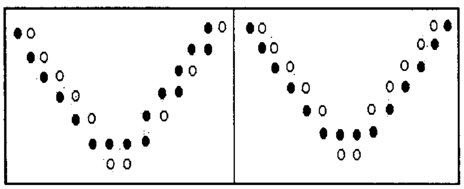
In Fig. 1, (a) is original image and (b), (c), (d), and (e) are each algorithm's performance. The black points are existing pixels and the white points are erased pixels. We can find that ZS algorithm makes one-pixel horizontal line but loses slanting lines. LW algorithm and WHF algorithm have some problems, however the proposed algorithm can settle the problems and make perfect slim lines of 1-pixel with 8-neighbor connectivity.



(a) Original image



(b) ZS algorithm (c) LW algorithm



(d) WHF algorithm (e) Proposed algorithm

Fig. 1 Algorithms' performance

2.1.1 ZS algorithm

ZS parallel thinning algorithm performs sub-iteration step twice.

The first step:
The pixels satisfied with following conditions are erased.

1. $2 \leq B(Pi) \leq 6$
2. A(Pi) = 1
3. P2*P4*P6=0
4. P4*P6*P8=0

Here, B(Pi) is the number of value 1 in 8-neighbor pixels of Fig. 2 (a) and expressed in following equation.

$$B(Pi) = P1 + P2 + \cdots + P8 \quad (1)$$

And, as shown in Fig. 2 (b), A(Pi) means the number of 0 to 1 ($0 \rightarrow 1$) patterns in 8-neighbor pixels.

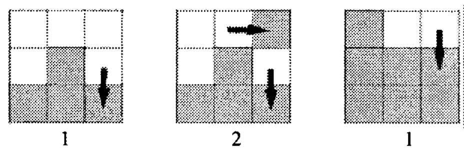
The second step:
Condition 3 and 4 in the first step are replaced with the following conditions.

3'. P2*P4*P8=0

4'. P2*P6*P8=0

P1	P2	P3
P8	Pi	P4
P7	P6	P5

(a) 3×3 mask's pixel position



(b) Number of $0 \rightarrow 1$ patterns

Fig. 2 Mask and number of $0 \rightarrow 1$ patterns

2.1.2 LW algorithm

To solve the problem which slanting lines with 2-pixel width are erased, Lu and Wang replaced the condition 1 ($2 \leq B(Pi) \leq 6$) in ZS algorithm with following condition $3 \leq B(Pi) \leq 6$. By using the modified condition, the slanting lines do not disappeared, however the algorithm can not make 1-pixel slanting lines.

2.1.3 WHF algorithm

In the WHF algorithm, a new condition equation (2) is added to LW algorithm and it improves the algorithm.

$$(P3 \oplus P5)\cdot(P2 \oplus P6)\cdot \overline{P4}\cdot P8 = 1 \quad (2)$$

This WHF algorithm makes 1-pixel width in slanting lines, but also has faults that it makes needless trees.

2.2 Proposed parallel thinning algorithm

The proposed algorithm improves the ZS algorithm's problem that the slanting lines with two-pixel width are erased and the LW algorithm's problem which can not make one-pixel slanting lines. The proposed algorithm executes thinning of input image through two iteration steps by the condition 1, and performs again the thinning by using the following additional condition 2.

<Condition 1>

The first iteration step:
1. $2 \leq B(Pi) \leq 6$
2. A(Pi) = 1
3. P2*P4*P6 = 0

4. P4*P6*P8 = 0

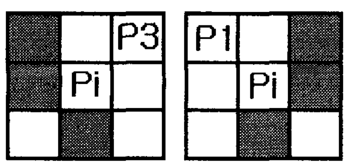
The second iteration step:
1. $3 \le B(Pi) \le 6$
2. A(Pi) = 1
3. P2*P4*P8 = 0
4. P2*P6*P8 = 0

<Condition 2>

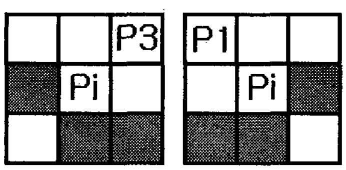
1. P1*P8*P6=1 & P3=0
2. P3*P4*P6=1 & P1=0
3. P5*P6*P8=1 & P3=0
4. P4*P6*P7=1 & P1=0

It means that all the pixels satisfied by above condition 1 are erased in the input image and the condition 2 finds to erase the remained lines with 2-pixel width. Thus, from the top of oblique lines, the process is performed to make the 2-pixel lines into 1-pixel lines. In condition 2, P1 or P3 must be zero. Because, as shown in Fig. 3, P1 or P3 must not be connected to other points of oblique lines. If there are any pixels in that position (P1 or P3), Pi is a connected point and it must not be erased. Consequently, the proposed thinning algorithm can make perfect 1-pixel lines with 8-neighbor connectivity.

When any end point is existed in top end or bottom end of oblique lines, the point is a removing pattern that makes to 1-pixel lines. It is shown in Fig. 3 (b). And, when any end point is existed in left end or right end of oblique lines, the point is also another removing pattern that makes to 1-pixel lines and depicted in Fig. 3 (b).



(a) Removing pattern 1



(b) Removing pattern 2

Fig. 3 Step-type oblique line removing patterns

III. EXPERIMENTAL RESULTS AND CONSIDERATION

To evaluate the effectiveness of this algorithm, the experimental results are shown and compared in Figs. 4, 5 and 6. In the figures, (a) is original image, (b) is image thinned by ZS algorithm, (c) is image thinned by LW algorithm, and (d) is image thinned by the proposed algorithm.

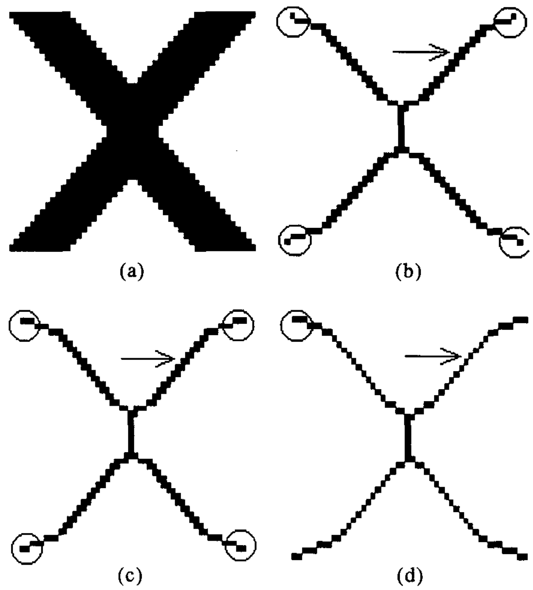


Fig. 4. (a) X-shaped image, (b) Result by ZS, (c) Result by LW, and (d) Result by the proposed algorithm.

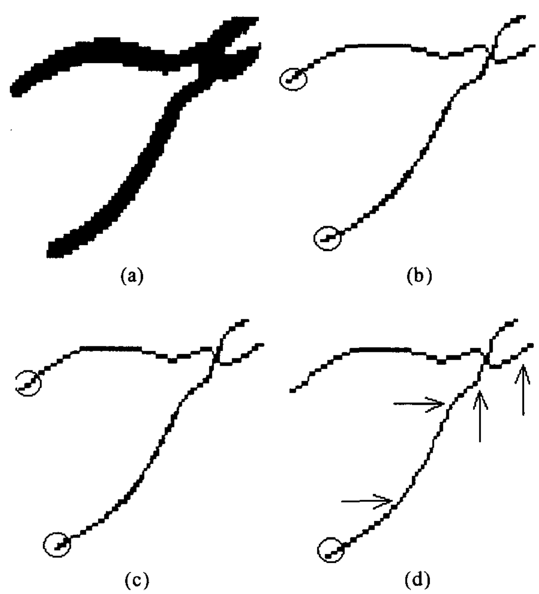


Fig. 5. (a) Stripper image, (b) Result by ZS, (c) Result by LW, and (d) Result by the proposed algorithm.

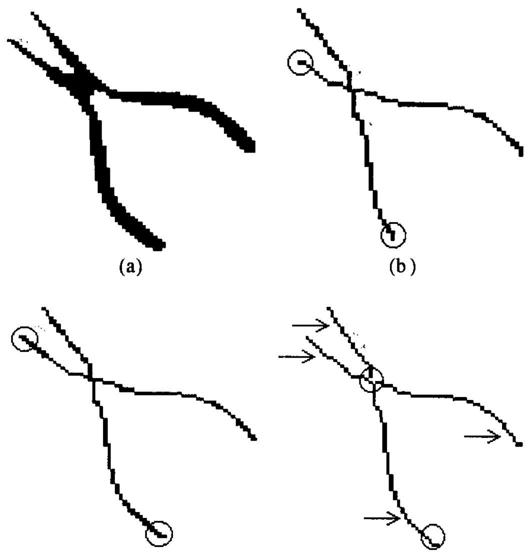


Fig. 6. (a) Longnose image, (b) Result by ZS, (c) Result by LW, and (d) Result by the proposed algorithm.

As shown in Fig. 4 (b), ZS algorithm loses the top end points of an X-shaped image and makes slanting lines into 2-pixel width lines. A stripper image(Fig. 5 (b)) thinned by ZS algorithm loses the top and bottom end points and has 2-pixel width lines. In a thinned longnose image(Fig. 6 (b)), more bottom pixels are shrunk and slanting lines of oblique parts are remained in 2-pixel width. LW algorithm shows the better performance than ZS algorithm. As shown in (c) of Figs. 4, 5, and 6, end points shrink less than in ZS algorithm, but slanting lines of oblique parts are still remained in 2-pixel width.

However, as shown in (d) of Figs. 4, 5, and 6, we can find the prominent performance of the proposed algorithm. It shows the better performance than the previous algorithms. End points do not shrink and thinned slanting lines of oblique parts have perfect 1-pixel width and 8-neighbor connectivity.

In the experimental results, we know that ZS algorithm makes end points shrinking seriously and lots of 2-pixel width lines. When we execute the thinning by using the LW algorithm, end point shrinking effect is reduced than in the ZS algorithm. But it makes the 2-pixel width lines like ZS algorithm's performance. However, in the proposed algorithm, the shrinking effect of end point is reduced remarkably, and the thinned skeleton has 1-pixel width and 8-neighbor connectivity.

IV. CONCLUSION

In this paper, we propose the new parallel thinning algorithm that can make the slanting lines thinned with one-pixel width, preserve the end points, and ensure the 8-neighbor connectivity. The previous ZS algorithm loses many end points and can not make the one-pixel slanting lines. The LW algorithm can reduce the end point shrinking phenomenon, but can not make the one-pixel slanting lines like ZS algorithm. And WHF algorithm can make the 1-pixel slim lines, but make also the needless trees. However, the proposed algorithm shows the better performance than previous algorithms in end point preservation effect and makes 1-pixel slanting lines that have a perfect 8-connectivity. In the experimental results by using the previous algorithms, we can not find the perfect 1-pixel slanting lines. But, as proven in experimental results, we can find that the slimmer 1-pixel skeletons can be extracted by proposed thinning method, and the extracted skeletons have a perfect 8-connectivity.

The feature of proposed algorithm is parallel thinning algorithm and the method can extract the one-pixel slim lines. It can settle also the end point shrinking phenomenon and has a perfect 8-connectivity. we think that the proposed algorithm can be used necessarily in character, figure and drawing recognition, because the proposed algorithm has the predominant features that are 1-pixel width, end point preservation, and perfect 8-connectivity. In the further study, our proposed parallel thinning algorithm will be applied to many application fields for preprocessing, image understanding and recognition, etc. And we will research to prove the effectiveness of the proposed algorithm.

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