VOL. 5, NO. 4, APRIL 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

NEW PARALLEL BINARY IMAGE THINNING ALGORITHM

A. Jagna[1] and V. Kamakshiprasad[2]
[1]Department of Computer Science and Engineering, BVRIT, Narsapur, Medak, Andhra Pradesh, India
[2]SIT, JNTU, Hyderabad, Andhra Pradesh, India
E-Mail: jagan225@yahoo.com

ABSTRACT

This paper describes new parallel thinning algorithm for binary images. The use of 3X3 mask for pixel deletability in parallel and pixel deletion criteria needed to preserve the connectivity of the image pattern is exclusively discussed. This algorithm preserves the connectivity of an input image. The experimental result shows the better performance in terms of thinning and excessive erosion.

Keywords: thinning, deletibility, parallel deletion, endpoint, excessive erosion.

1. INTRODUCTION

In image processing, Image thinning is a fundamental preprocessing step [1]. It reduces a large amount of memory usage for structural information storage. Binary digital image can be represented by a matrix, where each element in matrix is either zero (white) or one (black) and the points are called pixels. Thinning is a process that deletes the unwanted pixels and transforms the image pattern one pixel thick. In parallel binary image processing, the value of the pixel element at the n^{th} iteration depends on the current pixel value and its neighbor at the $(n - 1)^{th}$ iteration. We define non-zero pixels representing objects and zero-valued pixels representing the background. To avoid connectivity paradoxes, we define objects with eight-connectivity and background with four connectivity, our algorithm uses the 3 X 3 mask as shown in Figure-1. We define P1, P3, P5 and P7 are four connectivity representing the background and P2, P4, P6, P8 are eight connectivity representing the object. New image thinning algorithm is divided into two iterations. Parallel image thinning algorithms with 1-iteration have the disadvantage that they may yield no connected or even empty medial lines for connected Figures the case where a two-pixel wide straight stroke is entirely eliminated by a single iteration is widely known [2]. Based on these considerations and computational requirements, we propose a thinning algorithm with 2-iterations which is able to

a) Reduce the number of iterations and the time complexity of each iteration.
b) Produce a perfect 8-connected thinned image.
c) Prevent the excessive noise and erosion.

The meaning of these objectives will be clarified in the subsequent sections. According to the algorithm described in section 4, a pixel is deletable by analyzing the values of its neighboring pixels within the area of (3 X 3) mask in the first iteration. If the conditions specified in first iteration are not satisfied, then the same process is carried out in the second iteration. Experimental results in terms of degree of 8-connectedness, excessive erosion, boundary noise sensitivity are reported in section 6.

P1	P2	P3
P8	Pi	P4
P7	P6	P5

Figure-1. (3 X 3) Pixel mask under consideration.

2. SURVEY OF RELATED WORK

The popular and well-proved thinning algorithms in the literature are ZS algorithm and LW algorithm. The ZS algorithm [3] does not support for the two pixel thick image and also has the problem of discontinuity in the images. The LW algorithm [4] has the problems of noise sensitivity and disconnectivity in images. However the proposed algorithm can settle the problem of discontinuity in images and makes perfect one pixel thick with 8-neighbor connectivity even for the two pixel thick images and avoids the excessive erosion. The procedure followed in ZS and LW algorithms for image thinning is as follows.

ZS algorithm

ZS parallel thinning algorithm performs sub-iterations step wise.

The first step

1) $2 \leq N(Pi) \leq 6$
2) $S(Pi) = 1$
3) $P2 * P4 * P6 = 0$
4) $P4 * P6 * P8 = 0$

The Second step

Conditions 3 and 4 in the first step are replaced with the following conditions.

3) $P2 * P4 * P8 = 0$
4) $P2 * P6 * P8 = 0$

LW algorithm

To solve the problem of slanting lines with 2-pixel width are erased, Lu and Wang replaced the first step condition 1 ($2 \leq N(Pi) \leq 6$) in ZS algorithm with the condition $3 \leq N(Pi) \leq 6$.

3. BASIC NOTATIONS

In Image thinning algorithms, it is understood that a pixel P is examined for deletion is a non-zero pixel, and the pixels in its (3 X 3) neighborhood are labeled as $x_{i,}$ i =1… 8 as shown in Figure-1.

Definition 1

The pixels P_1, P_2… P8 are the 8-neighbors of Pi and are collectively denoted by N (P). They are said to be 8-adjecent to P.

Definition 2

The pixels P_1, P_3, P_5, and P_7 are the 4-neighbors of P and are said 4-adjecent to P.

Definition 3

A sequence of points Z_1, Z_2… Zn is called an 8-(or 4-) path if Z_{i+1} is an 8-(or 4-) neighbors of Z_i for i=1, 2,.., n-1.

Definition 4

A subset C of a picture P is 8(or 4-) connected if every pair of points (x,y) in C there exists an 8-(or 4-) path from x to y consisting of points in C.

Definition 5

The number of transitions from a zero pixel to a non-zero pixel and vice-versa (when the points in n (p) are crossed, for examples in a counter clockwise order) is defines as

$S(P) = \sum_{i=1}^{8} | x_{i+1}-x_i |$, where $x_9 = x_1$.

Based on the previous common definitions a lot of algorithms were stated. These algorithms are widely considered to be a well assisted set for benchmarking parallel thinning. In the next section the proposed thinning algorithm has been discussed.

4. NEW THINNING ALGORITHM

The proposed algorithm improves the ZS and LW algorithm's problem that the excessive erosion and discontinuity in the thinned images. The algorithm executes thinning of input image through two iterations which are discussed below. Some more definitions are to be joined to the previously reported definitions as they pertain to our algorithm.

Definition 6

Non-zero pixel P that has atleast one zero (white) pixel 4-neighbor is called an edge-point (i.e., it lies along the edge of the pattern).

Definition 7

Non-zero pixel P that has at most one non-zero pixel 8-neighbor is called an end-point.

Definition 8

Non-zero pixel P, the deletion of which would break the connectedness of the original pattern, is called a break-point.

In essence, the proposed thinning algorithm consists of executing several iterations over the pattern, where many non-zero pixels are deleted in each iteration. If no pixel is deleted at the end of iteration, the thinning procedure stops. The neighboring pixel values can be denoted by the eight directions (P2, P3…, P9) shown in Figure-2. Let S (P_1) be the number of patterns zero to one or one to zero in the order set of (P2, P3, P8, P9, P2) neighbors of $P_{1.}$ Then the pixel P1 is deleted from the input image.

P9	P2	P3
P8	P1	P4
P7	P6	P5

1	→1	↓0
1	P1	1
1	1	1

Figure-2. Number of 01/10 patterns representation.

To hold the above criterion, some rules should be stated. In iteration 1, the set of non-zero pixels P satisfying the following conditions

i) S (Pi) =1; ii) 2 ≤ N (Pi) ≤ 6;
iii) P2 * P4 * P6 = 0, iv) P4 * P6 * P8 = 0,
are deletable in parallel from any binary image.

Proof

According to the iteration 1 condition ii) there exist from two up to six non-zero pixels in the neighborhood of the candidate pixel P to be deleted. The condition i) means that there are only one zero to one (01 equivalently 10) transitions in the same neighborhood. This corresponds to have one non-zero pixel among $x_1,\ldots, x_8$ while the remaining seven pixels can be all zero(0) or four of them are non-zero(1). Based on these considerations, the set N (P) contains between two and six non-zero pixels which are 4-connected among themselves, i.e., all the possible pairs of these pixels are connected by 4-paths, thus, P is not a break-point. Since the entire set of non-zero pixels P that satisfying the conditions i) and ii) is deletable in parallel. With this the objects that of two pixels width are completely disappears. This difficulty cannot be solved by using the conditions i) and ii) only. To overcome this problem, conditions iii) and iv) are checked and if it is found to be true, its central pixel is saved, or equivalently, all non-zero pixels P that satisfies the conditions iii) and iv) can be deleted in parallel. Let us now illustrate the iteration 2.

In iteration 2, the set of non-zero pixels P satisfying the following conditions

v) S (Pi) = 1, vi) 3 ≤ N (Pi) ≤ 6,
vii) P2 *P4 *P6 = 0, viii) P4 * P6 * P8 = 0,
are deletable in parallel from any binary image.

Proof

According to the iteration 2, condition vi) there exist from three up to six non-zero pixels in the neighborhood of the candidate pixel P to be deleted. The condition v) means that there are one zero to one (0-1or equivalently 1-0) transitions in the same neighborhood. Based on these considerations, the set

N (P) contains between three and six non-zero pixels which are 4-connected among themselves, i.e., all the possible pairs of these pixels are connected by 4-paths, thus, P is not a break-point. Since the entire set of black pixels P satisfying condition v) is deletable in parallel. To face this problem, it is necessary to save pixels which do not satisfy condition v) indeed.

x	1	x
x	Pi	1
x	1	x

Figure-(3a)

x	x	x
1	Pi	1
x	1	x

Figure-(3b)

Figure-3. Mask corresponding to the deletion condition.

5. PROPOSED THINNING METHODOLOGY

Proposed algorithm considers only an eight neighborhood. However, it has difficulty in preserving the connectivity of a pattern. To deal with this problem, we use a 3 x 3 mask. The mask shown in Figure-3 (a and b) is used to indicate the variations of eight neighboring pixels. A connectivity value is the sum of each weight of eight directions. After the connectivity value is calculated and specific conditions are applied, it can be determined whether the object pixel is to be deleted or preserved. An essential point is defined as one which includes a connect point and an end point [5]. The connect point is a point that its removal causes a disconnectivity in 3 x 3 mask. The end point is a point that has only one of the eight-adjacent points. Proposed algorithm simply applies the above definitions to maintain the connectivity in to the entire image to over come the deficiencies in previous parallel thinning algorithms. The proposed algorithm consists of two steps i.e., Rule 1 calculates the connectivity value for the entire image step by step and Rule 2 eliminates non-essential pixels step by step from the entire image. If all pixels are essential, then the pixel deletion process is terminated. In sequential image thinning algorithm the deletion or retention of a (black) pixel *p* would depend on the configuration of pixels in a local neighborhood containing p, and the deletion of *p* in the n^{th} iteration depends on all the operations that have been performed so far, i.e., on the result of the $(n-1)^{th}$ iteration as well as on the pixels already processed in the n^{th} iteration. In proposed parallel image thinning algorithm, the deletion of pixels in the n^{th} iteration would depend only on the result that remains after the $(n-1)^{th}$ iteration, therefore, all pixels can be processed independently in a parallel manner, for achieving the better thinned images without excessive erosion and with 8-connectivity.

6. RESULTS AND COMPARISONS

In this section, the results obtained by the proposed algorithm, Zhang and Suen algorithm [3] and Lu and Wang algorithm [4] are compared by using as comparative terms.

a) Degree of 8-connectedness.
b) Degree of erosion.
c) Boundary noise sensitivity.

Comparisons concerning the time-units spent by the algorithm to converge are also compared with those spent by the algorithms of ZS and LW which turned out to be comparable in terms of computational complexity to our algorithm. Figure-4(a) is original images chosen to test the degree of 8-connectedness and excessive erosion. Figure-4(b) is the results obtained by the ZS algorithm. The results obtained by ZS algorithm are not having 8-connectivity and having the excessive erosion. This is shown in the results of ZS algorithm. Figure-4(c) is the results obtained by LW algorithm are having distortions in image shape and also not having 8-connectivity and having the excessive erosion. The thinning results shown in Figure-4(d) are obtained by the proposed algorithm are perfectly 8-connected and do not have an excessive erosion in the thinning images.

VOL. 5, NO. 4, APRIL 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

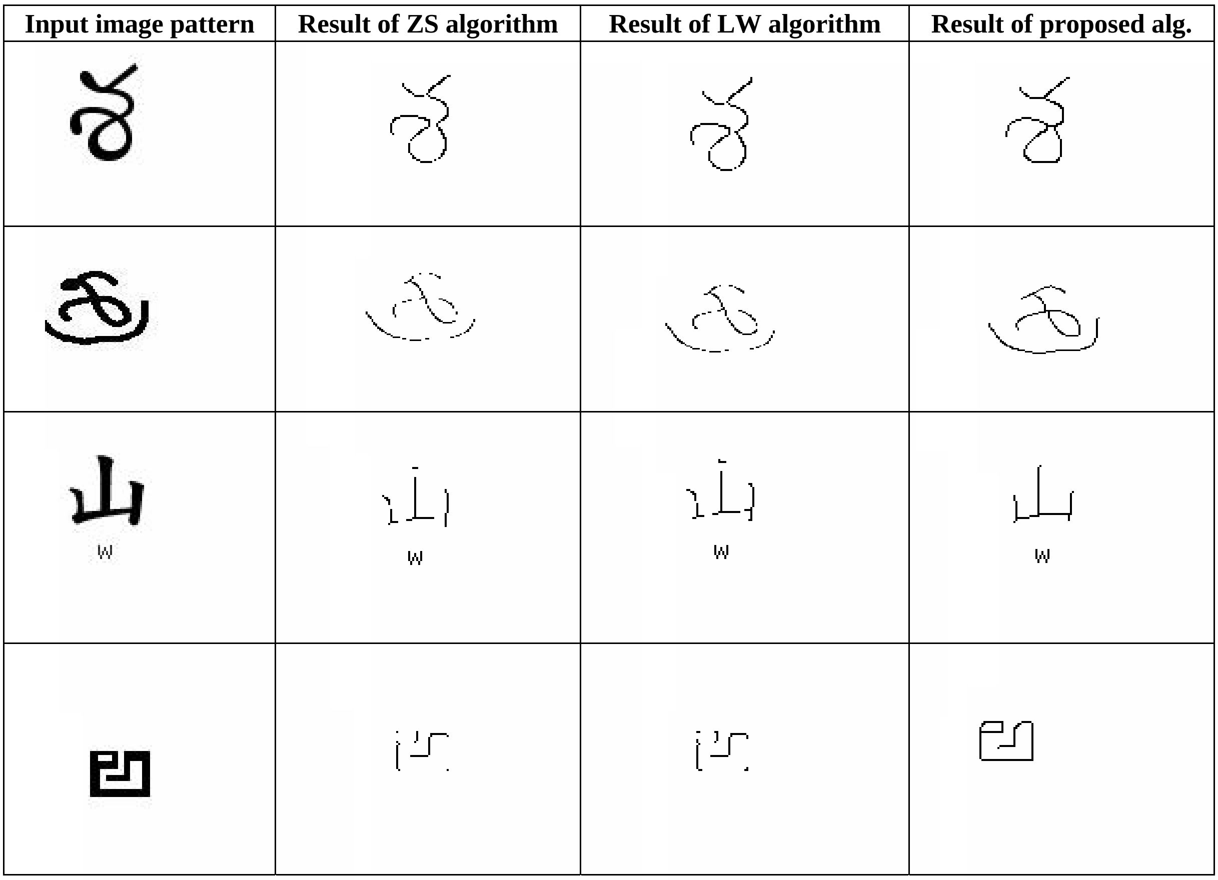

Figure-4(a) **Figure-4(b)** **Figure-4(c)** **Figure-4(d)**

7. CONCLUSIONS

In this paper we have presented a two-pass parallel binary image thinning algorithm that make the image one pixel thick and preserves the end points. This algorithm also ensures the 8-neighbour connectivity. The ZS and LW algorithm can reduce the end points [3-4]. However, the proposed algorithm shows the better performance and produces more quality images than the previous algorithms. The proposed algorithm is a parallel image thinning algorithm and the method can extract the one pixel thick lines. The proposed algorithm has the features like one-pixel thick, end point preservation, etc.

REFERENCES

[1] C Gonzalez and R.E Woods. 2002. Digital Image Processing. 2nd edition. pp. 650-660.

[2] Jun-Sik Kwon, Jun-Woong Gi and Eung-Kwan Kang. 2001. An Enhanced Thinning Algorithm Using Parallel Processing. Vol. 3, pp. 752-755.

[3] T.Y. Zhang and C.Y. Suen. 1984. A Fast Parallel Algorithms for Thinning Digital Patterns. Research Contributions, Communications of the ACM. 27(3): 236-239.

[4] H.E. Lu and P.S.P. Wang. 1985. An improved fast parallel algorithm for thinning digital patterns. Proc. of the IEEE Conf. on computer vision and pattern recognition. pp. 364-367.

[5] Alfredo Petrosing and Giuseppe Salvi. 2000. A Two-Sub cycle Thinning Algorithm and Its Parallel Implementation on SIMD Machine. IEEE Transaction on Image processing. 9(2): 277-283.