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RESEARCH ON PARALLEL ITERATIVE THINNING ALGORITHM

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Abstract. Aiming at the problem of excessive erosion in thinning diagonal lines, complete deletion of patterns in the well-known thinning algorithm proposed by the Zhang and Suen, which is very good in respect to both connectivity and insensitively to boundary noise. Based on it, an improved parallel iterative thinning algorithm has proposed. The experiment shows that the proposed algorithm has better performance in visual quality by comparing with the ZS algorithm. The experiment shows that the proposed algorithm has better performance in visual quality by comparing with the ZS algorithm.

Keywords: Zhang's fast parallel thinning algorithm, single pixel.

Introduction

Image thinning algorithm is a method to extract the image skeleton, which is widely used in character recognition, bio-engineering, fingerprint identification and so on. The purpose of refinement is to eliminate a large number of unwanted points to extract the refined skeleton, preserve the geometric features of the pattern so that the computer can perform image-related tasks efficiently. Image thinning algorithms can be roughly divided into two categories: non-iterative thinning algorithms and iterative thinning algorithms. Noniterative thinning algorithm directly extracts the image skeleton after a round of calculation. The iterative thinning algorithm can be divided into serial thinning algorithm and parallel thinning algorithm. For the serial thinning algorithm, the deletion of pixels depends on all operations previously performed, and the pixels are deleted as soon as the deletion condition is satisfied. For the parallel thinning algorithm, the deletion of pixels depends on the result after the last iteration. All the pixels satisfying the deletion condition will be marked and deleted after completing an iteration [1–4].

Among the parallel thinning algorithms, Zhang's algorithm [1] has the good performance in continuity and it can relatively precisely describe the straight line, inflection point and cross point. However, at the same time, Zhang's algorithm also has some aspects can improved, which will have better performance, this paper will base on Zhang's algorithm to propose an improved one.

The rest of the paper is organized as follows. Section 2, the proposed improved method is illustrated. Section 3 describes the results of experiment. Conclusion is given in Section 4.

Improvement Algorithm

The proposed algorithm works on a 20 neighbors window, which can provide more information than the more common 3×3 neighbor window used in other iterative thinning algorithms. As shown in Fig. 1.

The *P* in the center of the 20 neighborhood is a candidate pixel selected for deletion when its neighborhoods meet some certain conditions.

The conditions consist of several logical criteria, 2 restoring templates, 1 compulsory deletion template and 10 Extra deletion templates.

	A_1	A_2	A_3	
A_{12}	P_8	P_1	P_2	A_4
A_{11}	P_7	P	P_3	A_5
A_{10}	P_6	P_5	P_4	A_6
	A_9	A_8	A_7	

Fig. 1. 20-neighborhood used in proposed algorithm

In order to conduct the logical judgment, $AP(P)$ and $BP(P)$ should to computer at first. $BP(P)$ is the number of foreground pixels in the 8-neighbourhood field of *P*, and is defined as follows

$$BP(P) = \sum_{i=1}^{8} P_i. \tag{1}$$

$AP(P)$ is the total of the value of the corner state in the 8-neighborhood of *P*, $(P_9 = P_1)$ and is defined as follows

$$AP(P) = \sum_{i=1}^{4} (\overline{P_{2i-1}} P_{2i} + \overline{P_{2i}} P_{2i+1}), \tag{2}$$

$$\overline{P_{2i-1}} = 1 - P_{2i-1}. \tag{3}$$

All the deletable edge pixels are divided into two different groups to conduct the removing process according to their values $AP(P)$ and $BP(P)$.

For most pixels in one image, their values of the $AP(P)$ equal one and that of $BP(P)$ are within the range from 2 to 6. Under this circumstance, these pixels should be checked by the restoring template and compulsory deletion templates, as shown in Fig. 2. All the candidate pixels are removed and only those who match restoring templates but not match compulsory deletion templates are left.

Improvement algorithm including 4 main parts: Search Module, Connectivity Check Module, Single Pixel Correction Module and Contour Point Delete Module. The structure of these stages addressed in Flowchart as shown in Fig. 2.

X	X	X	X
0	P	1	0
X	1	X	X

a

X	0	X
X	P	1
X	1	X
X	0	X

b

X	0	X	t
0	P	1	t
X	1	X	t
t	t	t	

c

Fig. 2. Restoring templates (*a*, *b*) and deletion template (*c*)

The symbols «0», «1», «*P*» and «*X*» in these templates denote a white pixel, which values are equal 0, a black pixel, which values are equal 1. The currently tested pixel and an ignorable condition, respectively, whereas «*t*» denotes that at least two of the pixels represented by the set of symbols should be a black pixel.

For those edge candidate pixels, whose $AP(P)$ equal two and value of $BP(P)$ are above 4 but less or equal than 5, should be examined by the extra deletion templates as shown in Fig. 3. Only those pixels, whose pattern of neighbors completely matched with one of the extra deletion templates are deletable.

In the extra deletion templates, the symbols «0», «1», «*P*» and «*X*» share the same meaning with the restoring templates and compulsory deletion template. But the symbols «*E*1», «*E*2», «*G*1» and «*G*2» are defined as special symbols that symbols should satisfy the following rule: the values of two arbitrary pixels in a given template marked as identical special symbols should be equal. The difference between «*E*1», «*E*2» and «*G*1», «*G*2» is mainly that the value of a pixel marked as «*E*1» and the value of a pixel marked as «*E*2» are independent; however, the sum of the values of a pixel marked as «*G*1» and another pixel marked as «*G*2» should be greater than 1.

0	0	0	X	X
0	1	P	1	G2
0	0	1	1	G2
	X	G1	G1	

a

	X	E1	E1	
0	0	1	1	E2
0	1	P	1	E2
0	0	0	X	X

b

	E1	E1	X	
E2	1	1	0	0
E2	1	P	1	0
X	X	0	0	0

c

X	X	0	0	0
E1	1	P	1	0
E1	1	1	0	0
	E2	E2	X	

d

1	1	0
0	P	1
0	0	1

e

X	E1	E1	
X	1	1	E2
0	P	1	E2
0	1	0	X
0	0	0	

f

	E1	E1	X
E2	1	1	X
E2	1	P	0
X	0	1	0
	0	0	0

g

0	0	0	
0	1	0	X
0	P	1	G2
X	1	1	G2
X	G1	G1	

h

	0	0	0
X	0	1	0
E1	1	P	0
E1	1	1	X
	E2	E2	X

i

0	1	1
1	P	0
1	0	0

j

Fig. 3. Extra deletion templates

Tests and Results

To assess the performance, the proposed algorithm and the Zhang's algorithm were written in MATLAB R2018b. This data set compose characteristics and shapes. The results are shown in Fig. 4.

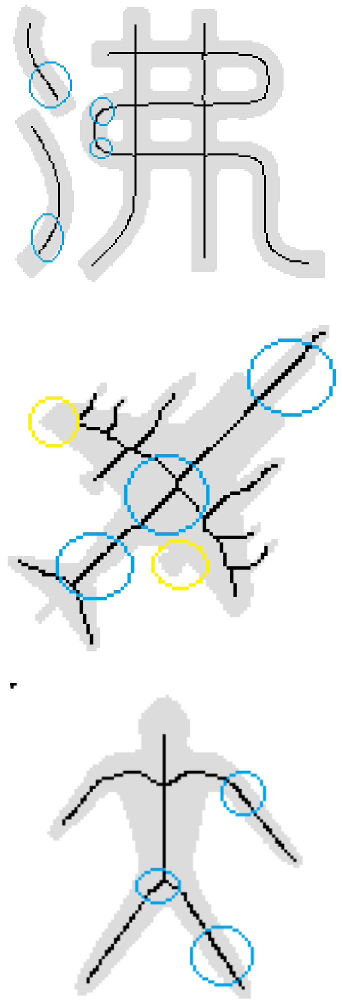
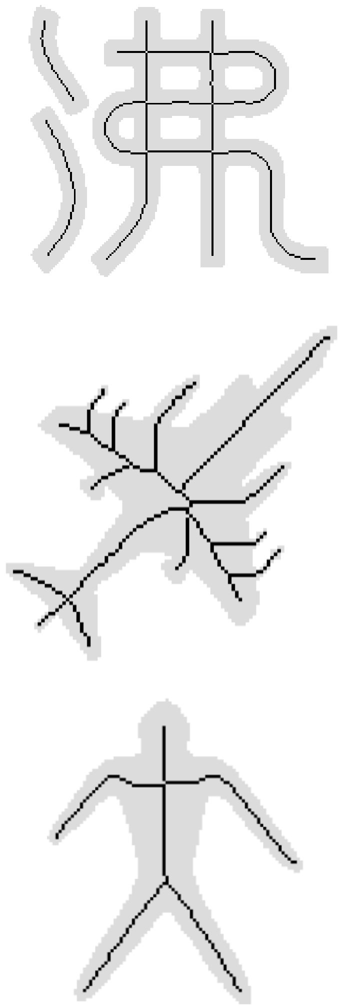
The result of the ZS algorithm	The result of the proposed algorithm
	

Fig. 4. Result comparison

Table has presented the number of iterations of both algorithms and real time consumed by the algorithms. From the perspective of these two parameters, it is convinced that the proposed algorithm has better performance in terms of the computational complexity, which can reduce about 30 % time consuming.

Comparison of the compute speed between algorithms

Original Binary image	Number of Iteration		CPU Time Consumed(s)	
	Zhang's Algorithm	Our Algorithm	Zhang's Algorithm	Our Algorithm
Character	18	16	0,2037	0,1446
Airplane	34	20	0,4983	0,3311
People	24	19	0,3693	0,2055

Conclusion

In this paper, we presented an improved algorithm based on the Zhang's algorithm, which has better performance in speed and single pixel. The experiments have proved the effectivity of the new algorithm.

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