# PARALLEL SKELETON ALGORITHM WITH ONE-SUBITERATION


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*The skeletonize of the binary image has crucial application in the field of target recognition. The thinning result of the Zhang's fast parallel thinning algorithm maintains the connection of the original image, has a good structural form and has no burs. However, Zhang's fast parallel thinning algorithm consists two subiterations in where the most of operations are similar, which cause the waste of the resources of the calculate. Besides, it can't ensure the single pixel width, which brings difficulties for post-processing.*


## Introduction

Skeletonization, also known as the image thinning, is a pre-processing which is widely applied in field of the pattern recognition. Image thinning refers to finding the skeleton or centerline of the original image as quickly as possible while maintaining the completeness of the topology of the original image, and then replacing the original image with a single-pixel skeleton. The processing of the image thinning can dramatically reduce the superfluous information from the image, which relieve the computation burden of the computer and shorten the time which spend on the process of the recognition [2][3][5].

In practice, there is a need for thinning images for obe or all of the following reasons: Preservation of topological and geometric properties, One-pixel thickness, Mediality, Insensitivity to boundary noise and efficiency.

Thinning algorithms can be classified in one of two broad categories: iterative thinning algorithms and non iterative thinning algorithms.

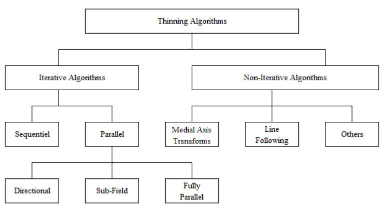


Рис. 1 – Classification of Thinning Algorithm

Iterative algorithms remove boundary pixels layer by layer until an appropriate skeleton is obtained. According to the way of examining pixels, they can be further divided into parallel and sequential. In a parallel algorithm, since the deletion of pixels depends on the results of the previous iteration, all the pixels can be processed simultaneously. By the contratry, the pixels in a sequential algorithm can not processe at the same time because the deletion of pixels not only depend on the previous iteration but also depend on the current iteration.

Non-iterative thinning algorithms unlike iterative ones are not based on examining individual pixels. Some popular non-pixel based methods include medial axis transforms, distance transforms, and determination of center-line by line following.

Over the years the ZS algorithm has become one of the most cited and used parallel thinning algorithms, which yields very good results with respect to both connectivity and contour noise immunity. Besides, it can process all pixels simultaneously and is relatively fast also on sequential hardware. However, there are three main difficulties: excessive erosion in thinning diagonal lines, complete deletion of patterns.

In this paper a parallel skeleton algorithm with one-subiteration based on the ZS has proposed to not only overcome the drawbacks of ZS, but also accerate the speed of process.

## I. Zhang's Algorithm

Zhang's algorithm consists of two sub-iterations. Iterative transformations are applied to original binary matrix point by point according to the values of a small set of neighboring points. It is assumed that a $3 \times 3$ window is used, and that each element connected with its eight neighboring elements which as figure shown below [1] [4].

| | | |
|---|---|---|
| $P_9$ (i-1,j-1) | $P_2$ (i-1,j-1) | $P_3$ (i-1,j-1) |
| $P_8$ (i,j-1) | $P_1$ (i,j) | $P_4$ (i,j+1) |
| $P_7$ (i+1,j-1) | $P_6$ (i+1,j) | $P_6$ (i+1,j+1) |

Рис. 2 – Designations of the nine pixels in a $3 \times 3$ window

The methods for extracting the skeleton of a picture consists of removing all contour pixes pf the picture except those belonging to the skeleton.In the first sub-iteration, the contour point P1 is deleted from the digital pattern if it satisfies the following conditions:

1. $2 \leq B(P) \leq 6$
2. $A(P_1) = 1$
3. $P_2 \times P_4 \times P_6 = 0$
4. $P_4 \times P_6 \times P_8 = 0$

In the second sub-iteration, the contour point $P_1$ is deleted from the pattern,if it satisfies the following conditions:

1. $2 \leq B(P) \leq 6$;
2. $A(P_1) = 1$;

3. $P_2 \times P_4 \times P_8 = 0$;
4. $P_2 \times P_6 \times P_8 = 0$ .

If any condition is not satisfied then $P_1$ will not be deleted from the foreground.

## II. Improvement Algorithm

Improvement algorithm includes 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. 3.

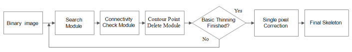


Рис. 3 – Flowchart of the purposed method

The binary image is acquisition into the proposed method as black pixels which considered as a foreground as well as consider an object pixel for deletion. The pixels having value 0 are considered as background pixels.

Before introducing the Search module, the scan window which we used in the Search Module need to present, which is a little different from Zhang's algorithm. As shown in Figure 4.

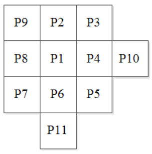


Рис. 4 – Designation of the scan window

In each iteration, if the current pixel belongs to the foreground pixel and its 8-neighbour pattern satisfied with the deletion condition, it can be considered as a candidate pixel which may be deleted and then they should be compared with the Restoring Templates. Those candidate pixels which different from the restoring templates will be deleted from the foreground.

1. $2 \leq B(P) \leq 6$;
2. $A(P_1) = 1$ ;
3. $\overline{P}_6 + P_2 + P_{11} = 1$ ;
4. $\overline{P}_4 + P_{10} + P_8 = 1$ .

When there is not anymore deletable pixel during the iteration process, the iteration is coming to the end and an additional procedure will be deployed to ensure the one-pixel width of the result by deleting the redundancy pixel. If one foreground pixel and its 8-neighbour satisfied with one of the following criteria, a pixel will be transformed into a background pixel.

1. $P_4 \times P_6 = 1$ *and* $P_9 = 0$ ;
2. $P_6 \times P_8 = 1$ *and* $P_3 = 0$ ;
3. $P_2 \times P_4 = 1$ *and* $P_7 = 0$ ;
4. $P_2 \times P_8 = 1$ *and* $P_5 = 0$ .

## III. Experiments and results

To assess the performance, the improvement algorithm and the Zhang's algorithm were written in Matlab R2018b.This data set has many class shapes.

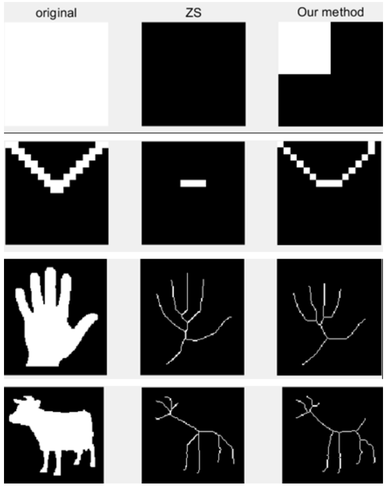


Рис. 5 – The original binary images and the thinning results by different algorithm

From the Fig.5, we know that the new method has a better performance in the single pixel.

Таблица 1 – Comparison of the compute speed between algorithms

| $BI_o$ | $A_{zhang}$ | $A_{new}$ | $C_{time(zh)}$ | $C_{time(n)}$ |
|---|---|---|---|---|
| $S_{2\times2}$ | 0 | 1 | 0.02 | 0.008 |
| $S_l$ | 4 | 16 | 0.008 | 0.004 |
| Hand | 333 | 260 | 0.1111 | 0.086 |
| Cow | 293 | 285 | 0.095 | 0.064 |

Original Binary image - $I_o$ ; $S_{2\times2}$ square - $S_{2\times2}$ ; Slope line - $S_l$ ; Remain points of Zhang's Algorithm - $A_{zhang}$; Remain points of New Algorithm - $A_{new}$; CPU Time Consumed(s) of Zhang's Algorithm - $C_{time(zh)}$; CPU Time Consumed(s) New Algorithm - $C_{time(n)}$.

According to the results of the experiment, improved algorithm not only overcome the three main drawbacks of the ZS algorithm, but also present a higher efficiency in procession.

## IV. 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.

1. Mangrum, J. M. The evaluation and management of bradycardia / J. M. Mangrum, J. P. DiMarco // N. Engl. J. Med. – 2000. – Vol. 342, № 10. – P. 703–709.
2. Zhang, Y. A fast thinning algorithm for thinning digital patterns /Y. ZHANG, C. Y. SUEN // A Communications of ACM.
3. Bushenko,D. A. Technology of thinning algorithms construction for skeletonization of extended objects /D. A. Bushenko,R. H. Sadikhov // Reports of BSUIR. – 2009. – Vol. 45, № 7. – P. 81–86.
4. Waleed, A. A. Skeletonization Algorithm for Binary Images /A. A. Waleed, B. Bataineh, T. Abu, O. P. Khairuddin //Technology, – 2013. – P. 704–709.
5. Ye,F. L. An improved Image Skeleton Extraction Algorithm /F. L. Ye //Journal of Xichuang Univeristy. – 2018. – Vol. 32, № 3. – P. 91–93.