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Analysis and Application of Iteration Skeletonization Algorithm in Recognizing Chinese Characters Image

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***Abstract*—The paper studied several image skeleton extraction algorithms, such as Zhang-Suen, Rosenfeld and Pavlidis etc. And compared extraction effects based on different Chinese characters by making computer programs, and gave advice how to choose the best algorithm for recognizing a certain Chinese characters image, and then gave a conclusion that Zhang-Suen and Rosenfeld algorithms were the best algorithms for extracting Chinese characters skeletons.**

***Index Terms*—Chinese Characters Image Processing; Image Skeleton Extraction; Zhang-Suen; RosenFeld; Pavlidis**

I. INTRODUCTION

With development of Internet and application of computer technology, a plenty of information exists in form of images. Retrieving among so many images becomes very difficult. When retrieving Image based on key words, we must add mark for them so that efficiency of retrieval is very low. In this case, image retrieval based on content (CBIR) which use color, strip, shape, space relation etc, is needed. Image retrieval based on space relation uses space topology structure of objects in images to retrieve. Image skeleton is one of the best effective ways to represent the topology structure. It is widely used in shape description, pattern recognition, and industrial inspection, and image compression coding etc. Image skeleton was proposed by Blum [1]. He represented image skeleton by means of axis.

Image skeleton extraction algorithm generally possesses the following characteristics: The first is connectivity, which means connectivity of image skeleton must be consistent with original image. The second is thinning, which means width of image skeleton should be one pixel. The third is axis, which means image skeleton should be as far as possible the center line of original image. The fourth is maintainability, which means image skeleton should retain as far as possible detail of original image. Last one is rapidity, which means running speed of algorithm should be as fast as possible.

Image skeleton extraction in Chinese character recognition is an important research topic. Image skeleton extraction algorithm consists of iterative algorithm and non-iterative algorithm. This paper mainly discusses several classical iterative skeleton extraction algorithms in the character image skeleton extraction applications.

II. MODELS OF IMAGE SKELETON EXTRACTION

A. Fire Spreading

Fire spreading refers to all border points of image are lighted at the moment of t=0, the flame spreads towards internal of image at the same speed. When the meet happens in front of wave, the flame goes out. Collection of points where flame goes out constitutes axis named image skeleton denoted by SKF shown as fig.1

B. Maximum Disc

Maximum disc indicates that suppose D is one of inscribed disc of image, this means at least two points of the disc are tangent to image edge. If D is not a subset of other inscribed discs within image, D is the greatest disc as shown in fig.2. Now image skeleton denoted by SKM can be defined as collection of the greatest discs within image.

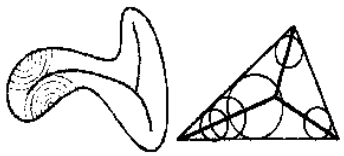

Figure 1. Fire spread skeleton. Figure 2. Maximum disc skeleton

C. Peeling Method

Peeling method indicates that staring from edge of line, you peels it off one layer with one pixel width at a time till the single pixel lines that are connected each other and constructed by single raster are obtained. One condition should be considered during peeling because a line in different locations may have different widths, that is to say the pixel that may result in lines disconnected can never be peeled. The basic principle of the algorithm is that peeling pixels that have no effect on connectivity of image raster topology, and conversely these pixels should be retained.

III. ANALYSIS OF SEVERAL CLASSICAL IMAGE SKELETON EXTRACTION ALGORITHMS BASED ON PEELING

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A. *Principle of Template Matching Algorithm*

Eight points adjacent to pixel p are called 8-neighborhood of pixel P as shown in fig.3, and it can be denoted by Pi such that the value of i is less than 1 and greater than 8. P1,P3,P5 and P7 are called four-adjacent area point, and P1,P2,P3,P4,P5,P6,P7,P8 are called eight-adjacent area point.

Template matching algorithm uses a template 3*3 to retrieve images and judges if there are points being the same case as the template. If there are such points, you should execute corresponding operations according to the operations of template such as retaining operation, deletion etc. In short, Rosenfeld, Zhang-Suan and Pavlidis algorithms are image skeleton extraction algorithm based on template matching.

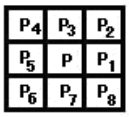

Figure 3. 8- neighborhood of pixel P.

B. *Rosenfeld Algorithm*

Rosenfeld algorithm was first advanced by Stefanelli R and Rosenfeld A in 1971[2].It is an image skeleton extraction algorithm based on parallel template matching. The algorithm defines condition for final pixel as shown in fig.4 and judges if edge pixel satisfies the condition so as to determine how to operate it. As shown in fig.4, there exists at least one black point among these points marked X, and the same is true for Y. here, black point represents foreground color, and white point represents background color, and gray point represents foreground or background colors. You should retain pixel points satisfying final pixel condition, otherwise remove them. Processing cycle of the algorithm consists of four main steps: completing a removal of edge pixels from four directions-moving up, down, left or right, then repeating this process until no deleting occurs in a certain cycle. Now process of image skeleton extraction is finished.

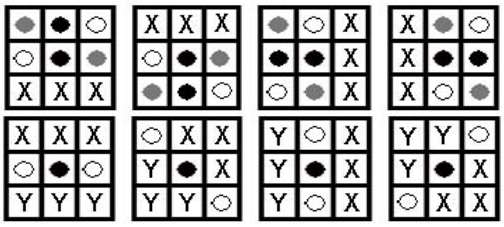

Figure 4. Final pixel condition

Image skeleton extraction procedure can be described as follows:

```
while(there still exist pixels to be deleted)
{
    For foreground color point P search:
    {
      If 8-neighborhood of the upper edge point of P matches templates 2,3,4,5,6,7,8, continue scanning.
      If 8-neighborhood of the lower edge point of P matches templates 1,3,4,5,6,7,8, continue scanning.
      If 8-neighborhood of the left edge point of P matches templates 1,2,4,5,6,7,8, continue scanning.
      If 8-neighborhood of the right edge point of P matches templates 1,2,3,5,6,7,8, continue scanning.
      Otherwise mark point P for deleting.
    }
}
```

C. *Zhang-Suen Algorithm*

Zhang-Suen algorithm was advanced first by Zhang T Y in 1984 [3]. It is also an image skeleton extraction algorithm based on parallel template matching and deletion. The algorithm defines condition for points to be deleted as shown in fig.5. For those points satisfying deleting condition, you should delete them. As shown in fig.5, if satisfying one black point or two gray points representing background color, you delete the point. Processing cycle of the algorithm consists of two steps. Finding a point matching with the template shown in fig.5(1) is the first step, the second step is to verify the point matching with the template shown in fig.5(2),then repeating the above process until there are no points to be

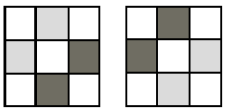

Figure 5. Zhang-Suen chinning template

deleted in a certain cycle.

Image skeleton extraction procedure of Zhang-Suen algorithm can be described as follows:

```
while (there still exist points to be deleted)
{
    For each foreground point P search:
    {
      If 8-neighborhood of edge point of P matches template 1, delete point P.
      If eight adjacent area of edge point of P matches template 2, delete point P.
    }
}
```

D. *Pavlisis Algorithm*

Palidis algorithm was advanced first by Pavlidis in 1982[4]. It is an image skeleton extraction algorithm based on template matching and retaining. The algorithm defines the condition for points to be retained showed in fig.6. For those points satisfying retaining condition, you should retain them. Processing cycle of the algorithm consists of four steps. The first step is to judge if point of right edge matches the template, then repeat the same operation to process its upper edge, left edge and lower edge until there are no points to be deleted. Now process of image skeleton extraction is finished.

Image skeleton extraction of Pavlidis was described as follows:

```
while(there still exist points to be deleted)
{
```

For each foreground point search:

{

If 8-neighborhood of right edge point of P matches templates 1,2,3,4,5,6, continue scanning.

If 8-neighborhood of the upper edge point of P matches templates 1,2,3,4,5,6, continue scanning.

If 8-neighborhood of the left edge point of P matches templates 1,2,3,4,5,6, continue scanning.

If 8-neighborhood of lower edge point of P matches templates 1,2,3,4,5,6, continue scanning.

Otherwise mark the point P for deletion.

}

}

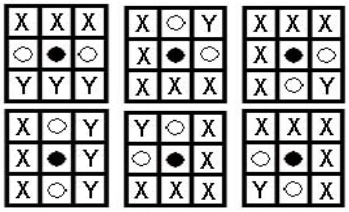

Figure 6. The condition of retaining point(At lease one of X,Y is 1)

E. Other Image Skeleton Extraction Algorithms

The deleting condition of Hilditch algorithm and retaining condition of Pavlidis algorithm are complementary [5]. Similar image skeleton using these two algorithms can be obtained, so their description will not be discussed in detail. Naccache algorithm marks safety point including either breakpoint or endpoint to be retained and otherwise these points are to be removed, then deletes all the points described as removed until there is no point to be deleted.

Deutsch algorithm is an image skeleton extraction algorithm based on deletion. It defines some deletion conditions, and if there exist such points that satisfy deletion condition, the points should be deleted. Otherwise the points should be retained. The algorithm extracts image skeleton by two cycles executed alternately.

F. Comparison of Skeleton Extraction Algorithms

From the discussion presented above, we can know that these algorithms mentioned obtain image skeleton by conditions matching and many times iterations. Some of them extract image skeleton through given conditions, such as Hilditch algorithm and Deutsch algorithm. Some of them extract image skeleton through templates matching, such as Zhang-Suen algorithm and Rosenfeld algorithm. Hilditch algorithm, Deutsch algorithm and Zhang-Suen algorithm extract image skeleton based on deletion, and Rosenfeld algorithm, Pavlidis algorithm and Naccache algorithm extract image skeleton based on retaining. Though reservation conditions are called by different names in these algorithms, final pixel condition in Rosenfeld, retaining point condition in Pavlidis, and safety point condition in Naccache, but their principles are the same.

All the skeleton extraction algorithms mentioned above are based on peeling. In other words, we can obtain image skeleton of single pixel connecting by peeling edge pixels many times. These algorithms have different times of iteration. One iteration cycle of Pavlidis algorithm and Rosenfeld algorithm consists of four steps, and Zhang-Suen algorithm consists of two steps in one iteration cycle. At the same time, different iteration processes lead to different number of templates. Zhang-Suen algorithm has the least number of templates so that its speed is the fastest. The number of templates and the times of iterations have effect on efficiency of algorithms. The less the algorithm uses the number of templates and the less the algorithm has the times of iteration, the faster the algorithm runs.

IV. EXPERIMENT RESULT AND ANALYSIS

Programming and running these algorithms including Hilditch, Pavlidis, Rosenfeld, Naccache, Deutsch and Zhang-Suen in turns to extract image skeleton for handwritten Chinese characters, printed Chinese characters and Chinese calligraphy as shown in fig.7 and processing results are shown in fig.8,fig.9 and fig.10.

Figure 7. Experiment images

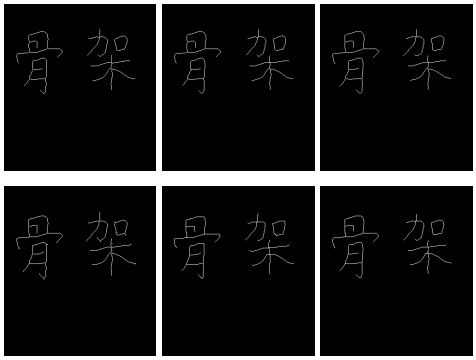

Figure 8. Handwritten Chinese characters

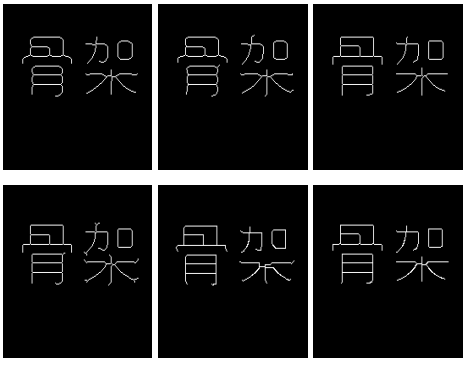

Figure 9. Printed Chinese characters

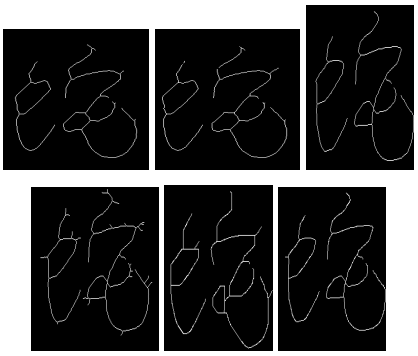

Figure 10. Chinese calligraphy

Drawing a comparison for experimental figures, conclusion is shown as follows:

- If you want to recognize Chinese calligraphy, handwritten Chinese characters and printed Chinese characters, the processing effect of Rosenfeld algorithm is better than Hilditch, Pavlidis, Daccache and Deutsch algorithms'.
- Both Hilditch algorithm and Pavlidis algorithm can produce similar image skeletons. They can result in good effect for processing handwritten Chinese characters and printed Chinese characters. But when it comes to processing Chinese calligraphy, they can not process the intersection of lines accurately.
- Considering image skeleton connectivity, Pavlidis algorithm is worse than Hilditch. When processing Chinese calligraphy by Pavlidis algorithm, image skeleton exists apparent fracture shown as fig.11.
- Using Rosenfeld and Zhang-Suen algorithms, we can obtain image skeleton with no superfluous branches, and they can process intersection of lines accurately.
- When processing handwritten Chinese characters and printed English characters, the processing effect of Naccache algorithm is better than that of others'. But for processing printed Chinese characters and Chinese calligraphy, the effect is not satisfactory, because there exist so many superfluous branches.
- When processing handwritten Chinese characters, Deutsch algorithm can get good effect, but if processing printed Chinese characters and Chinese calligraphy, the effect of it is not satisfactory, because there are not only many superfluous branches, but also a little deformity.

V. CONCLUSIONS

The paper introduces some classical models of image skeleton extraction, analyzes principles of several classical image skeleton extraction algorithms based on peeling and tests these algorithms through processing Chinese calligraphy, handwritten Chinese characters and printed Chinese characters. Experiment result shows that efficiency of Zhang-Suen algorithm is higher than that of other algorithms. Using Rosenfeld and Zhang-Suen algorithms to process Chinese characters, we can obtain image skeleton with a good topology features and without superfluous branches. So a conclusion can be drawn that Zhang-Suen and Rosenfeld algorithms are the best algorithms for extracting Chinese characters skeletons.

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