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A SIMPLE ITERATIVE THINNING ALGORITHM FOR TEXT AND SHAPE BINARY IMAGES

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ABSTRACT

Thinning or skeletonization is become a curial step in many document image analysis and recognition application as a pre-process stage. These applications such as optical character recognition OCR, optical script recognition OSR, and optical font recognition OFR widely adopt many exist methods, some thinning challenging defect the performance of these applications. However, further enhancement for thinning technique is indeed. A simple iterative thinning algorithm is proposed for binary images domain. Thereafter, a benchmark dataset is designed for thinning algorithm evaluation is used. Finally, The evaluation experiments result are compared with some other major thinning methods to proof the proposed method efficiency. The proposed algorithm visual experiments shows outperform for many thinning challenges such as one pixel width, topology preserving, rotation tolerance, and tail occurrences.

Keywords: *Thinning, Iterative Thinning, Skeletonization, OCR, OSR, OFR*

1. INTRODUCTION

Textual and shape are main two categories of DIAR [1], [2]. Extract the information to increase the knowledge by understand the document image based on document analyzing technique. Several applications based on text analyzing and recognition such as binarization, text extraction, skeletonization, object extraction, and text segmentation. DIAR consider as one of main branch in pattern recognition application.

Skeletonization become a fundamental step in pre-processing stage for many DIAR applications. Thus, a good thinning method should be able to extract a skeleton in one pixel width to represent the pattern shape precisely. Keeping the connectivity and topology of the pattern is main challenging [3]. Many DIAR application such as OSR[6], OCR[7] and writer identification [4][5][8] thinning become as important step in a pre-processing in these application.

Thinning approaches are divided into iterative and non-iterative [9]. In iterative methods, the contour pixels flake iteratively either parallel or sequentially; in the parallel way the completely undesirable pixels are removed after spotting all the required pixels [8], whereas in sequential methods the undesirable pixels are removed recognizing the wanted pixels in each iterative in [9]. In non-iterative approach, the skeleton is extracted without examining each pixel separately. However, these techniques demand a complicated implementation and require a high computation time that lead to slow performance [10]. The common problem in thinning methods is that some algorithms suffer from these traditional problems such as one pixel width of the skeleton and skeleton connectivity. Deformity in topology of the skeleton shape is a serious problem [11], whereas the shape topology preservation in several methods fail [12], [13]. Rotating and Spurious tails are other serious problems that most thinning methods fail to resolve [12], [13], [14].

In this paper, a new thinning algorithm for binary images is proposed to solve the problems of previous iterative methods. The proposed method is iterative and combines parallel and sequential processes. Shape benchmarked dataset experiments were conducted for evaluation phase. The presented results are much better than the previous methods and the problem of skeleton width, spurious branches, distortion, and tolerance to invariance rotation are solved.

The paper is organized as follows. Section 2 provides brief description of thinning approaches and iterative methodologies. Section 3 illustrates the proposed method. Section 4 describes the results of experiment and finally, Section 5 concludes.

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2. RSEARCH OVERVIEW

Thinning approaches and previous work in this field are overviewed. The following subsections are describing a various approaches.

2.1 Thinning Approaches

Thinning algorithms are categorized into iterative and non-iterative. The iterative approach is divided into sequential and parallel processes by removing the contour pixels iteratively until it reaches a one-pixel width [15]. Sequential and parallel thinning techniques are alike in defining the required and undesirable pixels, unlike in removing time. In sequential the removing of unwanted pixels start in the recognition of wanted process [16], [17], [18]. In parallel, the pixels are removed after identifying all the unwanted pixels [12], [19], [20], [21]. Non-iterative methods produce a skeleton directly without exploring all the pixels [22]. Many methods adopt the skeleton extraction using a non-iterative approach, as in neural networks [23], Voronoi diagrams [24] and wavelet transforms [25].

2.2 Iterative Approach

Twenty rules are applied at the same time in each iteration in parallel approach [13], the method shows a fair result in rotation. However, the method in [26] claimed that the method in [13] suffers from two-pixel width in some portion of the skeleton. Rockett has modified [13] method to treat two-pixel width. The modification has done by adding extra rules to avoid the two pixels width in post processing phase. However, the method suffers from superior tails. Other parallel approach consists of two sub-iteration proposed by [19]. Contour flaking is based on 8-neighbor pixels. The algorithm keeps the connectivity. However, a two-pixel width occurs in certain portion of the skeleton. The method in [13] proposes an enhancement of the [19] method is based on PTA2T template, in each iteration the deletion is based on 8-neighbor pixels, the algorithm keeps the connectivity with one pixel width and author claims the proposed method is faster than other algorithm. Nevertheless, it suffers from desertion at end of tails.

Based on fixed window, a parallel thinning algorithm proposed by [27] where each pixel is examined for deletion based on its 8-neighbor weight value. Certain rules are applied at the same time for each pixel. Supplementary phase consists of another rule utilized to keep the connectivity. The disadvantage of this method is that some portion of the shape totally vanishes.

In [10], a sequential iterative thinning method is proposed based on weights value of the 8-neighbors that used in [27]. The method runs through seven phases in each iteration that leads to an extremely computation time. In addition, a supplementary phase is used to guarantee one-pixel width of the skeleton. However, the result of the method did not preserve the topology of the examined shape. Furthermore, a desertion and extra tails appear during the rotation test.

3. PROPOSED METHOD

The algorithm is run through three steps. Iteratively repeated until one-pixel width skeleton is achieved. Step1: detect the pattern contour. Step2: contour deletion conditions. Step3: thinness skeleton width. The proposed thinning method framework is shows in figure 1.

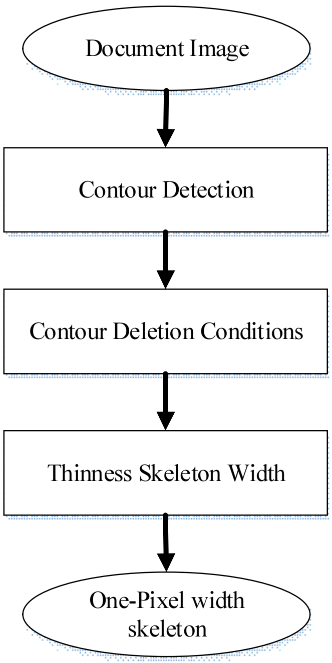

Figure 1: Proposed thinning method framework

The pattern of the document image is consider as foreground pixel represented by value "1" which it is black. Otherwise, the white will be consider as background pixels represented by value "0". The three steps illustrated in next section.

3.1 Contour Detection

Each foreground pixel is concatenated into any single background pixel is flagged as a contour

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pixels. If case of the pattern has a two-pixel width skeleton in any orientation, then the both side of the stroke are flagged as contour and will be deleted in the next stage. To overcome this problem, a most left side of the stroke is kept by return the flagged pixels to "1" as foreground in vertical orientation, and keep the most upper in horizontal orientation. Finally, flag all foreground pixels are positioned in elbow shape as a contour pixels.

3.2 Contour Deletion Conditions

The target pixels should be return either into "0" as a background or to "1" as foreground were represent the pattern contour pixels denoted by *T*. Each single flagged pixel enroll into eight-neighbor pixels inspection process. These eight sequence pixels contain either flagged "*T*" or foreground "1" see figure 2. Then, the connectivity is checked by examining if there is any background pixel "0" in this series of pixels. Afterwards the examined pixel is removed by assigned into "0". Otherwise, it will assigned into "1" as foreground. This process is repetitive until no more flagged pixels.

3.3 Thinness Skeleton Width

The skeleton resulted from two previous steps still suffering from two-pixel width in some portion. Further step required to guarantee a one-pixel width of the skeleton by removing unnecessary pixels. At this point, a weight value matrix is inspired from [24] as shown in figure 3(a). It is 3 by 3 starting value from upper target pixel in clockwise direction by following formula 2^n. Thereafter, these values are summed using $\sum_{n=0}^{7} 2^n$ identically to foreground pixel. Where these values range is [0-255].

Finally, all cases are examined and figured out separately where these cause fineness. All these values are calculated identically as shown in figure 3(b-c).

1	1	1
0	*T*	1
0	0	1

(a)

1	0	1
0	*T*	1
0	0	1

(b)

Figure 2: 3×3 mask (a) example of series of touched 1's (b) example of series of non-touched 1's, permeate '0'. Which T value is either 0, 1 as a target pixel.

2^7	2^0	2^1
2^6	*T*	2^2
2^5	2^4	2^3

(a)

2^7	2^0	2^1
2^6	*T*	2^2
2^5	2^4	2^3

➔

2^7	2^0	2^1
2^6	1	2^2
2^5	2^4	2^3

(b)

2^7	2^0	2^1
2^6	*T*	2^2
2^5	2^4	2^3

➔

2^7	2^0	2^1
2^6	0	2^2
2^5	2^4	2^3

(c)

Figure 3: (a) weight values matrix, (b) keep case, weight value=176, (c) delete case, weight value = 157

4. EXPERIMENTS AND RESULTS

The experiments are conducted into textual benchmark dataset namely DIBCO2010, as well as tested into shape benchmark dataset for generalization purpose. Then the results compared with most two known method namely Zhang-Suen [19] and Huang [27]. A different thinning challenging discussed. The one-pixel width, topological distortions and superior tails are considered the thinning challenges criteria's in this research.

The most popular textual and non-textual benchmark datasets used in pattern recognition area are used in experiments, which are "H_DIBCO 2010" and "MPEG-7 Core CE-Shape-1" respectively [28, 29]. For visual demonstration of the thinning result, a part of "H10_estGT" and the scissor class are chosen as shown in figure 4 and 5 consequently. While figure 6 prove the tolerance of the proposed thinning method against the rotation angles.

Some of the methods we compared with solved some thinning challenges such as, spurious tails and connectivity. However, some other challenges such as one-pixel width skeleton, shape topology perseverance, rotation tolerance and tails occurrences are remain unsolved.

Figures 4(b) and 5(b), shows that the proposed method produces the best result in the case of one-pixel width skeleton, shape topology perseverance, rotation tolerance and tails occurrences comparing with Zhang-Suen and Huang methods (figures 4(c-d) and 5(c-d)). Moreover, the proposed method has the smoother skeleton in the forepart of the scissors' shapes compared to the other methods.

Figure 6, shows that the angle of rotation of any textual or non-textual images does not distress the skeleton extraction and yields satisfactory results using the proposed method. Experimental results prove that the proposed method can thin both textual and non-textual binary image efficiently with any rotation angle. Table 1 shows a comparison of

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performance of the Zhang-Suen, Huang and proposed methods among the images in the datasets.

5. CONCLUSION

The proposed thinning algorithm consist of three steps. In first and second steps, the skeleton extracted is non-ideal. Thus, the third step required to guarantee one-pixel width of the skeleton. Experiment conducted for both textual and shape benchmark datasets. H_DIBCO 2010 for textual, MPEG-7 Core CE-Shape-1 for shape. The visual experiments shows outperform for non-traditional thinning challenges such as one pixel width, topology preserving, rotation tolerance, and tail occurrences.

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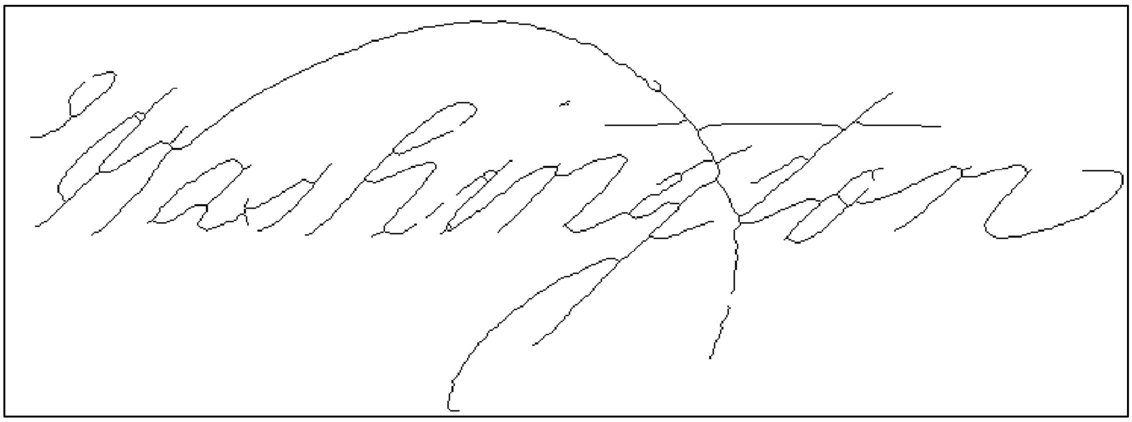
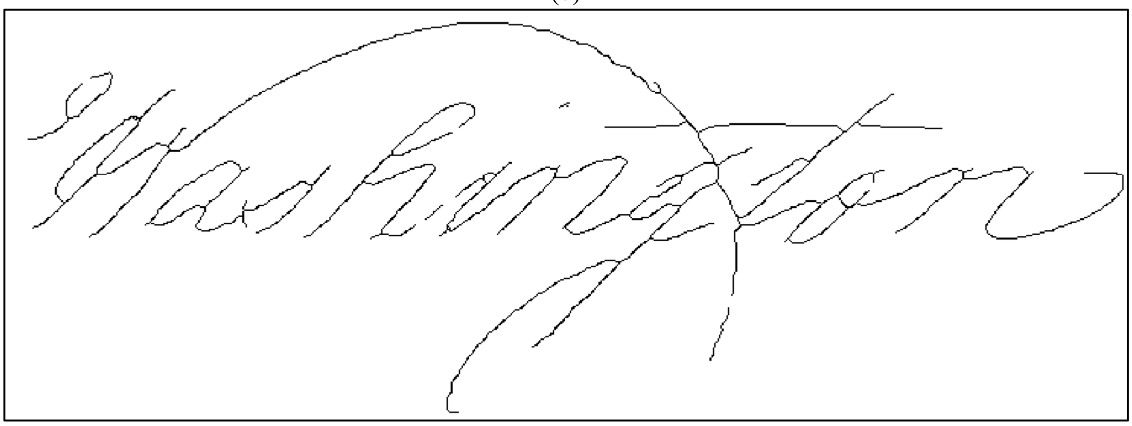
Table 1: The Proposed, Zhang-Suen, And Huang Methods Comparison Of The Thinning Challenges

	one pixel width	Keep Topology	Rotation Tolerance	Tails Occurrence
Proposed	Yes	Yes	Yes	Rare
Zhang-Suen [19]	No	Yes	No	few
Huang [27]	No	Yes	No	average

(a)



(b)



(c)

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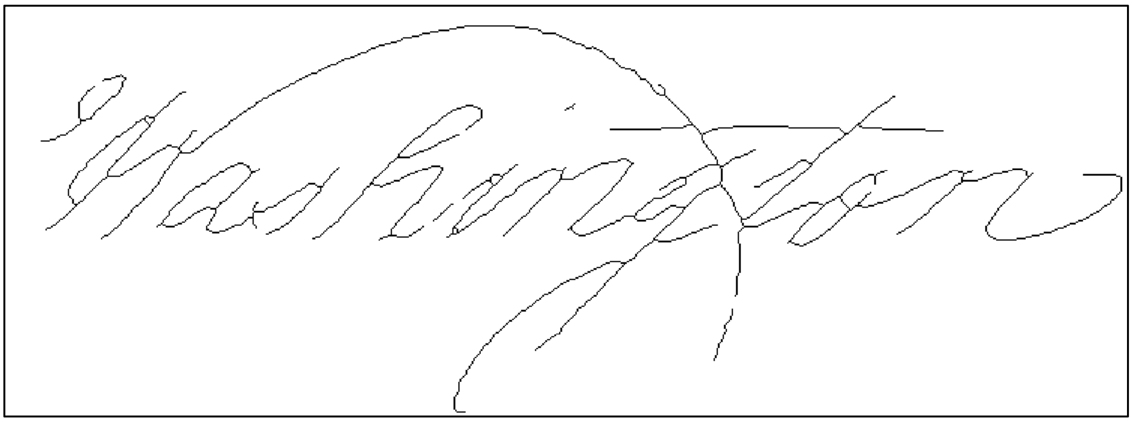
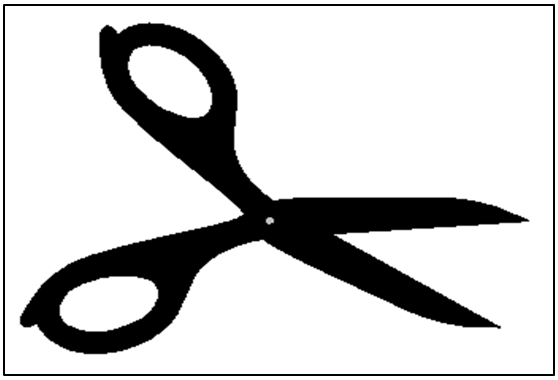
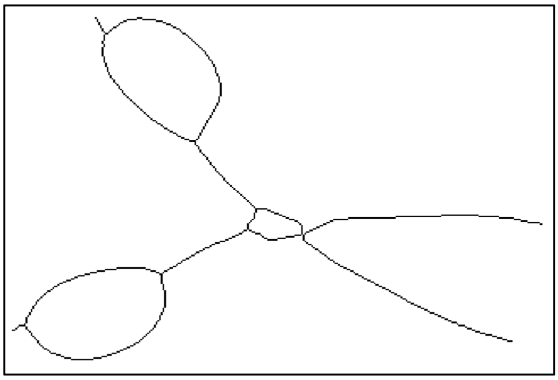


(d)

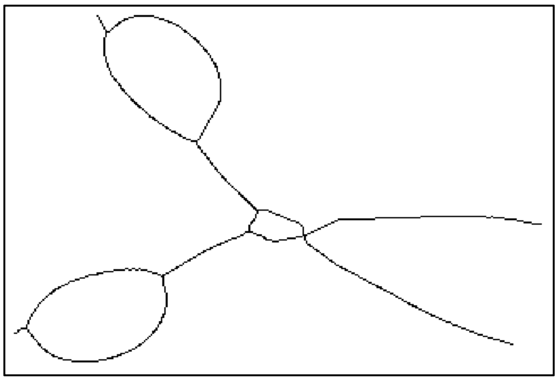
Figure 4: Examples Of Challenges In (A) The Textual Images; And The Skeleton Using (B) Proposed Method, (C) Zhang-Suen Method, And (D) Huang Method.



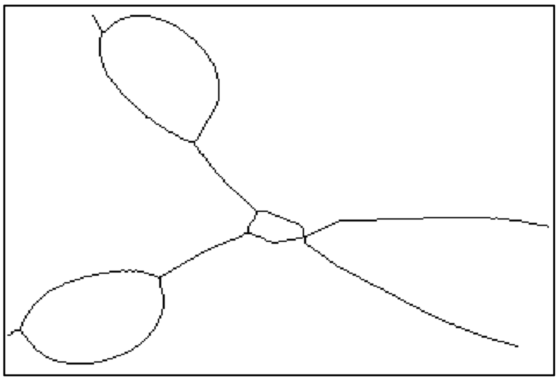
(a)



(b)



(c)



(d)

Figure 5: (A) Non-Textual Image (Scissors) Shape From "MPEG-7 Core CE-Shape-1" Benchmarked Dataset [28]; And The Skeleton Using (B) Proposed Method, (C) Zhang-Suen Method, And (D) Huang Method.

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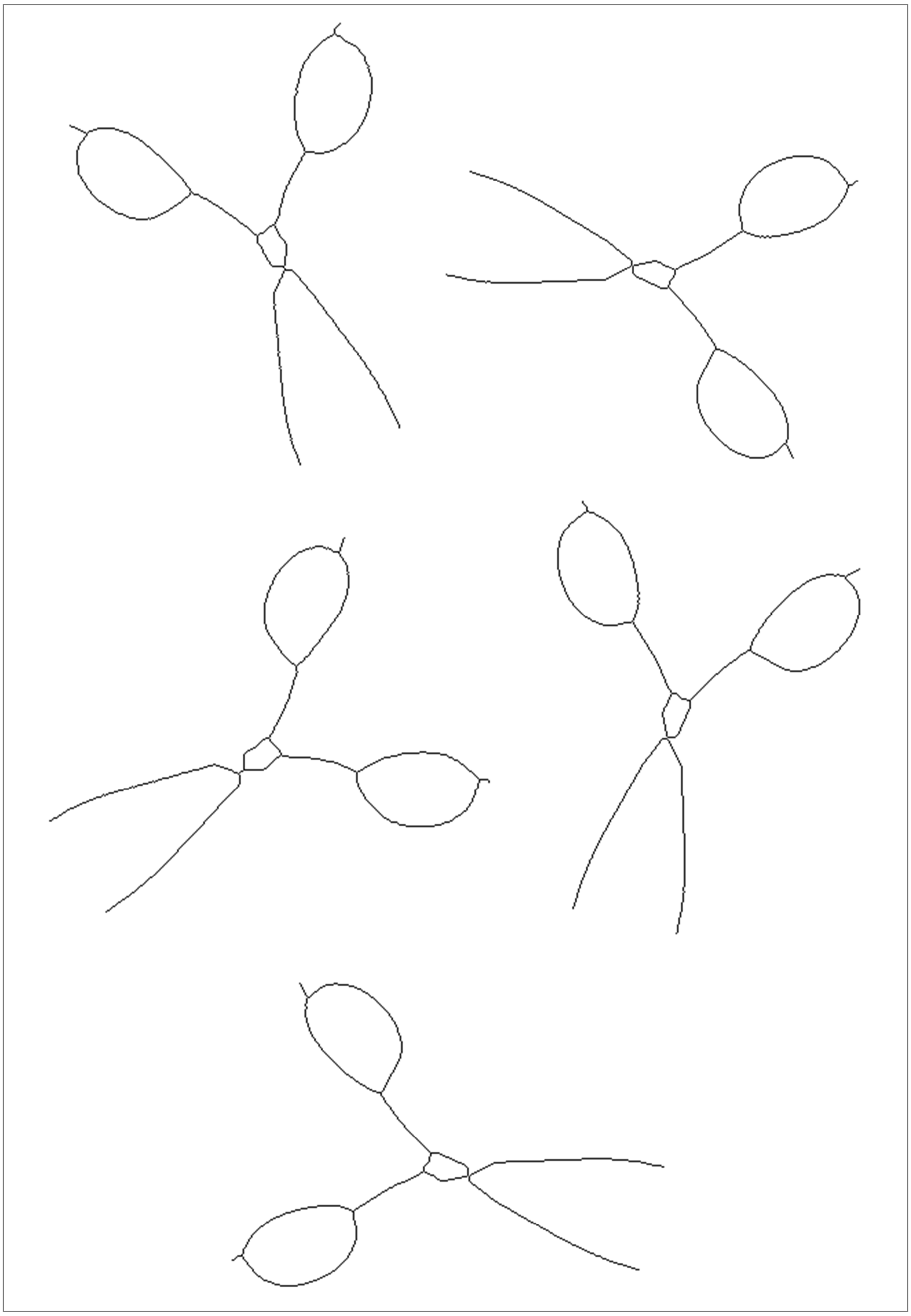

Figure 6: Scissors Skeleton Images Extracted Using The Proposed Method In Different Rotation Angles.