

# Evaluations of Thinning Algorithms for Preprocessing of Handwritten Characters

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**Abstract**— Thinning algorithms have played an important role in preprocessing phase which decides the success of recognition in the OCR system. This paper report on the performance of 11 thinning algorithms from the perspective of character recognition where different aspects of the performance of each algorithm like computing time, deviation from perfect 8-connectedness, and number of possible noise spurs present in the skeletons are considered.

**Keywords**- Thinning, skeleton, OCR, Pattern recognition, character recognition.

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## I. INTRODUCTION

The design and improvement in thinning algorithms have been very active research topics in recent years. Many thinning algorithms have been proposed, and a comprehensive survey of these methods is contained in [10]. As a result of the proliferation of these algorithms, the choice of algorithm for an application has become very difficult, and a researcher in this area is often asked the question of which algorithm to use. For this reason, we propose to evaluate the performance of 11 thinning algorithms from an OCR viewpoint, and to examine the effects of each thinning algorithm on this particular application.

Thinning is a procedure which transforms a pattern to a skeleton of a unit width. Generally, for a thinning algorithm to be effective, it should ideally compress data and retain the significant features of the pattern. The thinning of segmented binary images is a much-used and well-studied topic in image processing and related fields. Around 100 thinning algorithms has been reviewed by Lam and Suen[1] and significant numbers of new algorithms have been proposed in the intervening years by number of researchers. Of recent note is the rotation-invariant thinning algorithm of Ahmed and Ward [2] which used the particularly elegant device of deriving a set of predicates over the 8-neighbors of a given pixel to determine if that pixel is on the boundary of a shape and can thus be deleted. Pattern recognition often involves data where a great amount of redundant information hides the relevant details[4]. For instance, handwritten characters show usually strong variations in thickness while only direction, curvature and length of the curves are important. This superfluous information makes the recognition task much more difficult. Indeed, due to the enormous variability of handwritten symbols and writing styles, time is a basic constraint when developing algorithms for its recognition. That is why a

preprocess eliminating some redundant variability could allow for the identification of characters at a reasonable velocity. To this respect, thinning algorithms may play an important role and many attempts to find suitable procedures have been made.

## II. ALGORITHMS SELECTED FOR COMPARISON:

Good thinning algorithm [6] must meet the following requirements:

1. Approximate the medial axis.
2. Preserve the connectivity of skeletons.
3. Converge to skeletons of unit width.
4. Achieve a high data reduction efficiency

The A-W [2] algorithm proceeds by deriving a set of rules over the 8-neighbors of the pixel which is a candidate for deletion. In its initial form, however, the algorithm cannot handle lines of two pixel width and, consequently, Ahmed and Ward added further rules to deal with two pixel wide lines which involved extending the window over which the deletion decision was computed to include the four blocks of three pixels immediately above, below, to the right and to the left of the original 3X3 region - 20 pixels in all. The unique feature that distinguishes this thinning system is that it thins symbols to their central lines. This means that the shape of the symbol is preserved using rotation invariant method. The system has 20 rules in its inference engine. These rules are applied simultaneously to each pixel in the image. Therefore, the system has the advantages of symmetrical thinning and speed. The results show that the system is very efficient in preserving the topology of symbols and letters written in any language.

Peter Rockett [3] shows examples where the A-W algorithm fails on two-pixel wide lines and propose a modification to the rotation invariant thinning algorithm of

Ahmed and Ward based on their set of 20 rules to carry out most of the thinning, thus preserving the property of invariance to rotation. To deal with the case of two pixel wide lines, Peter Rockett use the two-stage thinning procedure which uses the A-W rules to thin down to a skeleton which includes 2-pixel wide lines in first stage. The second stage examine the 2-pixel wide lines in the provisional skeleton produced by the first processing stage to see which pixels, if any, can be deleted without compromising the connectivity of the skeleton.

A good thinning algorithm is proposed in modified way by Robert M. Haralick [5]. Connectivity properties of images is important to preserve while thinning. For thinners which use reduction only operators, where only 1 to 0 pixel transformations are allowed at any iteration there are 3 fundamental , connectivity properties to consider:

- P1. An object in S (a connected set of 1's) should not be disconnected into two or more distinct objects;
- P2. An object in S should not be completely deleted; and
- P3. Distinct components in S' (connected sets of 0's) should not be merged.

The thinning process for connectivity analysis about behavior of the fully parallel (FP) algorithm is examined bellow. The deletion criteria are applied fully in parallel (FP)is

A pixel  $P = 1$  is deleted if a,b,c are met:

- a.  $1 < B(P) < 8$ ;
- b. P is 4-connected to at least 1 zero; and
- c. P's 8-neighborhood contains exactly 1 4-connected component of ones.

By applying FP to each of the 3 connectivity properties it is possible to identify the specific additional conditions required to guarantee that P1,P2, and P3 are satisfied.

Majid Altuwajri and Magdy Bayoumi [6] proposed a new thinning algorithm based on clustering the data image using ART2 network which is a self-organizing neural network for the clustering of Arabic characters. The skeleton is generated by plotting the cluster centers and connecting adjacent clusters by straight lines. This algorithm produces skeletons which are superior to the outputs of the conventional algorithms. It achieves higher data reduction efficiency and much simpler skeletons with less noise spurs. To make the algorithm appropriate for real-time applications, an optimization technique is developed to reduce the time complexity of the algorithm. This algorithm can also be used for thinning of characters of other languages.

Majid M Altuwajri and Magdy A Bayoumi [7] propose the new thinning algorithm to reduce the time complexity, steps are as follows:

Test the neighbors X2, X3, X4, X5 (see fig. 1) of the pixel under consideration P. Count the number of colors (clusters).

- a) If the number of clusters =0, which means that the neighbors are all background pixels, do the following:
  - i) Calculate the Ecludian distances from all clusters centers
  - ii) Find the cluster with the least Ecludian distance.
- b) If the number of clusters=1, which means that the neighbors belong to only one cluster, calculate the Ecludian distance between the pixel and the neighboring cluster only. If the distance is  $> p$ , find the closest cluster from the remaining clusters in the image.

If the number of clusters=2 or 3, calculate the Ecludian distances from the neighboring clusters centers, then find the closest cluster.

X <sub>4</sub>	X <sub>3</sub>	X <sub>2</sub>
X <sub>5</sub>	P	X <sub>1</sub>
X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>

Figure 1. A 3x3 window for the pixel & its 8-neighbors.

G S Ng et.al. [8] propose a new sequential algorithm, which uses both flag map and bitmap simultaneously to decide if a boundary pixel can be deleted, as well as the incorporation of smoothing templates to smooth the final skeleton. Ideally a skeleton must be topologically equivalent to the object. If the object is connected then the skeleton must be connected. The skeleton should possess following characteristics: It should preserved connectivity. In general skeleton should be 4-connected in background, 8-connected in foreground and is one pixel thick. A break point test is incorporated into many thinning algorithms to prevent disconnectivity. Excessive erosion should be prevented. The end points of a skeleton should be detected as soon as possible so that the length of a line or curve that represents a true feature of the object is not shortened excessively.

The skeleton should be immune to small perturbations in the outline of the object. Noise or small convexities which do not belong to the skeleton will often result in a tail after thinning. The length of these tails should be minimized by the deletion of loop points which will introduce extra holes in the skeleton should be avoided.

Pradeep M. Patil et.al. [9] modify the thinning algorithm proposed by Ahmed and Ward [2]. The unique feature that distinguishes the algorithm is its ability to thin any symbol or fingerprint to its central line taking care that the shape of the symbol is preserved while being rotation invariant. This algorithm also incorporates a process to thin zigzag diagonal lines having a width of two pixels which was not considered in [2]. The algorithm is iterative and makes use of parallel

processing to speed up execution. The system has 21 rules in its inference engine which are applied simultaneously to every pixel in each iteration. The algorithm is implemented for thinning fingerprints, fonts and symbols to a single pixel width. This algorithm can also be used for thinning the characters of different languages.

Louisa Lam and Ching Y. Suen [10] study the performance of 10 parallel thinning algorithms for character recognition. The algorithms evaluated include the complete range of 4-subcycle, 2-subcycle, parallel methods. Each algorithm is considered with different aspects of the performance. Statistics are gathered such as deviation from perfect 8-connectedness, computing time, and number of possible noise spurs present in the skeletons.

M Melhi et.al. [11] propose a novel approach for thinning binary text images by generating graphical representations of words within the image. A smooth polygonal approximation of the boundaries of each word is first decomposed into a set of contiguous triangles. Each triangle is then classified into one of only three possible types from which a graph is generated that represents the topological features of the object. At last joining graph points with straight lines generates a final polygon one pixel wide fully connected skeleton.

### III. DISCUSSION AND CONCLUSION:

In this work we have considered the performance of thinning algorithms from a number of aspects required to OCR. The results on processing time would suggest that parallel thinning algorithms can operate at high speeds even when they are implemented on a sequential computer. Generally, the less significant cases arise from the retention of pixels that form T-junctions or 90° corners while the major problems result from the incomplete thinning of diagonal strokes. In algorithms that use only templates for thinning, the problem can be solved by a modification or addition of thinning templates so that extra post processing would not be necessary. The recognition rates may increase for most characters, their correct classification by choosing correct thinning algorithm. Distortions in the skeletons can contribute to errors in classification, causing higher substitution rates. In order to reduce misclassifications caused by the thinning process, certain minor adjustments can be made.

Consequently, recognition systems that make use of skeletons should be designed with an awareness of their limitations, and with an ability to compensate for the major ones. In conclusion, skeletons have been a useful aid as well as a source of dissatisfaction for researchers in OCR. Here our intention was to examine the results of different thinning

algorithms, and to arrive at an evaluation of their performance from this perspective.

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