A New Skeletonization Method Based on Connected Component Approach

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Summary
Thinning is a popular approach for morphological shape representation. For the complex shapes the simple morphological thinning does not yield a good automatic boundary description. This is because the approach does not take in to consideration the connected component approach. The present paper presents a novel scheme for thinning, using connected component approach. One of the disadvantages of the existing morphological thinning method is that it is not automatic. It always requires human interaction to detect the good skeleton, and then by stopping the iterative process. The novelty of the present paper is that it always measures the value of the connected components by which the proposed method makes the algorithm as automatic. The present scheme is applied on English alphabets which possess different structures and shapes, and good results are obtained.

Key words:
Mathematical morphology, thinning, connected components, automatic, iterative process.

1. Introduction

Skeletonization is a global space domain technique for shape representation [1]. It has been studied extensively since skeletons have attractive properties which make them suitable for structural pattern recognition [1] [2].There are two types of skeletonization methods: pixel-based and non-pixel-based. In a pixel-based method, all pixels inside a shape are used in the skeletonization process. Pixel based methods often use thinning techniques [2][3] or distance transforms [3][4]. In a non-pixel-based method, only the contour pixels of a shape are used for skeletonization. The skeleton of the shape is analytically derived from its contour [5][6]. Skeletonization has been a part of image processing for a wide variety of applications [9]. Digital skeletons, generated by thinning algorithms, are often used to represent objects in a binary digital image for shape analysis and classification. Thinning is a process of reducing patterns to their skeleton; however, skeleton is defined as a set of thin lines, arcs and curves (usually one pixel thick), which are connected with each other in such a way that the geometrical and topological properties of its originating object must be preserved.

There are numerous definitions of the digital thinning process. In general, it is defined as the successive removal of outer layers of pixels from an object while retaining any pixels whose removal would alter the connectivity or shorten the legs of the skeleton. This process is completed, or converged, when no further pixels can be removed without altering the connectivity or shortening skeletal legs [17][l8].The usefulness of reducing patterns to thin line representation can be attributed to the need to process a reduced amount of data as well as to the fact that shape analysis can be more easily made on thin-line patterns. Thinning methods [9] are very popular for skeletonization mainly because of their implementation simplicity and high computational speed. The thin line representation of certain elongated patterns, like handwritten characters, would be closer to the human perception of these patterns; therefore, they permit a simpler structural analysis and more intuitive design of recognition algorithms. Many skeletonization algorithms (or modifications of existing ones) have been proposed over the years [7][8][11][12][13]. A comprehensive survey of these methods is contained in reference [9]. Lam and Suen [14] evaluated, from an OCR prospective, 10 parallel skeletonization algorithms that represented a wide spectrum of modes of operation. Lee et. al [15] systematically evaluated 20 algorithms based on the criteria of reconstructibility, quality of skeletonization, connectivity and degree of parallelism. Recently, Fan et. al [10] proposed a skeletonization algorithm that uses block decomposition and contour vector matching. Kegl and Krzyzak[16] developed a piecewise linear skeletonization algorithm that uses principal curves. Skeletons are often sensitive to noise and geometrical transformations, such as rotation and scaling, in particular for high resolution images. This is a common problem for most skeletonization methods [2]. This study is aimed to increase the efficiency and robustness of skeleton computation. Discrete local symmetries are generalized to accomplish the goal. The present paper is organized as follows. The section (2) describes the methodology, the results and discussions are made in section (3) and conclusions are listed in section (4).

2. Methodology

The present paper is based on applying thinning based on morphological hit or miss transform, since the morphological hit or miss transformation is a basic tool for shape detection.
The morphological hit-or-miss transform is defined by the following equation

$$A \circledast B = (A \Theta X) \cap [A^c \Theta (W - X)] \quad (1)$$

$A \circledast B$ - Denotes hit-or-miss transform
$A \Theta X$- Denotes erosion transform
W- Denotes a small window

We can generalize the notation somewhat by letting B = (B_1, B_2), where B_1 is the set formed from elements of B associated with an object B_2 is the set of elements of B associated with the corresponding background. From the preceding discussion, by considering B_1 = X and B_2 = (W-X), then the Eq (1) becomes

$$A \circledast B = (A \Theta B_1) \cap (A^c \Theta B_2) \quad (2)$$

Thus, set $A \circledast B$ contains all the (origin) points at which, simultaneously, B_1 found a match ("hit") in A and B_2 found a match in A^c. By using the definition of set differences and the dual relationship between erosion and dilation we can write Eq (2) as

$$A \circledast B = (A \Theta B_1) - (A \oplus \hat{B}_2) \quad (3)$$

However, Eq (2) is considerably more intuitive. We refer to any of the preceding three equations as the morphological hit-or-miss transform.
The reason for using a structuring element B_1 associated with objects and an element B_2 associated with the background is based on an assumed definition that two or more objects are distinct only if they form disjoint (disconnected) sets. This is guaranteed by requiring that each object have at least a one-pixel-thick background around it. In some applications we may be interested in detecting certain patterns (combinations) of 1's and 0's within a set, in which case a background is not required. In such an instance, the hit-or-miss transform reduces to simple erosion.
The present paper that assumes extraction of connected components in a binary image is central to many automated image analysis applications. For extracting connected components the present paper proposes a scheme based on dilation. For this we assume Z represents a connected component contained in a set A. To implement this scheme a point q of Z has to be based on this an iterative equation is derived. For evaluating connected component Z

$$X_k = (X_{k-1} \oplus B) \cap A \quad (4)$$

k = 1, 2, 3…
where $X_0 = q$, and B is a suitable structuring element. If $X_k = X_{k-1}$, then we say the algorithm has converged, with connected component. This can be expressed as $Z = X_k$. This can be further explained as the intersection with A at each iterative step eliminates dilations centered on the elements labeled 0.The shape of the structuring element assumed in the present paper is an eight-connectivity between pixels.

The thinning of a set A by a structuring element B, denoted $A \otimes B$, can be defined in terms of hit-or-miss transform:

$$A \otimes B = A - (A \circledast B) \quad (5)$$

The equation (5) can be expressed as

$$A \otimes B = A \cap (A \circledast B)^c \quad (6)$$

The present paper main objective is only in pattern matching with the structuring elements. For this no background operation is required in the hit-or-miss transform, that's why the equation (6) has been adopted in the present paper for thinning. The present method uses the above definitions for obtaining the skeleton images. The present method is given in the form of the following flow chart. The novelty of the present scheme lies in evaluating the connected components.

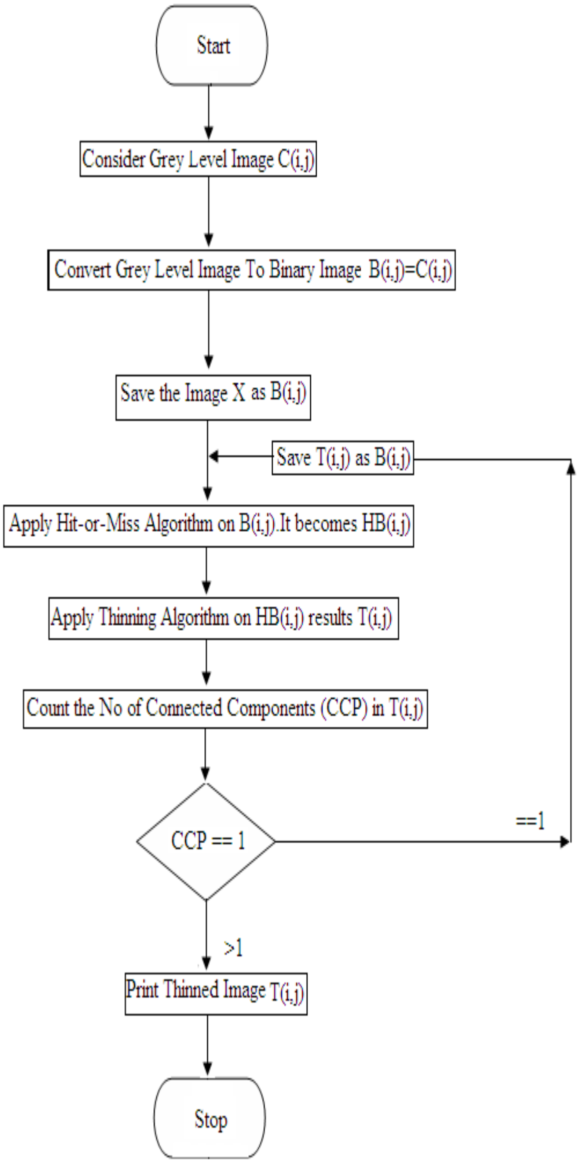

Figure 1.Flowchart for thinning of an image.

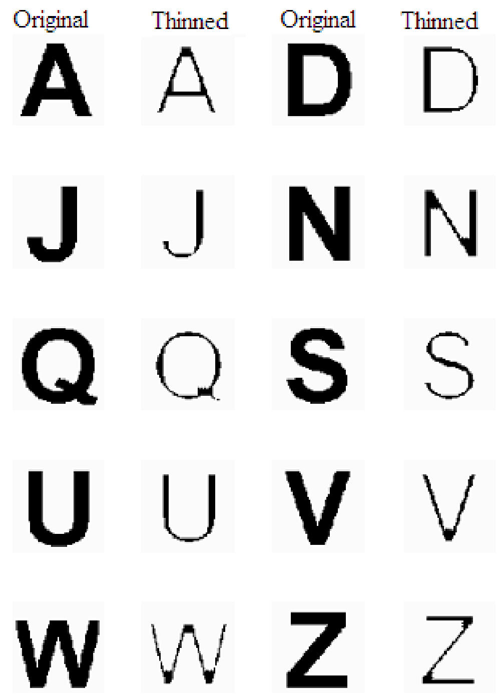

Figure 2. Original and Thinned Image of English Upper-case alphabets.

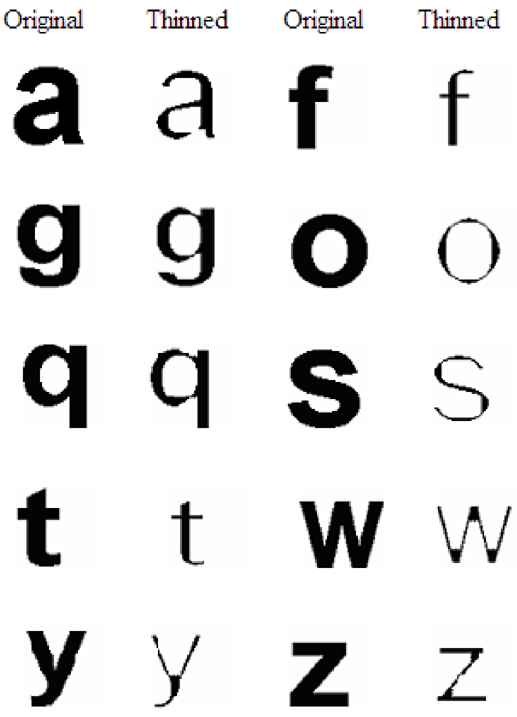

Figure 3. Original and Thinned Image of English Lower-case alphabets.

3. Results and Discussions

The present method is applied on English alphabet set both on lower case and upper case as shown in figure 2 and 3. The English alphabets are chosen for experimental analysis because they contain different shapes. The thinned alphabet set contains no restoration and they are not affected by any border noises which are usually present in most of the skeleton approaches. One of the advantages of the connected component approach as evident from the figure 2 and 3 is, that this particular method is useful for any region filling algorithms in which a point is known in each connected component. One of the main problems with thinning method was loss of information due to binarisation because it could not always be possible to correctly binarise the whole character image using one threshold value. The good skeleton result indicates that the present method has overcome this problem though thinning has done on binary image.

4. Conclusions

The present paper presented a very comprehensive, practical and simple thinning algorithm. The proposed algorithm is independent in shape and font and does not require any preprocessing. The novelty of the present scheme is it is based on hit or miss transforms and derived from connected component method. The present method has overcome the loss of information problem due to binarisation for thinning. The main advantage of present thinning algorithm is it is automatic and it does not require any human interaction. This fact is clearly evident from the flowchart given.

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