Pattern Recognition Letters 32 (2011) 1836–1842

Contents lists available at SciVerse ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

An improved contour-based thinning method for character images

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ARTICLE INFO

Article history:
Received 3 September 2010
Available online 11 September 2011
Communicated by A.M. Alimi

Keywords:
Ambiguous region
Contour
Medial axis
Shape characteristics
Skeleton segment
Thinning

ABSTRACT

Digital skeleton of character images, generated by thinning method, has a wide range of applications for shape analysis and classification. But thinning of character images is a big challenge. Removal of spurious strokes or deformities in thinning is a difficult problem. In this paper, we propose a contour-based thinning method used for performing skeletonization of printed noisy isolated character images. In this method, we use shape characteristics of text to get skeleton of nearly same as the true character shape. This approach helps to preserve the local features and true shapes of the character images. As a by-product of our thinning approach, the skeleton also gets segmented into strokes in vector form. Hence further stroke segmentation is not required. Experiment is done on printed English, Bengali, Hindi, and Tamil characters and we obtain much better results comparing with other thinning methods without any post-processing.

1. Introduction

Thinning of shape has a wide range of application in image processing, machine vision, and pattern recognition. But removal of spurious strokes or shape deformation in thinning is a difficult problem. In the past several decades many thinning algorithms have been developed considering all these problems (Lam et al., 1992; Vincze and Kővári, 2009). They are broadly classified into two groups: raster scan-based and medial axis-based. Raster scan-based methods are classified into two other categories: sequential and parallel. Sequential algorithms consider one pixel at a time and visit the pixel by raster scanning (Arcelli and di Baja, 1989) or contour following (Arcelli, 1981). Parallel thinning algorithms are based on iterative processing and they consider a pixel for removal based on the results of previous iteration only (Datta and Parui, 1994; Huang et al., 2003; Leung et al., 2000; Zhang and Suen, 1984; Zhu and Zhang, 2008). Many of the raster scan-based character thinning methods can not preserve the local properties or features of the character images properly. As a result, they give slightly shape distorted output. Medial axis-based methods generate a central or median line of pattern directly in one pass without examining all the individual pixels (Martinez-Perez et al., 1987). They also give slight distorted result at some local regions. Here we attempt to minimize local distortions by making use of shape characteristics of text. Next we begin a brief description about few prominent raster scan-based thinning algorithms.

Datta and Parui (1994) have proposed a parallel thinning algorithm which preserves connectivity and produces skeleton of one pixel thickness. Each iteration of the algorithm is divided into four sub-iterations. These sub-iterations use two 1×3 and two 3×1 templates for removing boundary pixels along east, west, north, and south directions, respectively. The method uses one 3×3 window to avoid the removal of critical point (which alters the connectivity) and end point (which shortens a leg of the skeleton).

Leung et al. (2000) have introduced a contour following thinning method having no sub-iteration. They have used a lookup table to avoid the use of multiple templates for removing boundary pixels. The lookup table has 256 entries and each entry contains three fields (neighbor number, weight number, and connection number). The number of entries depends on the different possibilities of 8-connectivity of a pixel. The determination of the possibility of pixel removal depends on the values of the patterns of the spatial contour pixels.

To improve the pixel connectivity of thinned character images, Huang et al. (2003) have introduced a new set of templates (three 4×3, one 4×4, and three 3×4). This algorithm considers all possible patterns of 8-connectivity of a pixel (similar to Leung et al. (2000)) and generates template-based elimination rule for deleting boundary pixels. The pixel deletion is done based on the number of black pixels in the 8-neighbor connectivity. Additionally, it compensates information loss by integrating the contour and skeleton of pattern. The information loss is detected based on the ratio of the skeleton and contour pixels. If the value is less than a predefined threshold then the thinned image is replaced by the contour image.

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0167-8655/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.patrec.2011.07.001

Fig. 1. Distortions of different thinning methods: (a) input image; (b) thinned image (Red circle indicates distortion at junction and end points; Red arrow indicates spurious strokes at curvature region). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The main contribution of Zhu and Zhang (2008) method is that it does not consider all pixels equally for performing character thinning. It is based on the substitution of pixels of strokes or curves which are most valuable parts for character recognition. This method uses a set of thinning templates, similar to Datta and Parui (1994), for boundary pixel removal and handling corners or junction points. This method has tried to preserve the shape of character images such as Chinese characters, English alphabets, and numerals after thinning. All the above discussed algorithms perform boundary pixel deletion using various thinning templates or values from lookup tables. Next we discuss medial axis-based thinning algorithm.

For performing thinning of regular shape, Martinez-Perez et al. (1987) have introduced a medial axis-based thinning method. This approach does not use thinning templates or lookup tables for performing thinning. They have generated medial points in between two parallel contour segments and repeat the procedure for all remaining parallel contour segments. But they have not applied this concept for curve. Finally, we give a brief description of a thinning method which is used for skeleton simplification.

Telea et al. (2004) have introduced a method to simplify skeleton structure of an image by removing few skeleton branches. The simplification is done by analyzing the quasi-stable points of the Bayesian energy function, parameterized by boundary of contour and internal structure of the skeleton. The experimental results show that it gives multi-scale skeleton at various abstract levels.

Apart from these common methods, some new techniques (such as graphical method, wavelet, neural networks, critical kernels, and pulse coupled neural network) have been introduced into image thinning. Melhi et al. (2001) have proposed a method for thinning binary handwritten text images by generating graphical representations of words within the image. Tang and You (2003) have introduced a wavelet-based scheme to extract skeleton of ribbon-like shape. You and Tang (2007) have presented a scheme of extracting the skeleton of English and Chinese characters based on wavelet transform. Krishnapuram and Chen (1993) have applied recurrent neural networks to image thinning. Altuwaijri and Bayoumi (1995) have used a self-organizing neural network to thin digital images. Gu et al. (2004) and Shang et al. (2007) have proposed a binary image thinning algorithm by using the auto-waves generated by pulse coupled neural network (PCNN). Bertrand and Couprie (2006) have introduced a new 2D parallel thinning algorithm using critical kernels.

All the above mentioned algorithms can not retain the shape of the character images at the junction and end points properly and produce spurious strokes at high curvature region (Fig. 1). From that point of view, we address a contour-based thinning method for generating proper skeleton of isolated character images. The algorithm is non iterative and template free. The main advantage is that it uses shape characteristics of text to determine the areas within the image region to stop thinning partially. This approach helps to preserve the local features and true shape of the character. Additionally, it produces a set of vectorized *strokes* with the thin skeleton as by-product. These resultant skeletons have stronger ability to oppose shape deformation and more convenience to shape analysis and classification.

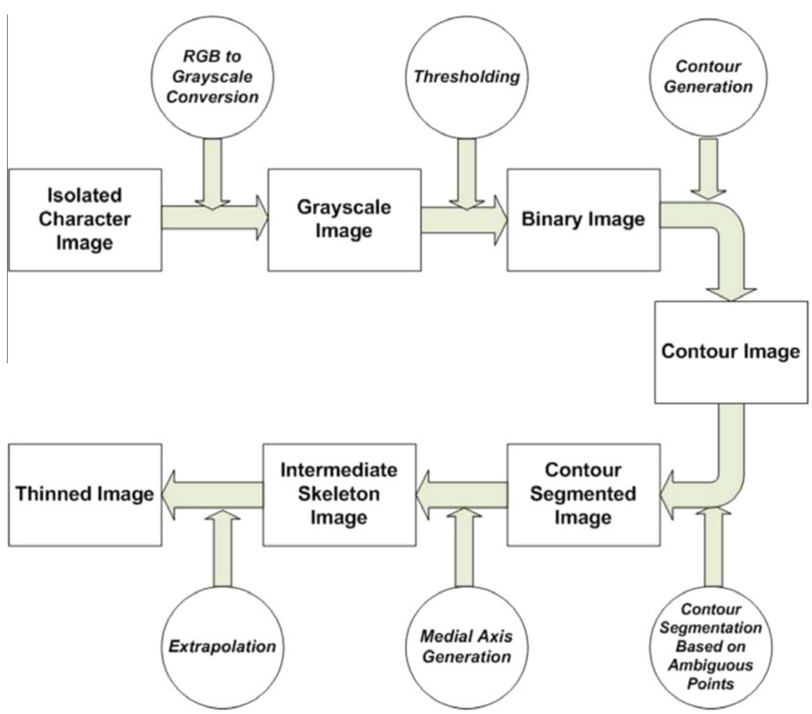

Fig. 2. System architecture of the proposed method.