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Skeletonization Algorithm for Binary Images

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Abstract

Skeletonization and also known as thinning process is an important step in pre-processing phase. Skeletonization is a crucial process for many applications such as OCR, writer identification ect. However, the improvements in this area still remain due to researches recently. A new skeletonization algorithm is proposed in this paper. The algorithm is combining between parallel and sequential which categorized under iterative approach. The proposed method conducted into experiments of benchmark dataset for evaluation. The result is obtaining much better results comparing with other thinning methods is included in comparison part.

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*Keywords :*Skeletonization; Thinning; Document image analysis; Text images; OCR.

1. Introduction

Document image analysis and recognition (DIAR) techniques are a primary application of pattern recognition. DIAR techniques aim to extract information from document images to enhance knowledge. There are two categories of DIAR applications: textual applications and graphical applications [1-2]. Textual applications deal with the text body in a document image. They include tasks related to text processing and text recognition. Text processing represents several applications such as text skew detection and correction, text extraction, text skeleton, layout analysis and text segmentation.

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Skeletonization is the result of the thinning process, which peeling the contour of the text until reaches most medial one pixel width. Goodness of the thinning method is measured by how much the skeleton extracted preserve the topology of the shape without any interrupt [3]. Skeletonization is used in preprocessing phase for several applications such as writer identification [4-5], script identification [6], optical character recognition OCR [7].

Skeletonization is divided into two main approaches; iterative and non-iterative [8]. Iterative techniques, the peeling contour process iteratively parallel or sequentially; in the parallel way the whole unwanted pixels are erased after identify the whole wanted pixels [8]. Whereas in sequential techniques; the unwanted pixels are removed in the identifying the desired pixels in each iterative in [8]. In non-iterative approach the skeleton is extracted direct without examine each pixel individually, but these techniques are difficult to implement and slow as well [9].

Even most of traditional problem for thinning concepts; there are some algorithms suffer from these traditional problems such as one pixel width of the skeleton and skeleton connectivity as well. Distortion in topological of shape skeleton is a serious problem in thinning application [10]. Whereas, several techniques are failed preserve the shape topology [11-12]. Spurious tails and rotating the text shape is other serious problem and most thinning methods are failed [11-13].

A new thinning algorithm is proposed in this paper solved the problems with previous methods. The proposed method is combine iterative approach categories which it's parallel and sequential process. Experiments are conducted into shape benchmark dataset to evaluate the proposed technique. The results shown much better other than previous methods and solve skeleton width, spurious branches, distortion, and tolerance to invariance rotation.

The rest of the paper is organized as follows. In Section 2, brief description on general overview in thinning approaches and iterative methodologies. Section 3, the proposed method is illustrated. Section 4, describes the results of experiment. Conclusion is given in Section 5.

2. General overview

This section we describe the various approaches to image skeletonization and overview of prior work on this field.

2.1. Thinning categories

Two appraoch of skeletonization; iterative and noniterative, the iterative approch divided into sequential or parallel process by removing the contour pixels iteratively till reach one pixel width [14]. Sequential and prallel thinning tehniques are similar in dertermining the wanted and unwanted pixels, while dissimilar in removing time. In sequential the removing unwanted pixels start in the identyfing wanted process [15-17]. While in parallel the pixels are removed after identifiy all unwanted pixels [11, 18-20].

Non-iterative techniques produce a skeleton directly without investigating all of the individual pixels [21]. Numerous methods have been appointed to extract the skeleton using a non-iterative approach, including neural networks [22] , Voronoi diagrams [23] and wavelet transforms [24].

2.2. Iterative methods

Parallel iterative thinning is proposed [12]. Twenty rules are applied at same time in each iteration. Method has shown a fair result in shape rotation. However, the method in [25] claimed that the method in [12] is extracted a skeleton with two pixel width in shape portion. Rockett has modified [12] method to treat two-pixel width. The modification has done by adding extra rules to avoid two pixels width in post processing phase. However, the method suffering from superior tails.

Parallel iterative method consist of two sub-iteration proposed by [18]. Contour peeling based on 8-neighbor pixels pass over each pixel. The algorithm keeps the connectivity but two pixel width accord in some portion of the skeleton. The method in [12] is proposed a enhancement of [18] method based on PTA2T template, in each iteration the deletion based on 8-neighbor pixels pass over each pixel, the algorithm keep the connectivity with one pixel width and author claim the proposed method is faster than other algorithm. But, it is suffering from desertion in end of tails by extra branch are appear in the skeleton.

A parallel thinning algorithm is proposed based on fixed window, pixel is examine for deletion based on 8-neighbor weight value [26]. Certain rules are applied at same time for each pixel. Supplementary phase consist from other rules is used to keep the connectivity. The drawback is some portion of the shape is totally disappeared.

A sequential iterative thinning method is proposed [9] based on weights value of the 8-neighbors used in [26]. The method go through seven phases are applied in each iteration, which lead to slow running time. Supplementary phase is used to guarantee one-pixel width of the skeleton. Furthermore, claimed that the extremely computation time indeed due to the big number of phases. However, the method did not keep the topology of shape and suffer from rotation variant by extra tails are appear.

3. The Proposed Method

The proposed algorithm is consisting of three main stages; conditional contour selection, pixel removing, and one pixel width stage. The structure of these stages addressed in Flowchart as shown in Fig. 1.

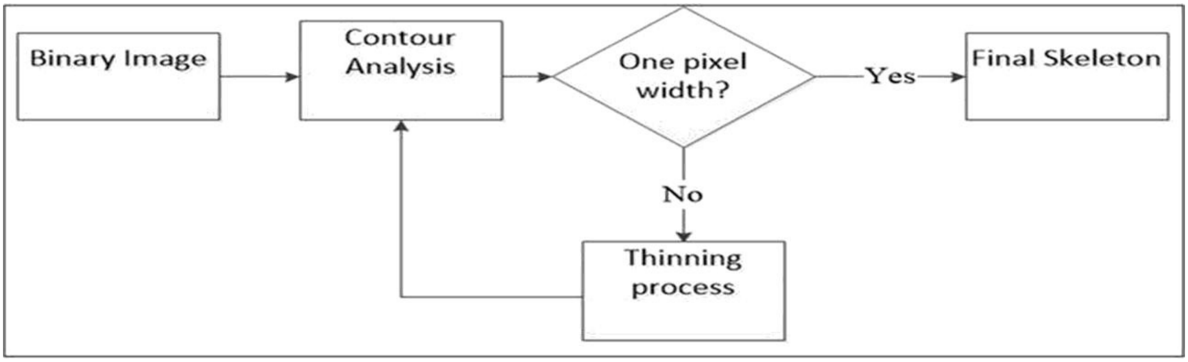

Fig. 1.Flowchart of the proposed method.

The binary image is acquisitioned into the proposed method as black pixels which considered as a foreground as well as consider as object pixel for deletion. The pixels having value 0 are considered as background pixels.

Contour detection and analysis phase; the contour is flagged where any foreground pixel ‘1’ is boarder with any single background pixel ‘0’ consider as contour pixels. In case of the flagged pixels are adjacent either vertically or horizontally; it will cause for desertion in deletion process orstork will be disappeared. To avoid this problem a single side of flagged pixels is return as a foreground ‘1’. Before move to thinning process phase, the foreground pixels sited in corner positions are flagged as contour pixels.

Thinning process stage; in this stage, all flagged pixels should be either removed ‘pixel assign to 0’ or return it back to foreground ‘pixelsassign to 1’. Each flagged pixel the examination process for the 8 surrounding pixels is performed. These 8 sequence pixels are containing either flagged ‘×’ or foreground ‘1’ see Fig. 2. Then, the connectivity will be check by examine if there no any background pixel ‘0’ in this series of pixels. Afterwards the examine pixel is removed to be assign into ‘0. Otherwise, it will assign into ‘1’ as foreground. . This process repeateduntil all pixels are un-flagged.

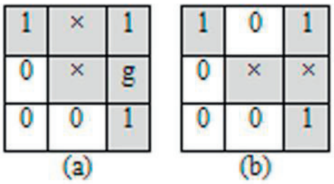

Fig. 2 Example of 8 neighboring pixel (a) examples on discontinuance sequence by '0' (b) example on continuance sequence by '0'.

One pixel width stage; the skeleton is extracted till two previous stages imperfectly since a two-pixel width occur in some portion and superior tails as well. Thus, one more stage indeed to overcome these problems. In this stage a 3 × 3 weight value matrix adopted from [23]. Starting from upper center matrix value will be assign in clock wise to 2^n. Then the summation of these values $\sum_{n=0}^{7}$ will equal to 255. Then all cases are studdedindividually where these cause accurately. All these values are calculated identically as shown Fig. 3.

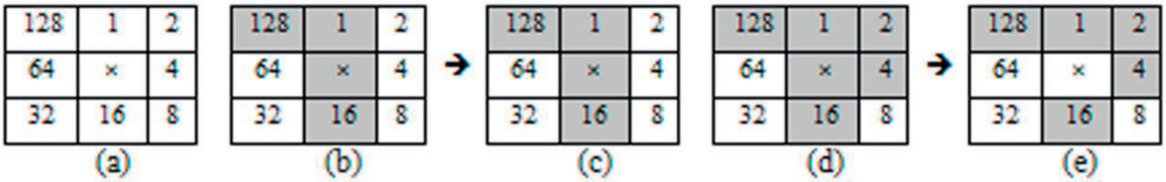

Fig. 3 (a) weight values of the 8-neighbor pixels, (b) is case of 145 weights and it is result in (c), (d) is the case of 1451 weight and it is result in (e).

4. Experiments and results

In this section, theMPEG-7 CE-Shape-1 Dataset [27] is used to evaluate proposed method. This data set has many class shapes. Owing to space some of these dataset are shown in this paper. The 1-pixel width, shape preservation, and connectivity will be considered in the result.

	Set of MPEG-7 Shape Dataset classes			
	Beetle	bone	camel	stef
Original	 (a)	 (b)	 (c)	 (d)

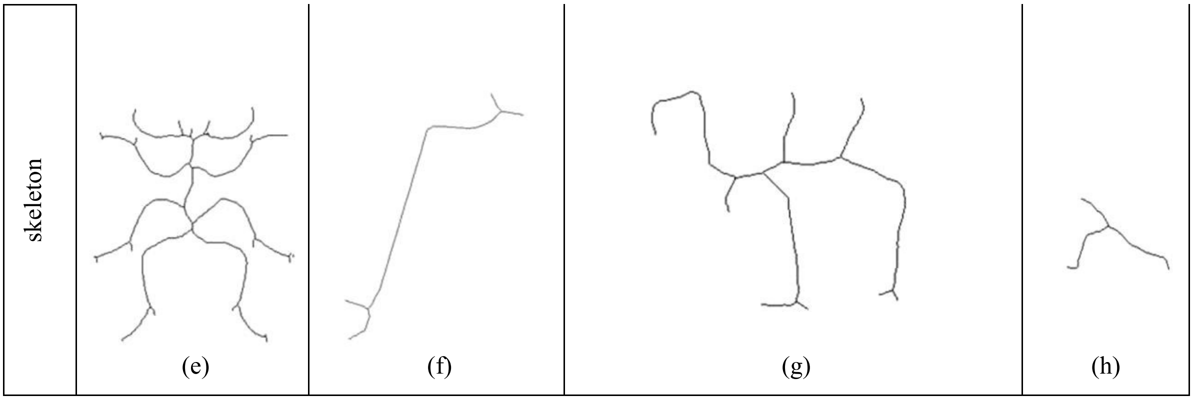

Fig 4 (a-d) Original image from different classes of MPEG-7 dataset , (e-h) The result skeleton from proposed method.

The experiments visually illustrate in Fig. 10. It shows that how much the skeleton is going smoothly into original shape. In all images from different classes the skeleton is sensitive even into the small protrusion accurately without any superior tail in the ends. The skeleton resulted is one-pixel width without any interception. The topology preserved well in all classes.

5. Conclusion

A new iterative thinning algorithm is proposed. The method consists of three stages. First two stages conceder to extract the skeleton and the third is conceder for optimizing the skeleton into one-pixel width. The experiments are conducted into multi class chosen from Set of MPEG-7 Shape Dataset classes to evaluate the proposed method. The visual experiments prove the high-quality performance for shape binary images. The superior tails and the topology problem are highly achieved as shown in Fig. 4. The proposed method is applicable for any shape with any rotation.

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