Skeletonizing a Handwritten Image Object.

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ABSTRACT

Applying a suitable threshold converts a handwritten image object to binary image. A modified medial axis transform is presented in this paper which skeletonizes handwritten image objects. The binary image object is scanned both in horizontal and vertical directions, which preserves the continuity of the handwritten strokes. Numerical derivatives on all elements of a scan line detect the binary edges on the line. To obtain the skeleton pattern, the median position indexes of all ones segment in a scan line are found. Applicability of the algorithm is tested on handwritten numerals, characters, words, and signatures.

(Key words: image thinning, skeleton, binary image)

INTRODUCTION

Research in the field of machine recognition has received significant attention in the last fifty years. Among many successful applications of skeletonization, automatic visualization of industrial parts, biomedical analysis of white blood cells and chromosomes, character recognition, fingerprint classification, quantitative metallography, and X-ray image analysis can be noted. Skeleton of an image serves the purpose of data compression and makes shape analysis easier. As an intuitive and intelligibler structural analysis, the skeleton of image objects bears more distinctness to human perception. An effective skeletonization algorithm should be able to keep the essential features and remove the redundancy and local noise.

There are over ten methods for skeletonizing an image object found in the literature. The presented one provides proper skeletonization for the handwritten image objects. The widely used methods for skeletonization are iterative ones. These methods successively delete layer of pixels on the boundary of the pattern until only a skeleton remains. The deletion or retention of a pixel depends on the configuration of the local neighborhood containing the pixel.

Based on how the iterative algorithms examine pixels, they can be classified in two broad categories – parallel and sequential. The parallel algorithms characterized by reduction operators are presented in [1 - 3]. Another iterative method in conjunction with contour tracing is applied for the skeletonization [4, 5]. The algorithm becomes burdensome for multiply connected objects and/or labeled skeletons. The implementation of a 4-distance transform detects the skeleton preventing contour simplicity [6]. The method relates the geometry of the digital contour with that of the real curve supposed to delimit the continuous set of which the digital object is the discrete counterpart. It is shown that detecting the multiple pixels is computationally more convenient than applying standard removal operations. In parallel algorithms, the number of iterations gives a measure of speed; the lower is the number of iterations, the higher is the parallel speed. Main complexity in parallel algorithms arises from the fact that the connectivity needs to be preserved while using parallel operation in a small local neighborhood.

The sequential counterpart functions processing only the contour pixels [7 - 9]; the pixels examining for deletion are picked up in a fixed sequence in each iteration and the deletion of a particular pixel depends on all the operations that have been carried out so far. Another approach for skeletonization can be finding the Fourier descriptors on quantitative basis [10]. Extracted Fourier descriptors considering a finite set of

harmonics from a closed curve can describe the skeleton of a handwritten image object.

The design of a skeletonizing algorithm has been a dynamic research area as far as intrinsic appeal in machine recognition of patterns is concerned. The proposed non-iterative algorithm finds the skeleton of handwritten image objects scanning the image both in horizontal and vertical directions.

THE SKELETONIZATION PROCESS

Skeletonization is a process by which the medial shape or skeleton of an image is extracted. If the object shape is regular, skeletonization is easy to find using geometric medial shape; but for irregular shape and multiply connected region an algorithm is necessary to find the skeleton. The first step of the skeletonization starts with the scanning of a handwritten image object. The scanned image is converted to an intensity image, and then resized to a suitable scale. A suitable threshold transforms the resized image to a binary one. We assumed that 0 stands for the background and 1 does for the handwritten strokes. The binarization is inverted for depicting the handwritten images and their skeletons. The following five-step algorithm is applied to any scan line in the binary image:

Step 1: find the consecutive difference (–1, 0, or 1, 0 is ignored) of the elements in the scan line, where the transitions 1 to 0 and 0 to 1 are represented by –1 and 1, respectively,

Step 2: the position indexes corresponding to the difference –1 or 1 are stored in a vector,

Step 3: append 0 and the number of elements in the scan line before and after the vector found in step 2, respectively,

Step 4: find the median of the position indexes if the elements between the successive intervals of the vector found in step 3 are all ones, and

Step 5: form a zero vector of the same size as that of the scan line and fill the median position indexes by ones.

We apply the algorithm first for all rows and then for all columns of the whole binary image. Averaging and thresholding further provide the skeleton of the hand written image objects. The block diagram of the whole process is presented in Figure 1.

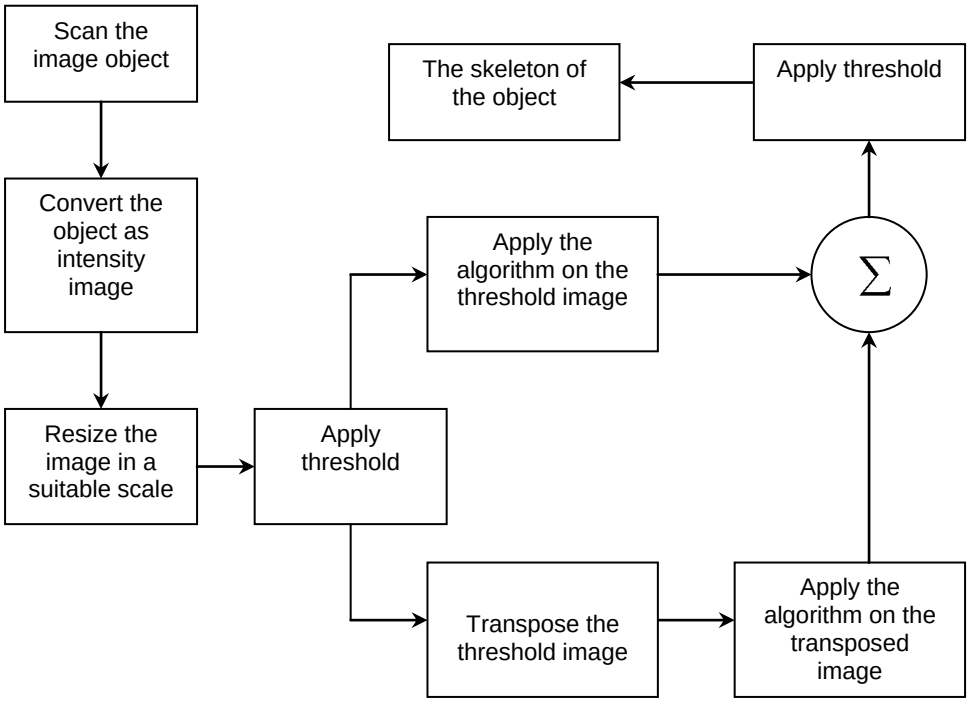
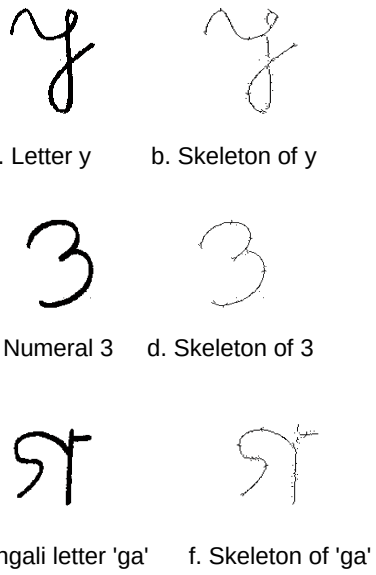


Figure 1: The Skeletonization Process of a Handwritten Image Object.

SIMULATION RESULTS

The aptness of the process is seen on handwritten English letter y and numeral 3, Bengali letter 'ga', an Arabic word, and a signature written in plain paper. Plustek OpticPro UT 12 (as B/W photo with 600 dpi) performed the scanning task of the handwritten objects. We saved the scanned objects as windows bit map files (.bmp), converted them to intensity images in [0,1] scale, and resized the converted image to pixel size 200×200 by utilizing the nearest neighborhood interpolation. A threshold 0.9 binarized the handwritten objects as in Figures 2.a, 2.c, 2.e, 3.a, and 4.a for letter y, numeral 3, Bengali 'ga', arabic word, and signature respectively. We obtained the skeletons of the chosen handwritten objects following the implementation of the skeletonization process as shown in Figures 2.b, 2.d, 2.f, 3.b, and 4.b, respectively.

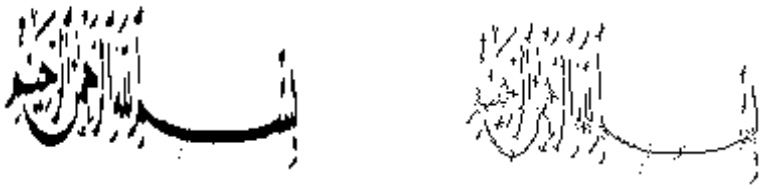


a. Letter y b. Skeleton of y

c. Numeral 3 d. Skeleton of 3

e. Bengali letter 'ga' f. Skeleton of 'ga'

Figure 2: Handwritten Characters and Numeral and their Skeletons.



a. An arabic word b. Skeleton of the arabic word

Figure 3: Handwritten Word and its Skeleton.

a. A signature b. Skeleton of the signature

Figure 4: A Signature and its Skeleton.

CONCLUSION

Handwritten image objects are skeletonized by a non-iterative algorithm, which can be regarded as the modified medial axis transform. The algorithm is proved to be effective for the handwritten characters, numerals, words, and signatures. The method is computationally efficient compared to sequential or parallel counterpart. Applying the algorithm both in horizontal and vertical directions preserves connectedness of the handwritten strokes.

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