Optimised Homotropic Structuring Element for Handwriting Characters Skeleton

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Abstract: - This paper is focused on the study of skeleton transformations involved in the hand printed & handwritten documents’ images preprocessing. A new homotropic transformation structural element is proposed in order to optimize the sequential thinning procedure: reduced number of thinning cycles and less coarse skeleton lines.

Key-Words: - Hand-written Character Recognition, homomorfic transformation, Java Programming.

1 Introduction

The skeleton procedure (i.e. the reduction of the analyzed characters to one pixel thick lines and curves) is one of the most important steps in the typed & hand written images’ preprocessing. This procedure has to be done in order to eliminate recognition errors caused by the dissimilar line thickness. Stroke thickness is a specificity of each man’s handwriting, mainly caused by different pressure put on the writing instrument. Even in the situations involving a single subject, different “writing thickness” may occur in diverse situations due to the specificities of the used pen or the writing speed. Line thickness can also arise from image acquisition and subsequent geometrical transformation (especially scale) [3].

Basically the skeleton is obtained by using recursive thinning till analyzed characters are reduced to a set of one pixels thick lines and curves. Subparts connectivity points and stroke’s end pixels have to be preserved.

The straightforward approach to realize this task is employing the set of structuring elements described in eq.(1)

\[
\begin{bmatrix}
1 & 1 & 1 \\
1 & 1 & 0 \\
0 & 0 & 0 \\
\end{bmatrix}
\]  \[\begin{bmatrix}
1 & 1 & 1 \\
1 & 1 & 1 \\
0 & 0 & 1 \\
\end{bmatrix}
\] ...

(1)

The process is a little slow but gives adequate response in the case of simple test images as the one in Fig.1.1. Because of the typographical quality requirements all images presented in this paper are negatives of the real ones.

Fig.1.a. Test image, rectangle b. Skeleton

Unfortunately when real life images (i.e. hand printed & handwritten documents’ images) are processed the resulting skeleton is very coarse (see Fig. 2). Thus a supplemental curve relaxation procedure became compulsory [4].

Fig.2. a. Handwritten document image b. Skeleton with recursive standard thinning

Better techniques rely on a sequence of successive thinning with homotropic structuring elements L (1.2.) or M (1.3.) able to deliver one pixel thick connected lines and curves (skeletons approximations) in a less time consuming process. The symbol "*" is used in order to mark the position where the “white” or “black” color of the pixel is of no consequence for the local thinning decision and...
therefore no test is to be made about them in the software implementation.

\[
\begin{bmatrix}
1 & 1 & 1 \\
* & 1 & * \\
0 & 0 & 0
\end{bmatrix}
\quad \begin{bmatrix}
* & 1 & 1 \\
0 & 1 & 1 \\
* & 0 & *
\end{bmatrix}
\]

(2)

\[
\begin{bmatrix}
1 & 1 & 1 \\
* & 1 & * \\
0 & 0 & 0
\end{bmatrix}
\quad \begin{bmatrix}
* & 1 & 1 \\
0 & 1 & 1 \\
* & 0 & *
\end{bmatrix}
\]

(3)

The other structuring elements reported in the image processing literature (C, D, E) are crafted for some slightly different targets and behave poorly with both typed and handwritten documents images.

The recursive thinning results with the two homotrophic structuring elements on the same image are presented in Fig.3. The software implementation of the recursive thinning with all structuring elements in this paper is the same, thus the comparisons among them is made on an objective basis.

The L structuring element commonly gives better skeletons approximation when it is employed with handwriting but it is slower. The M structuring element is always quicker but the curves are coarser and disconnection errors occur.

Fig.3.a. Image processed with M structuring element

b. Image processed with L structuring element

The slow - quick discussion generally tend to become obsolete with the processing speed and the vast resources of actual computers. Therefore the L element technique is preferred in almost all cases.

The problem resides in the fact that the L structuring element does not behave quite well with the handwritten documents’ processing and the resulting skeletons are still coarse and sometimes thorny.

2 The H structuring element

Therefore the authors tried to improve the procedure performances employing an optimized structuring element resulting from combining the standard skeleton structuring element and the L structuring element.

We started from the straightforward simplification of the standard structuring element eq. (1). Each pair of matrixes can by mathematically described by a common model as shown in eq. (4).

\[
\begin{bmatrix}
1 & 1 & 1 \\
* & 1 & 1 \\
1 & 1 & 1
\end{bmatrix} \quad \begin{bmatrix}
1 & 1 \\
* & 0 \\
1 & 0
\end{bmatrix} \rightarrow \begin{bmatrix}
1 & 1 \\
* & 0 \\
1 & 1
\end{bmatrix}
\]

(4)

Consequently the eight matrixes in the initial set become four as shown in (5):

\[
\begin{bmatrix}
1 & 1 & 1 \\
* & 1 & 1 \\
* & 0 & *
\end{bmatrix} \rightarrow \begin{bmatrix}
1 & 1 \\
* & 1 \\
0 & 0
\end{bmatrix}
\]

(5)

In order to improve speed and accuracy an auxiliary set of four matrixes were borrowed from the L technique.

\[
\begin{bmatrix}
1 & 1 & 1 \\
* & 1 & 1 \\
* & 0 & *
\end{bmatrix} \rightarrow \begin{bmatrix}
1 & 0 \\
* & 0 \\
1 & 1
\end{bmatrix}
\]

(6)

Thus the H structuring elements set is:

\[
\begin{bmatrix}
1 & 1 & 1 \\
* & 1 & 1 \\
* & 0 & *
\end{bmatrix} \rightarrow \begin{bmatrix}
1 & 1 \\
* & 0 \\
1 & 1
\end{bmatrix}
\]

(7)

This homomorphic structuring elements set behaves better with the hand printed & handwritten documents’ images, as it will be shown in section 4. The resulting skeletons are less coarse and the number of needed processing cycles is equal or less the one in L technique.

3 Software implementation

The program performing the processing tasks has been developed in Java (JDK 1.3). It is a Window application and it is able to:

- Display the document’s image;
- Execute the recursive thinning until skeleton stage is reached;
- Display a contour showing the number of cycles performed;
- Save the final image resulted after the process.
The class structure contains a main class \textit{W} (extending the \texttt{javax.swing.JFrame} and implementing the \texttt{Runnable} interface) and a processing \textit{Sb} class (extending \texttt{java.awt.image.ImageFilter}).

![Image 1](image1.png)

Fig. 4. The Skeleton program frame in the starting state.

The main class is the program main thread and contains code to implement the window frame. This window has a file menu with open, filter, save and exit menu items and a display image place as shown in Fig. 4. Consequently “\textit{W}” class also has the methods for performing opening, saving and exiting.

![Image 2](image2.png)

Fig. 5. The program class structure as shown in Borland JBuilder 4 environment, Structure Window

The \textit{Sb} class is focused on the thinning and contains the set of “if...else if” statements implementing the Hit or miss procedures needed for finding the pixels to be changed from letter pixels to background ones.

The sequence of successive thinning is realized through the Thread mechanism inside a “while” statement. It stops when \textit{Sb} report no more changes has been done over the last thinning cycle.

The contour is also declared incremented and displayed within the “\textit{W}” class, shows the number of cycles in real time. In the end its figure represents the skeleton stage thinning cycles needed for the currently processed image.

Final image saving has been done using the method in [2]. It gave the possibility to preserve in JPEG format the skeletonized images for the further processing steps.

4 Experimental Results

The experiments were carried out over the standard NIST database for hand printed & handwritten characters. The processing with each set of matrixes was performed in identical software environments.

![Image 3](image3.png)

Fig. 6.a. Image processed with L structuring element
b. Image processed with H structuring element

each of the four skeleton techniques were analyzed and it resulted that:

A. The standard thinning and the M homotropic structuring element technique are not able to perform satisfactory with the hand printed & handwritten documents’ images.

B. The L homotropic structuring element technique behaves better, but the resulting skeleton is still coarse and it has a thorny aspect. The coarse parts and the thorns are sometimes source of inadequate final classifications.
The proposed H homotropic structuring element technique is more precise while it is at least as fast as the L technique. The skeletons have almost 4% less pixels due to the absence of the coarse parts and thorns.

It is also important to stress here that the final recognition results on the experimental test set improved with 0.62% because of using H instead L homotropic technique.

The explanation of this resides mainly in the less coarse strokes that leave less space for misinterpretations.

5 Conclusion

The skeletonization is an important step in preprocessing documents’ images. If the skeleton is accurate it avoids a great number of mistakes in the final character recognition stage. The process consists of a recursive thinning that usually employs a homotropic set of structuring elements.

Experiments show that the largely known and used L structuring element does not behave well with the hand printed & handwritten character documents’ images.

Thus the authors proposed another solution coming out from combining standard thinning and L set. The results prove to be better and the improvements also echoed in the final recognition stage.

As researches about skeleton reach the final conclusive state it became clear the need for implementing also a more flexible binarization technique in order to reduce the strokes and curves disruptions.

Team thought about reevaluating the results after a better binarization method will be find and adapted to the documents’ images specificities. It is highly probable that the two preprocessing steps could be improved not only as separate entities, but also as interacting stages of the image preparation for the later automatic interpretation.

References:


