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COMPARATIVE ANALYSIS STUDY OF BINARY IMAGE SMOOTHING TECHNIQUES

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ABSTRACT

Image smoothing, or denoising, is a very important pre-processing operation in almost all applications of digital image processing ranging from enhancement of space-probe pictures to automatic finger print identification. In this paper we present the results of a comparative analysis study of four different smoothing techniques for digitized binary images.

The techniques considered are: Majority smoothing, Directional logic smoothing, Majority smoothing with contour checking, and a simple 1-D median filter-type smoothing. The first three are two dimensional. Three criteria for judging the performance of the examined techniques are selected, which are: The qualitative effect on the image quality, the processing time, and the effect on the image compression efficiency.

The four techniques are implemented and tested on a wide range of test images. A sample of the test images, original and smoothed, will be presented to illustrate quantitatively the effect of the different methods. The 1-D smoothing was found to require the least processing time , while the majority smoothing method was found to have the best effect on the compression efficiency (average increase of 20%). The study was done using the Wang Professional Image Computer (PIC), which is a microcomputer-based imaging system.

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INTRODUCTION

Image processing is a field which has been experiencing a rapid growth since the 1960's. It was the combined advents of large-scale digital computers and the space programs that brought into focus the potentials of image processing concepts [1] . Areas of application are wide and varied, from restoration and enhancement of space-probe pictures to industrial robotic vision. Binary images, or two-level images, constitute a class of images which is important in many applications and which is easy to process, characterize, store and communicate[2] .

One of the problems of binary images is that they have a high probability of being noisy. Noise may come from different sources, e.g.,the scanner electronics, quantization and thresholding or due to a noisy environment. Noise degrades the quality of the image as well as produce spurious black pixels and/or pinholes in the image that might fragment the contents of the image, which in turn causes problems when automatically trying to recognize objects or written text in the scanned image. Noise will also reduce the compression ratio achieved when the image is coded for storage or transmission. Smoothing, or de-noising, is a very important pre-processing operation in several image processing applications, it enhances the quality of the image and improves the automatic recognizability of the image contents[3,4] Smoothing can also result in compression improvements.

In this paper we present a comparative analysis study of four different smoothing techniques for binary images. The techniques considered are: directional logic smoothing, majority smoothing, majority smoothing with contour checking[5] ,and a simple 1-D median filter-type smoothing. A general overview of the problem will first be given with a description and analysis of the four techniques. The effect of each technique on the compression ratio achieved when using the modefied run-length Huffman coding method [6] is examined and illustrated. The four techniques are examined and tested over a wide range of test images which represent a variety of situations, i.e., clean images, noisy images , all graphics images, text images, and mixed images. Three criteria for judging the performance of the smoothing techniques are used: (1) the qualitative effect on the image appearance, (2) the processing time required to implement the algorithm, and (3) the effect on compression.

The results of the study, accompanied by a sample of the test images, will be presented in the last section of the paper. It is worth noting that the study was carried out using the Wang Professional Image Computer (PIC), which is a microcomputer-based imaging system. The system scanner scans the images at a resolution of 200 dots per inch (dpi), the digitized image is th then thresholded using an adaptive thresholding technique to result in a binary image. Each picture element (pixel) in the binary image will be represented by only one bit, since its value will either be "one" or "zero", i.e., "black" or "white".

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IMAGE SMOOTHING TECHNIQUES

The classical technique of combating noise in a digitized image is smoothing. In this section we describe the four spatial smoothing techniques that were selected for implementation in our study. The basic idea is to replace the value of the picture element at a specific point f(i,j) by an average value of the picture function in the immediate vicinity. One should be aware that too much smoothing might blur details in the image.

Directional Logic Smoothing

In logical smoothing, a neighborhood N(x,y) is defined around the pixel at (i,j) and the smoothed value is determined by the presence and/or absence of specific configurations of black or white pixels. A logical function can be defined using the pixels in the neighborhood as variables. The neighborhood that we considered is a 3x3 window centered around point (i,j). As the window size increases more pronounced blurring of the image occurs.

In the directional logic smoothing method that we implemented, the decision for a black or white bit is made as follows: make the (i,j) bit in the smoothed pattern "0" unless at least one of the bits labelled "A" and at least one of the bits labelled "B" in Fig.1 is "1" OR at least one of the bits labelled "C" and at least one of the bits labelled "D" is "1".

	A	A
B		A
B	B	

C	C	
C		D
	D	D

Figure 1. Directional Logic Smoothing

This method provides continuousand smoothed corners, but it tends to fill in internal corners and cause serifs on characters to be exaggerated.

Majority Smoothing

In majority smoothing the value of the pixel is determined by the value of the majority in the neighborhood. A pixel is set to "1" when more than half of the pixels in the 3x3 window centered around that pixel are black, otherwise it is set to "0" . This method results in objects with smooth contours, but small holes in an object or small characters tend to be filled in by this process. Sometimes it also results in loss of connectivity of thin lines.

Majority with Contour Checking

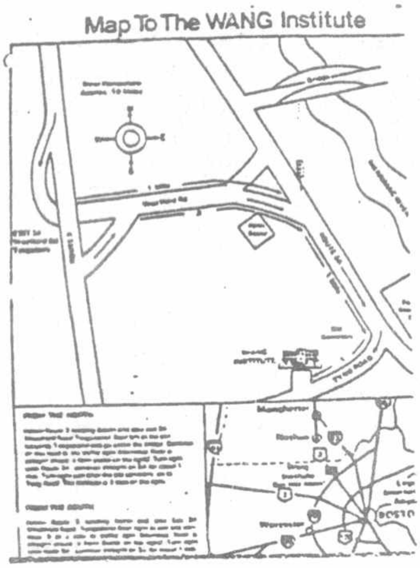
To remedy the problems of the majority smoothing method, an additional check is incorporated to ensure that connectivities within the window are preserved. If no connectivities are found, then the majority technique is used to determine the smoothed value of the pixel. The configurations that we selected to preserve are shown in Fig.2 .
This method provides image smoothing without fragmentation of thin objects or characters, and without much serif exaggeration.

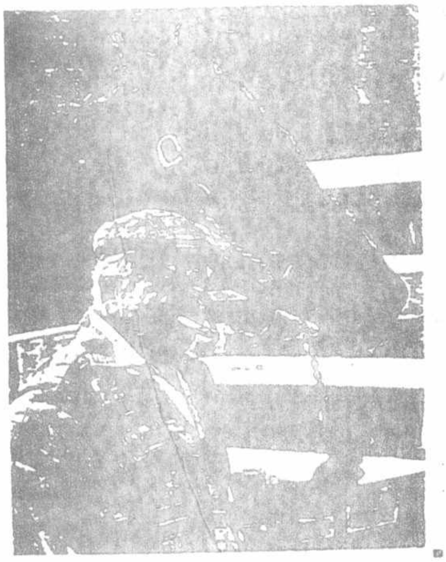
```
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
!   ! X !   !   ! X !   !   !   !   !   !   !   !   !   ! X !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
!   ! X !   !   !   ! X !   !   ! X ! X ! X !   !   ! X !   !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
!   ! X !   !   !   !   ! X !   !   !   !   !   ! X !   !   !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!

!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
!   ! X !   !   !   ! X !   !   ! X !   !   !   !   !   ! X !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
!   ! X !   !   !   ! X !   !   !   ! X !   !   !   ! X !   !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
! X !   !   !   !   !   ! X !   !   ! X !   !   !   ! X !   !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!

!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
!   !   ! X !   !   !   !   !   ! X !   !   !   !   !   !   !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
! X ! X !   !   ! X ! X !   !   !   ! X ! X !   !   ! X ! X !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
!   !   !   !   !   !   ! X !   !   !   !   !   ! X !   !   !
!---!---!---!   !---!---!---!   !---!---!---!   !---!---!---!
```

Figure 2. The preserved configurations by the contour checking method.

1-D Smoothing

This method is a special case of the majority smoothing method. The window used here is a one dimensional 3 bit window centered around the bit in question. The bit is set to "1" if it was "0" and the surrounding two bits are 1's, and is set to "0" if it was "1" and the surrounding two bits are 0's . Otherwise the bit is left unchanged. This operation tends to reduce the effect of what is sometimes known as "salt and pepper noise". The major





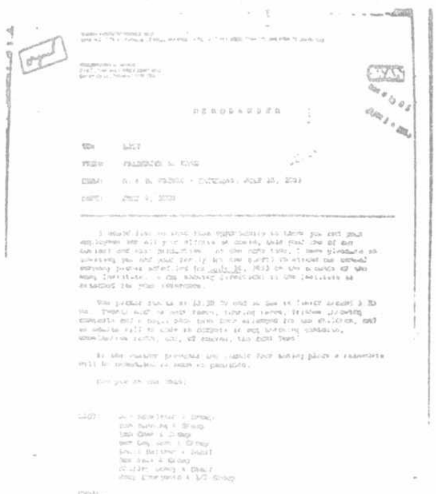


Figure 3. A Sample of Test Images

drawback of this method is that it does not take into account the second dimension of the image and treats it as a sequence of uncorrelated 1-D lines. The quality of the images processed by this technique is expected to be poorer than those processed by the other techniques, but it should require less processing time since the operation is much simpler than the other 2-D methods.

IMPLEMENTATION AND TESTING

The four mentioned techniques are implemented on the Wang PIC. The programs were written in the C language and the 8086 assembly language. They were tested on tweleve different images representing a variety of circumstances: claen and noisy multi-level original images, text documents with different type fonts and page structures, maps, mixed text and graphic documents, and an IEEE standard test chart. A sample of the test images used is given in Fig.3 .

Each document (picture) after being scanned, digitized, thresholded and stored in the system memory is processed by each smoothing method. The original images and the processed ones are displayed, printed out, then compressed and stored on the system hard disk. The PIC scanner resolution is 200 dpi, and for each 8.5 by 11 inch original document it produces a 1728x2200 digitized binary image which takes 475 K Byte of memory storage. The compression technique we used is the modefied run-length Huffman coding method, which is the CCITT (International Telephone and Telegraph Consultative Committy)recommendation for the group III facsimile machines.

RESULTS

As mentioned before, three criteria were selected to judge the performance of each smoothing technique.

The first is the effect of the smoothing process on the image compression: the four techniques were found to result in compression improvement. The average compression improvement achieved by each, i.e., the average saving in storage space and in image transmission time, is: 7.4 % for directional logic smoothing, 18.7 for majority smoothing, 9.7 % for majority with contour checking, and 11.8 % for the 1-D smoothing.
Table 1 shows the amount of storage (in Bytes) needed for compressed un-smoothed document along with the percentage of the compression improvement achieved by each smoothing method, for six of the test images.

The second criterion was the processing time. Table 2 shows the time taken by each smoothing method to process each of six of the test images. The average time taken by each method is:39 sec by directional smoothing, 39 sec. by majority smoothing, 31 sec. by majority with contour checking, and 13.5 sec. by the 1-D smoothing method.

Document	Un-smoothed	Directional smoothing	Majority smoothing	Majority + Contour Check	1-D smooth.
References	53,248	0 %	4 %	4 %	4 %
Memo	77,824	10.5%	18.42%	13.15%	13.15%
Page	180,224	4.55%	20.45%	11.36%	15.9%
Map	102,400	2%	10%	6%	8%
PIC	61,440	10%	16.66%	10%	10%
IEEE	194,560	16.84%	30.53%	13.68%	18.94%

Table 1. Storage requriments (in Bytes) and percentages of compression improvement (storage saving).
[all documents are encoded by the 1-D runlength coding]

Documents	Directional smoothing	Majority smoothing	Majority + Contour Check	1-D smoothing
References	24 sec.	23 sec.	20 sec.	10 sec.
Memo	29 sec.	29 sec.	24 sec.	11 sec.
Page	59 sec.	59 sec.	47 sec.	19 sec.
Map	36 sec.	36 sec.	30 sec.	13 sec.
PIC	23 sec.	24 sec.	20 sec.	10 sec.
IEEE	62 sec.	64 sec.	46 sec.	18 sec.

Table 2. The processing time of the 4 smoothing methods

The third criterion is the effect of the smoothing techniques on the image quality. In this regard, the following points are observed:

1) the best quality is obtained when using the majority smoothing with contour checking. No fragmentation and no lost edges, but some inner corners might get filled in. Text characters are generally clear.

2) the 1-D method produce lighter images and breaks connectivity of thin vertical lines. It causes characters to look more fragmented, and small characters are filled in occasionally

3) directionalsmoothing smoothes corners and strengthens thin lines, but produce a darker and thicker image. Majority smoothing has a tendancy to fragment thin contours.

4) none of the methods seriously degrade the overall quality of the image. The quality is either improved or maintained.

Fig.4 shows a noisy original picture of a girl's face, from the IEEE test chart. The same picture after being smoothed using the majority smoothing method and the directional logic smoothing method is shown in Fig. 5 and 6 respectively.

Figure 4. Original Noisy Picture

Figure 5. Majority Smoothing

Figure 6. Directional Smoothing

CONCLUSION

Four spatial smoothing techniques were evaluated and their effect on digitized binary images was examined and studied using the Wang Professional Image Computer. The majority smoothing method was found to result in the best improvement in compression with a relatively long processing time, while the 1-D smoothing was the fastest without much improvement in compression. The majority with contour checking was the best to preserve imag image details and enhance quality, the second best in processing time but on the expense of not saving much in compression. The selection of which technique is to be used is an application dependent problem.

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