A Fuzzy Based Handwriting Extraction Technique for Handwritten Document Preprocessing

*Yan Solihin, *C.G. Leedham, **V.K. Sagar
*School of Applied Science, Nanyang Technological University, Singapore
**Department of ESE, University of Essex, Colchester, U.K.

ABSTRACT: *In handwritten document image processing, a handwritten document is scanned by a flatbed scanner or camera arrangement. Ideally, we require to retain only the image of the handwriting without the background. Unfortunately, in many cases, background detail is also present in the scanned image. There are several factors contributing to this. One factor is the nature of the paper; it may contain color, pictures or patterns, it may be thin so handwriting on the reverse side shows through. Another factor is the handwriting implement used to produce the handwriting. Other possible factors can be defects of the scanner and improper setting of the scanning parameters. In this paper, a fuzzy based image enhancement technique to extract just the gray scale handwriting from a handwritten document image is presented. The technique is based on fuzzy if-then rules applied on two fuzzy sets whose parameters are estimated. The technique has been tried successfully on images of handwriting with bright-colored handwriting media, color paper, very thin paper, and paper with colorful pattern. The technique is particularly useful to the application of document processing that deal with gray level images.*

1. INTRODUCTION

Previous research in document image processing has mainly dealt with black and white images. In applications such as optical character recognition, a thresholded and thinned image of handwriting is often sufficient. In other application like recovery of on-line information, for example, detection of character sequence construction for forensic analysis purposes or enhanced signature verification, a thresholded and thinned image of handwriting is no longer sufficient. To obtain sufficient information, one needs a gray scale non-thinned version of the handwriting image [2]. There is a problem occurring from usage of a gray level image, that is the inclusion of background in the scanning process. The ideal image is a gray level handwriting image with totally white background where the handwriting is unchanged in its representation in term of shape, detail, and gray scale. Only the background has been removed. By carefully selecting and tuning the scanner's parameters sometimes one can obtain the ideal image. However, there are some situations in which the background is inevitably included in the image and in an automatic system it is not possible to tune the scanning process for each image. The situations may be due to very thin paper [5], color paper, paper with light-colored picture on it, and thin or bright handwriting media such as pencil and light-color marker. Therefore, a technique is needed to enhance the image so that the handwriting can be separated from the background.

The theory of fuzzy sets were first introduced by Lofti Zadeh in 1965. Its aim is to model ambiguity in the real physical world [8]. Since then, fuzzy set theory has been applied to image processing such as image enhancement [1,3,10,12,16], noise removal [13], image segmentation [7,14], clustering [15], character recognition [6], image reconstruction [10], thresholding [12], object recognition [11], etc.

In his paper on Softcomputing, Lofti Zadeh listed two important concepts of fuzzy logic: *linguistic variable* and *fuzzy if-then rule*. Linguistic variable is a variable whose values are words or sentences in a natural or synthetic language. Fuzzy if-then rule is a rule in which the antecedent and consequents are propositions containing linguistic variables. He argues that it mimics the remarkable ability of the human mind to summarize data and focus on decision-relevant information [9]. The fuzzy rule if-then has been successfully applied to numerous applications in image processing such as image enhancement, edge detection, filtering [1,3,4].

2. FUZZY IF-THEN RULES

There is an assumption used in this technique. The first is that the handwriting (foreground) and the background are intensity separable. It is not necessary, though, to have a single threshold value that can separate foreground and background completely. In many cases, it is hard to find a single threshold value. This is where the fuzzy logic plays its part.

In normal cases, handwriting will appear black and the background will appear gray or white. So, suppose there are two intensity values A and C, $A < C$, such that all pixels with intensity value less than or equal to A belong to the foreground, and all pixels with intensity value greater than or equal to C belong to the background. We also have pixels with intensity greater than A but less than C which we are not sure belong to foreground or background. We can divide the image into three subimages (see Table 1): foreground, background, and subimage between foreground and background. The method to estimate parameters A and C is discussed in section 3.

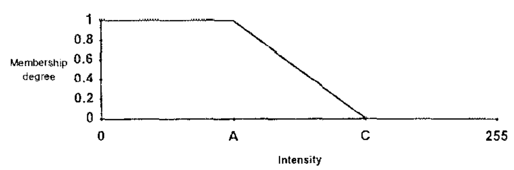
0-7803-3679-8/96/$5.00 © 1996 IEEE

Table 1. Subimages of handwriting document

Intensity (i)	Subimages
$m \le i \le A$	foreground
$A < i < C$	can be foreground or background
$C \le i \le M$	background

Now assume the lowest intensity value m = 0 and the highest intensity value M = 255, which means 256 gray scale. Two fuzzy sets need to be defined. The first is fuzzy set **foreground**. The membership function of the set is described below (also see Fig. 1).

$$\mu_{foreground}(x) = \begin{cases} 1, & 0 \le x < A \\ \dfrac{(C-x)}{(C-A)}, & A \le x < C \\ 0, & C \le x \le 255 \end{cases}$$

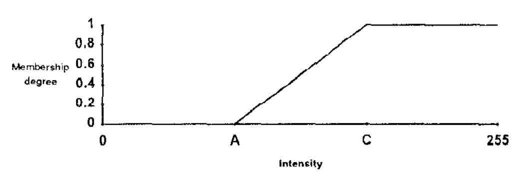


F

Fig 1. Membership function of fuzzy set foreground

The second fuzzy set is **background**. The membership function of the set background is described below (also see Fig. 2)

$$\mu_{background}(x) = \begin{cases} 0, & 0 \le x < A \\ \dfrac{(x-A)}{(C-A)}, & A \le x < C \\ 1, & C \le x \le 255 \end{cases}$$



F

Fig 2. Membership function of fuzzy set background

The fuzzy if-then rules are defined as follows.

(1) **If** the pixel belongs strictly to the background **then** make it bright (white)
(2) **If** the pixel belongs to the background **then** make it brighter
(3) **If** the pixel belongs strictly to the foreground **then** make it dark (black)
(4) **If** the pixel belongs to the foreground **then** make it darker

A pixel belongs strictly to the background means it is a member of fuzzy set background and it is not a member of fuzzy set foreground ($\mu_{foreground}(x) = 0$). This means pixels with intensity greater than or equal to C belong strictly to background. Similarly, a pixel belongs strictly to foreground means it is a member of fuzzy set foreground and it is not a member of fuzzy set background ($\mu_{background}(x) = 0$). This means pixels with intensity less than or equal to A belong strictly to foreground. Pixels with intensity greater than A but less than C belong to both fuzzy set foreground and background.

Let x denote a pixel's intensity and y denote a new pixel's intensity after applying the fuzzy rules to x. The following pseudo-code is the implementation of the fuzzy if-then rules listed above.

Rule (1) translates to:

If $x \ge C$ then $y = 255$ /* white */

To implement rule (2), an intensity transformation needs to be chosen so that pixels with intensity near C are brightened the most, and pixels with intensity near A are brightened less. If a linear transformation is used, then rule (2) translates to:

If $A < x < C$ then $y = x + \Delta x$ where

$$\Delta x = \frac{(x-A)(255-C)}{(C-A)}$$

Rule (3) translates to:

If $x \le A$ then $y = 0$ /* black */

As in rule (2), the intensity transformation has to be chosen in a way such that pixels with intensity near A are darkened more than pixels with intensity near C.

Rule (4) translates to:

If $A < x < C$ then $y = x - \Delta x$ where

$$\Delta x = \frac{A(C-x)}{(C-A)}$$

To optimize computation, the implementations of rule (2) and rule (4) can be combined in one transformation:

If $A < x < C$ then $y = x + \Delta x$ where

$$\Delta x = \frac{x(255+A-C)-255A}{(C-A)}$$

3. PARAMETERS ESTIMATION

The method of estimating parameters makes use of the frequency histogram of the image. Let xi denotes pixel with intensity i and $f(xi)$ denotes number of pixels with intensity i. The method to estimate parameters A and C is described below.

1. Pick a local maximum that is nearest the lowest intensity (black) and call it p.
2. Pick the second local maximum that is nearest to the lowest intensity and call it q.
3. Maximize the following function by varying u from 1 to (q-p)/2. Then choose umax = u such that it maximizes the function g(u).

$$g(u\max) = \max_{u=1..(q-p)/2} \{g(u)\} \quad \text{where}$$

$$g(u) = \frac{\sum_{i=p}^{i=p+u-1} f(xi)}{\sum_{i=p+u}^{i=p+2u-1} f(xi)}$$

4. Choose $A = p + u\max - 1$
5. Maximize the following function by varying v from 1 to (q-p)/2. Then choose vmax = v such that it maximizes the function h(v).

$$h(v\max) = \max_{v=1..(q-p)/2} \{h(v)\} \quad \text{where}$$

$$h(v) = \frac{\sum_{i=q-v+1}^{i=q} f(xi)}{\sum_{i=q-2v+1}^{i=q-v} f(xi)}$$

6. Choose $C = q - v\max + 1$

The estimation is based on maximizing the ratio of the cumulative frequency of the part that is nearest to the local maximum and the part that is second nearest to the local maximum. The value of umax tends to be close to p if the frequency histogram's curve around p is a steep peak. The less steep the peak is, the farther the value umax is from p. The same property applies to vmax, which tends to be close to q when the peak around q is steep, and tends to move farther from q when the peak is less steep.

In most cases, images of handwriting tend to cluster in the lowest intensity, which means p=0. There can be one or several local maxima at intensity value greater than p. It is found that in most cases the intensities that are greater than q (the second local maximum from the lowest intensity) belong to the background. Therefore only two local maxima that are nearest the lowest intensity need to be considered.

4. EXPERIMENTATION RESULTS

The technique was tried on four combinations of paper and handwriting media. The documents were scanned with resolution 600 dpi and 256 gray scale using a flatbed scanner. The parameters of the scanner were set up in a way such that the image of the handwriting was readable to a human, i.e., distinguishable from background.

In experiment 1 (see Fig. 3a) the handwriting media's color differed little from the background (silver vs. white). In experiment 2 (see Fig. 4a), a color paper was used. The image appears similar to that of experiment 1. This is due to the slight difference in intensity of the handwriting and the background. In experiment 3 (see Fig. 5a), the handwriting on the reverse side of the paper is included in the scanned image because the paper was very thin. In experiment 4 (see Fig. 6a), the paper contains a colorful pattern.

Table 2. Experiments Type

No	Paper Type	Hwr Media	Fig
1	white paper	fell-tipped silver pen	3
2	uniform color paper	ball-point pen	4
3	thin white paper	ball-point pen	5
4	paper with colorful pattern	ball-point pen	6

The technique was applied to the scanned images. After one pass of the technique, we can see that the resulting images contain only the handwriting (see Fig 3b, 4b, 5b, 6b) and very little or no background. The background has been successfully removed from the images. The estimated parameters A and C for each image are given in table 3.

Table 3. Value of Estimated Parameters

No	A	C
1	10	181
2	15	123
3	13	165
4	10	170

In Fig 5b and Fig 6b, there is a small part of the background that was not eliminated in one pass of the technique. To overcome this, the resulting image can be passed for a second time to the technique. Alternatively, in the case of Fig 5b, since the remaining background is scattered and has low intensity value, it can be treated as salt and pepper noise and can be removed by, say, a median filter.

In Fig 7a and 7b (a magnified version of Fig 5a and Fig 5b respectively), we can see that the background is removed, but the original handwriting image is still well preserved. However, some pixels at the end of letter 'w' are gone. This is due to the intensity values of the pixels that are about the same with the background. In fact, such intensity values appear somewhere else in the background. Therefore, by the assumption that foreground and background are intensity separable, this problem cannot be solved. An adaptive version of the technique is needed to solve it.

5. CONCLUSIONS

The technique presented in this paper is a tool to separate handwriting from the background in a handwriting image. The technique also has the desirable property that it maintains the gray scale of the handwriting image. This is necessary in some handwriting processing techniques. Other advantages are listed below.

1. The fuzzy if-then rules are image type-independent. They can be applied to other type of images other than handwriting images. What may need to be adapted is the criteria by which a pixel is determined to belong to the foreground or the background. If the foreground and the background of the image are still intensity separable, then what may need to be adapted is only the parameters estimation technique.
2. The fuzzy if-then rules are linguistic rules, thus they are simple, flexible, and easy to understand.
3. The technique only requires minimal knowledge of the image, i.e., the frequency histogram. It works well when the assumption that the handwriting and the background in the image are intensity separable is met.

6. REFERENCES

[1] Ching Yu Tyan and Paul P. Wang, "Image Processing - Enhancement, Filtering, and Edge Detection Using the Fuzzy Logic Approach", *2nd IEEE Int. Conf. on Fuzzy Systems*, 1993, pp. 600-605.

[2] David S. Doermann and Azriel Rosenfeld, "Recovery of Temporal Information from Static Images of Handwriting", *Proc. IEEE Comp. Society Conf. on Computer Vision and Pattern Recog.*, 1992, pp. 162-168.

[3] Fabrizio Russo and Giovanni Ramponi, "Combined FIRE filters for Image Enhancement", *Proc. the 3rd IEEE Int. Conf. on Fuzzy Systems*, 1994, pp. 260-264.

[4] Fabrizio Russo and Giovanni Ramponi, "Edge Extraction by FIRE Operators", *Proc. the 3rd IEEE Int. Conf. on Fuzzy Systems*, 1994, pp. 249-253.

[5] Dimauro, S. Impevodo, G. Pirlo, "Document Analysis Systems: Problems and Perspectives, a Real Case Study", *IEE European Workshop on Handwriting Analysis and Recog. : A European Perspective*, 1994, pp. 18/1-8.

[6] Gary, M.T. Man and Joe, C.H.Poon, "A Fuzzy-Attributed Graph Approach to Handwritten Character Recognition", *2nd IEEE Int Conf. on Fuzzy System*, 1993, pp. 570-575.

[7] Jing Wu, Hong Yan, and Andrew N. Chalmers, "Color Image Segmentation Using Fuzzy Clustering and Supervised Learning", *Journal of Electronic Imaging*, vol 3(4), Oct 1994, pp. 397-403.

[8] Lofti A. Zadeh, "Fuzzy Sets", *Inform, Control*, vol.8, 1965, pp. 338-353.

[9] Lofti A. Zadeh, "Soft Computing and Fuzzy Logic", *IEEE Software*, Nov 1994, pp. 48-56.

[10] Osama K. AlShaykh, Srikrishna Ramaswamy, and Hsien-Sen Hung, "Fuzzy Techniques for Image Enhancement and Reconstruction", *2nd IEEE Int. Conf. on Fuzzy Systems*, 1993, pp. 582-587.

[11] Popovic, D. and Liang, N., "Fuzzy Approach in Model-based Object Recognition", *Proc. the 3rd IEEE Int. Conf on Fuzzy Systems*, 1994, pp. 1801-1808.

[12] Sankar K. Pal and Azriel Rosenfeld, "Image Enhancement and Thresholding by Optimization of Fuzzy Compactness", *Pattern Recognition Letters*, vol 7., 1988, pp. 77-86.

[13] Shaomin Peng and Lori Lucke, "Fuzzy Filtering for Mixed Noise Removal During Image Processing", *Proc. the 3rd IEEE Int. Conf on Fuzzy Systems*, 1994, pp. 89-93.

[14] X.Q.Li, Z.W.Zhao, H.D. Cheng, C.M.Huang, and R.W. Harris, "A Fuzzy Logic Approach to Image Segmentation", *Proc. the 12th IAPR Int. Conf. on Pattern Recog.*, vol I, 1994, pp. 337-341.

[15] Yizong Cheng, "Fuzzy Clustering as Blurring", *Proc. the 3rd IEEE Int. Conf. on Fuzzy Systems*, 1994, pp. 1830-1834.

[16] Zhiwei Zhao and Xueqin Li, "An Effective Fuzzy Logic Approach to Image Enhancement", *Proc. SPIE Visual Communi-cations and Image Processing '93*, vol. 2094, 1993, pp. 244-251.

Fig 3a. Original Image (felt-tipped silver pen)

Fig 3b. After Extraction

Fig 4a. Original Image (color paper)

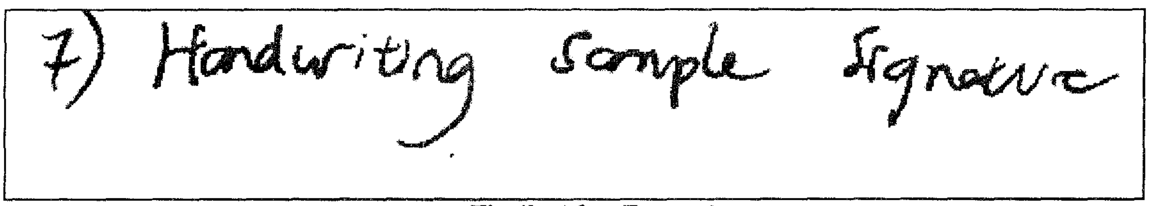


Fig 4b. After Extraction

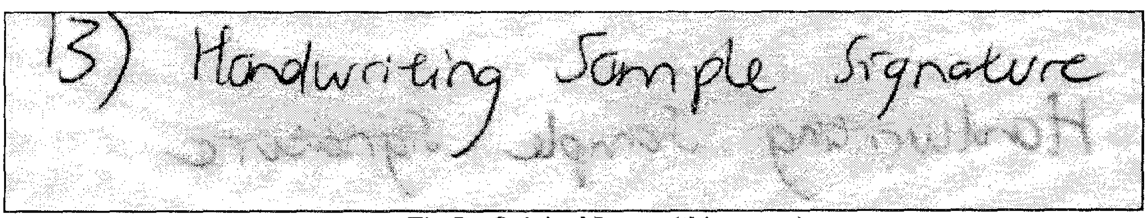


Fig 5a. Original Image (thin paper)

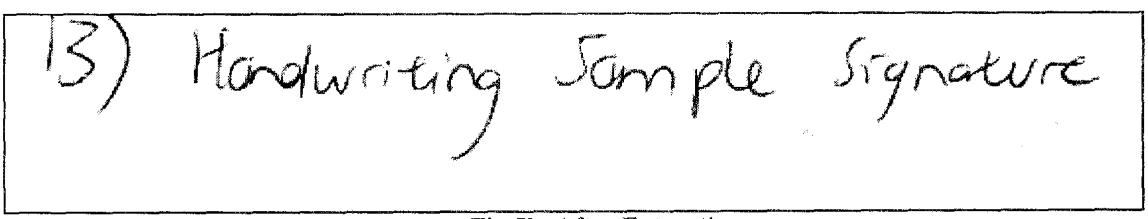


Fig 5b. After Extraction

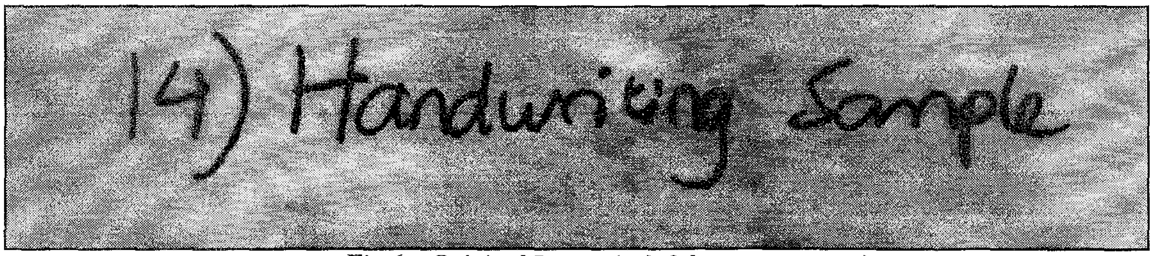


Fig 6a. Original Image (coloful-pattern paper)

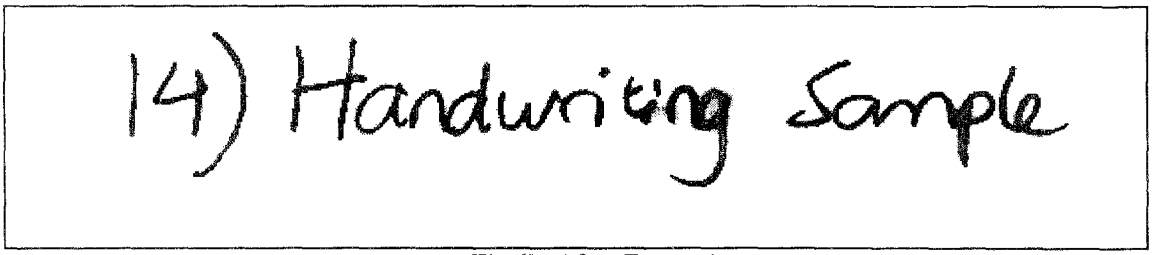


Fig 6b. After Extraction

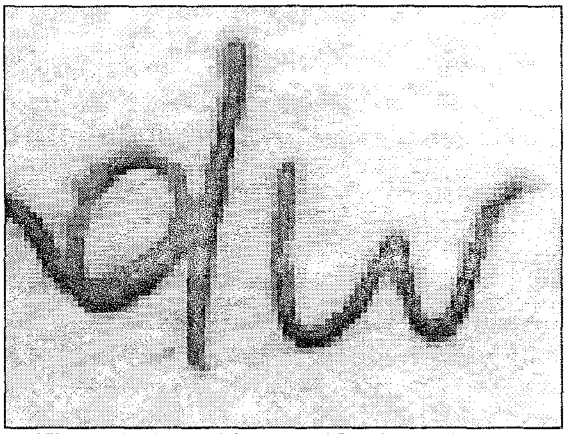


Fig 7a. Enlarged Letters 'dw' From Fig. 5a

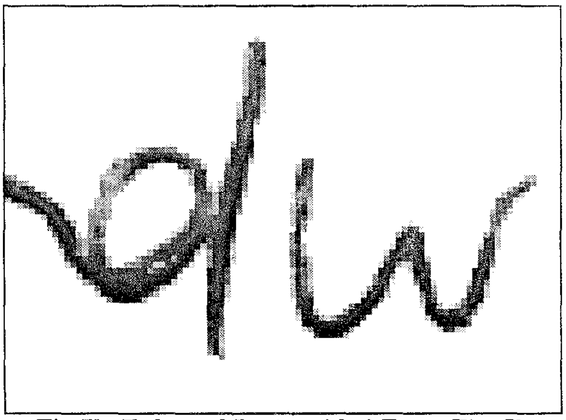


Fig 7b. Enlarged Letters 'dw' From Fig. 5b