MVA '92 IAPR Workshop on Machine Vision Applications Dec. 7-9,1992, Tokyo

CHARACTER EXTRACTION FROM GRAY IMAGES BASED ON MATHEMATICAL MORPHOLOGY

Yasuko Takahashi, Akio Shio, and Kenichiro Ishii

NTT Human Interface Laboratories

Nippon Telegraph and Telephone Corporation

1-2356 Take, Yokosuka-Shi, Kanagawa, 238-03 Japan

E-mail:yasuko@nttcvg.ntt.jp

ABSTRACT

A morphology-based thresholding technique for character extraction from outdoor images is developed. Such extraction is traditionally difficult because of the influence of illumination changes, such as lightness, shadow, and reflection. Changes in character font, apparent size, and inclination also make extraction more difficult. Though there are some character reading systems for format and size determined characters, such as the automatic license plate reader, their strong assumptions limit their applications. We assume for character extraction merely that characters occupy plane areas and consist of narrow lines. The proposed method makes it possible to choose an appropriate threshold for each point using the gray level of the nearest edge points. The method yields more robust thresholding results against changes in illumination conditions and character.

1 Introduction

There are many kind of characters in contemporary society: vehicle license plates, signs, doorplates, and signboards. There are posters and book titles in book stands, too. If these characters could be recognized by a machine under different conditions, very useful applications could be created. Large data bases may need to be established to control stocks. Poor eyesight may be supplemented while the seeing-eye dog system could be greatly enhanced. However, character recognition from outdoor images always presents many problems, the main problem is the variation in the environment and illumination variations. The position, size and variation of characters themselves will also change.

Among the many characters that exist, license plate characters have been most often used to test character recognition systems. The chief reason is that, a data base of license plates furnishes many kinds of information. License plates have been the first target because fonts, size and form, are well defined. This allows a license plate recognition system to be drastically simplified; many problems are eliminated. For example, given the position and size of characters, the difficulty of shadowing can be almost eliminated using MMS(minimum-maximum subtraction) [1]. Some license plate recognition schemes are already being used in some systems. The assumptions used to develop the schemes, however, prevent the target from being extracted.

There is one recognition technique for general character extraction, i.e., the target is any general character, that also considers illumination changes[2]. This technique works well under normal illumination conditions, but very strong illumination changes lead to the erroneous extraction of shadows.

This paper presents a thresholding method for extracting characters from outdoor images. Only the uniformity of character line form is assumed in this method. In order to extract specific form of characters, mathematical morphology is used for character enhancement. Enhancement is followed by a revised thresholding method, which absorbs color depth.

2 Enhancement of Characters

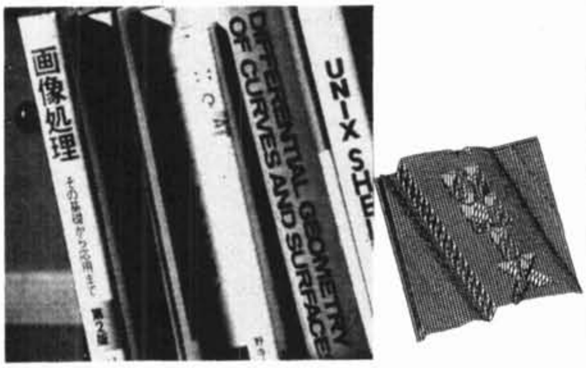
2.1 Feature of Character

What are the features of characters? This is the most important and basic assumption for character extraction. We assume that each character consists of a set of narrow lines on a plane background. This is reasonable, since characters are generally written by pen or printed.

Let's consider characters darker in intensity than their background. Fig.1(a) is an image of a character, and 1(b) is its 3-dimensional representation. The vertical axis indicates the gray value of the image. In this representation, the character lines form "ditches". The most important characteristic of a ditch is that it is bounded by two edges that form a closed set. As the ditch is traversed across its width, the pixel intensity decreases at the first edge, and increases toward the second edge. By specifying some reasonable width limits, most ditches will be caused by characters, exceptions may be the thin shadows of sticks or cables. The relationship between a ditch and its edges always holds under any reasonable change in illumination. This fact suggests that mathematical morphology can be used to extract characters under general situations, since it can measure the structure of a function or a set.

2.2 Enhancement

Mathematical morphology can be used to extract the geometric features of a function or set. In the case of character extraction, the function and set processing filter (FSP filter), one mathematical morphology technique[3], is most appropriate. Among several functions, closing and opening are most useful in detecting characters; they involve special smoothing related to the form of the local function.



(a) Image with characters (b) Characters form "ditchs"
Figure1: Image with characters

Let $f(x)$, $x \in \mathbf{Z} \times \mathbf{Z}$ be a function representing the gray image, and B is a closed subset of $\mathbf{Z} \times \mathbf{Z}$. FSP closing and opening of f by B is

$$f_B = (f \ominus B^s) \oplus B \quad \text{(closing)} \quad (1)$$

$$f^B = (f \oplus B^s) \ominus B \quad \text{(opening)} \quad (2)$$

where

$$f \ominus B^s(x) = \min_{y-x \in B}\{f(y)\} \quad \text{(erosion)} \quad (3)$$

$$f \oplus B^s(x) = \max_{y-x \in B}\{f(y)\} \quad \text{(dilation)} \quad (4)$$

$$B^s = -B$$

In this paper, the rotation independent set $B = B_r = \{|x| \leq r\}$ will always be used because our purpose is the extraction of characters and lines can appear in any direction. Note that $f_B = -(-f)^B$, so we will only discuss here closing, which is used to extract ditches.

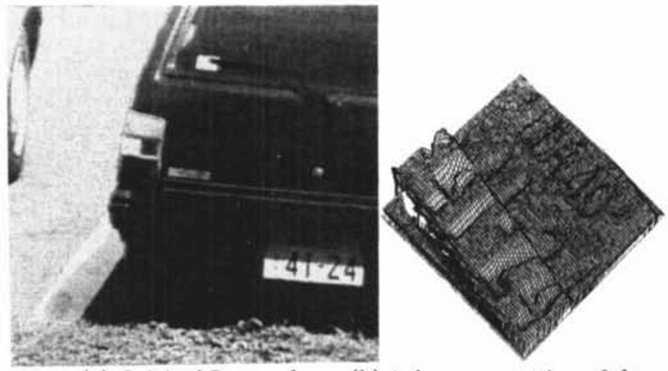
Fig.2(a) and (b) are examples of images containing characters and a shadow, and (c) is the result of closing with $r = 6$. (All images are 512×480 specified with 8 bit gray scale level.) Note that the originally smoothed area is not affected, same for the shadow's edge, however character lines disappear completely. To obtain this result, the value of r must depend on the width of characters and possible shadow width. To be precisely, $2r$ must be exceed the character's width but not the shadow's. For these images $r = 6$, because we can assume that the characters do not occupy a large percentage of the image.

Once image f^B is obtained, we denote $f - f^B$ as the character enhanced image. Fig.2(d) is the inverted character enhanced image, i.e. $f^B - f$. Note that the strong shadow edge is not visible.

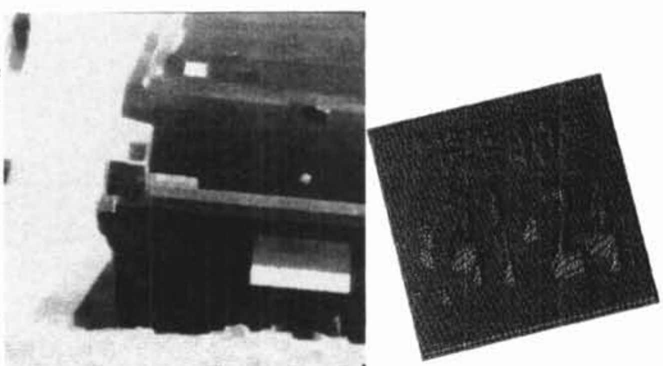
2.3 Using Reflectance Model

The character enhanced image $f - f^B$ has a value near zero at point x if the area surrounding x is smooth. The value $|f(x) - f^B(x)|$ will be large if the point x is at the bottom of a ditch. Note that this value is the same as the ditch's depth of the original image.

As shown in Fig.2, if a strong shadow crosses a character line, the ditch depth depends not only on the character's reflectance, but also on the brightness at the point.



(a) Original Image f (b) 3-d representation of f



(c) Closing f^{B_r} for $r = 6$ (d) Character enhanced image $f^B - f$
Figure2: Characters

Using the reflectance model, it is possible to transform depth into a value independent of the brightness.

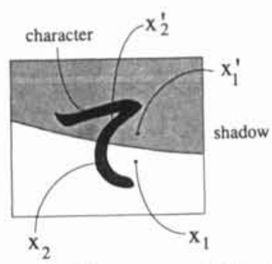


Figure3: Character and Shadow

Let suppose that a line and shadow coexist as shown in Fig.3. Since the apparent gray level f is proportional to the reflectance R and the brightness I, we can write

$$f(x_1) \propto I_o \times R_b \quad (5)$$

$$f(x_1') \propto I_i \times R_b \quad (6)$$

$$f(x_2) \propto I_o \times R_c \quad (7)$$

$$f(x_2') \propto I_i \times R_c \quad (8)$$

where R_c and R_b are the reflectance of the character and the background, and I_i and I_o are the brightness within

Log used enhancemnet
$(\log f)^B - \log f$
Figure4: Character enhancement

(a) Character enhaned image

(b) Simple threshold

(c) MTC result
Figure5: Thresholding results

or out of the shadow. The closing characteristic yields the following.

$$f^B(x_2) = f(x_1) \tag{9}$$

$$f^B(x_2') = f(x_1') \tag{10}$$

If in the state of f we use $\log(f)$ for closing, subtraction becomes division. From equations (1), (9), (5) and (6),

$$\log f(x_2) - (\log f)^B(x_2) = \log f(x_2) - \log(f^B)(x_2)$$

$$= \log \frac{I_o \times R_c}{I_o \times R_b} = \log \frac{R_c}{R_b} \tag{11}$$

In the same way,

$$\log f(x_2') - (\log f)^B(x_2') = \log \frac{R_c}{R_b} \tag{12}$$

can be obtained. Equations (11) and (12) are equal, thus the character enhanced image is independent of brightness. Fig.4 is the result of this transformation. It shows the ditch depth is affected much less than is obvious in Fig.2(d).

3 Binarization

3.1 Simple thresholding

Once the character enhanced image is obtained, it seems simple to obtain binary data using a fixed thresholding level. If the position of a character or it's strength (i.e., ditch depth) is known, the question becomes very simple. This is the case of MMS[1], an appropriate threshold value is calculated using character position. But can one choose the most appropriate value when the ditch depth changes or position is unknown? Fig.5(a) is the character enhanced image of Fig.1. The ditch depth changes because of the illumination change and the variation of characters. The simple thresholding result is shown in Fig.5(b).

3.2 Using Edges

For thresholding, it's possible to obtain an appropriate binary image if and only if the threshold value distinguishes the background from the characters. This fact suggests that gray values of edge points can be used for the distinction, since their gray values lie between those of the background and the characters. The edge position must be accurate, but once this condition is attained, any edge detection method can be used. In this paper we use Canny's edge detection[4], since the results are sharp and accurate.

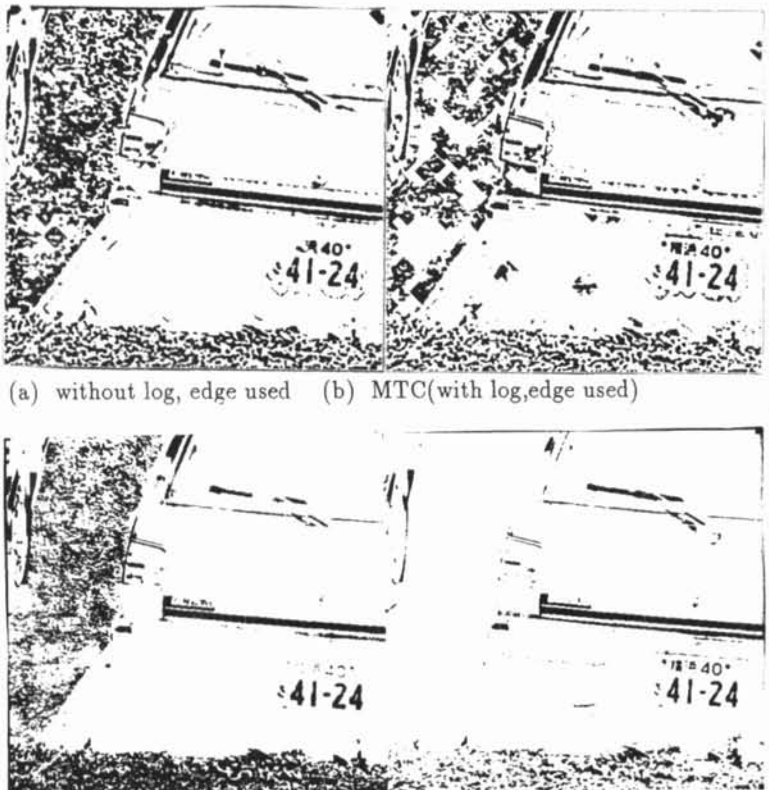
The threshold value can be chosen close to the nearest edge's point value. Fig.5(c) is the thresholding result from the character enhanced image using such edge values. It is clear that the result is not affected by either the depth of the original ditch or shadow.

We call the above method MTC for Morphology based Thresholding for Character Extraction. It consists of log transformation, morphology enhancement, and nearest edge thresholding.

4 Experimental Result

4.1 Comparing Binary Result

This section compares the effectiveness of the log transformation, as well as the nearest edge thresholding method. The four schemes that are indicated in Fig.6 were tested. Fig.6 shows 4 binary images. The simple thresholding values were chosen manually to obtain good binary results. Be sure that when these values change, the binary results change drastically. Note also that when log transformation is not used, the character width depends on brightness.



(a) without log, edge used (b) MTC(with log,edge used)

(c) without log, simple (manual thresholding) (d) with log, simple (manual thresholding)

Figure6: Comparing thresholding methods

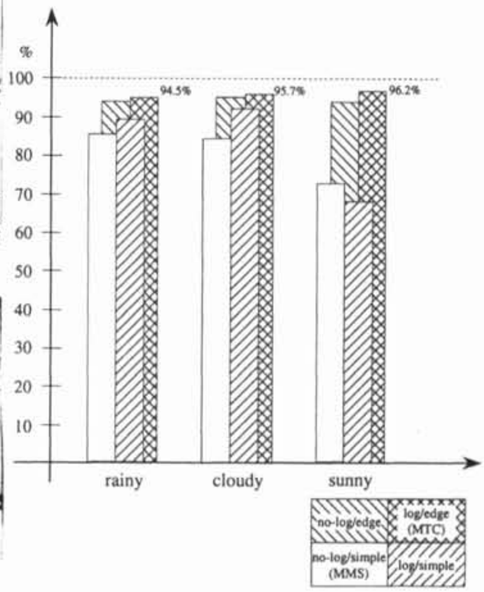


Figure7: Recognition rate

4.2 License plate recognition rate

It is normally difficult to evaluate the quality of binary images. In the case of character extraction, the recognition rate can be used. About 5000 images of Japanese license plates captured under various conditions, sunny days with strong shadow and rainy days, from morning to evening, were processed. They were binarized using MTC and recognized using a license plate reading system[5]. For a comparison, the recognition result from the 3 other schemes were collected. Fig.7 plots the plate recognition rates for sunny, cloudy, and rainy days. The simple thresholding value was chosen so as to obtain the best recognition rate for each case.

The recognition rates of the simple thresholding methods change depending on the weather. It was strongly decreased on sunny days, when illumination changes are most strong. Nearest edge thresholding always yields good and stable recognition, and use of log transformation yields even better rates.

We can conclude from the experimental results, that log transformation and nearest edge thresholding significantly improve the efficiency of MTC.

5 Conclusion

Morphology based Thresholding for Character Extraction, MTC was presented. The assumptions for this method are only the uniformity of character line form and the smoothness of the back ground. This method permits the extraction of characters under various illumination conditions. The resulting binary images are not affected by shadow, thus the recognition rate of license plate images is stable, 94.5% to 96.2%, under different illumination conditions. This was confirmed with a large number of outdoor images.

References

[1] Masao Takatoo, Morio Kanasaki, Tadaaki Mishima, Toshiro Shibata, and Hideo Ota : "Gray Scale Image Processing Technology Applied to Vehicle License Number Recognition System", Proc. IEEE Int. Workshop on Industrial Applications of Machine Vision and Machine Intelligence, pp.76-79, Tokyo (1987).

[2] A. Shio : "An automatic Thresholding Algorithm Based on an Illummination-Independent Contrast Measure", CVPR '89, pp.632-637, San Diego (1989).

[3] P. Maragos and R. W. Schafer : "Morphological Filters–Part I: Their Set Theoretic Analysis and Relations to Linear Shift-Invariant Filters", IEEE ASSP-35, No.8, pp.1153-1169 (1987).

[4] J. Canny : "A Computational Approach to Edge Detection", IEEE Trans., PAMI-8, No.6 pp.679-698 (1986).

[5] A. Shio : "Character Recognition in Scene Images", Proc. CASA/SME AUTOFACT '89, pp.10-3–10-44, Detroit (1989).