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Multi–thresholding Character Extraction in a Map

. Hsi–Ming Yang and Dr. Hsi–Jian Lee

Department of Computer Science and Information Engineering
National Chiao Tung University, Hsinchu, Taiwan 30050, R.O.C.
Tel:886–03–5731835, Fax:886–03–5724176
E–mail:hjlee@csie.nctu.edu.tw

Abstract

Maps provide many pieces of information such as countries, cities, rivers, etc, which are useful to human beings in a geographic information system(GIS). This paper aims to extract the information automatically from a map to build a data base for user retrieval. Character extraction and recognition is one of the essential tasks for entering the map information into a computer. Because the input to the system is a grayscale map, we propose a method to extract Chinese characters in the map via the multi–thresholding scheme in two phases. In the first phase, we extract the Chinese characters from a map, which is represented by multi–level values. After performing binarization, the character extraction operations containing three processes, named blurring, connected component extraction and rotation angle detection are conducted repeatively based on different thresholds. After characters are extracted from the map, they are sent to a statistical–based character recognition module and substracted from the map. In the second phase, we extract simple components from the remained map by the run–length method to remove long components, which may be road lines. Then character extraction operations used in the first phase are performed again to extract characters. These extracted characters are also sent to the recognition module. The extraction rate for the testing maps in our system is over 82%.

1. Introduction

The research of Geographical Information Systems (GIS) has received much attention recently. A GIS system is a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the Earth. (Chorley, 1987) This technology has developed so rapidly over the past two decades that it is now accepted as an essential tool for the effective use of geographic information [1]. Many books have been published on this field in times past [1]–[5]. The technology of a GIS has provided an exciting potential for geographic information to be used more systematically [1].

A GIS is designed for the collection, storage, and analysis of objects and phenomena where geographic location is an important characteristic or critical to the analysis [1]. Undoubtedly, maps play an important role in a GIS. Maps are central to all GISs both as a source of input data and as a means of demonstrating the output from such systems [2]. Maps contain many pieces of information such as countries, oceans, rivers, cities and roads, which are useful to human beings. However, the input of a map into a GIS is very difficult. Typically, there are two ways for a map input into a GIS: manual input by human beings and automatic input by the computer. The first way may take a lot of time and efforts of human beings. The second one is more convenient and preferable to human beings although it is more difficult. Therefore, this research aims to improve the technique of entering a map by the computer.

Entering a map consists of two steps: map digitization and map interpretation. In the first step, a map is scanned by an optical scanner. Then it is stored on disk or tape in some image formats like BMP, TIFF, etc. In the second step, a map is interpreted for queries. There are many ways to achieve this. Human interpretation is the most obvious but also the most expensive because of the time required [6]. Interpretation by the computer is another way. This research will pursue this method

Character extraction and recognition is one of the major tasks in map interpretation by the computer. Maps usually have many geographical symbols and long lines such as grid lines and road lines. Characters in a map often distribute non–uniformly. They may rotate, vary in size and touch lines or touch each other seriously. These properties make it very difficult to extract them correctly. Although many character extraction methods for formatted documents have been proposed, only a few methods for unformatted documents have been reported [7]–[10].

This paper presents a multi–thresholding character extraction method for extracting Chinese characters in a map. Extracted Chinese characters are sent to the statistical character recognition module to be recognized. The technique proposed in this paper can be used to extract information in a map to build a data base automatically for user retrieval in a GIS.

In digital image processing, thresholding is a well–known technique for image segmentation [11]. Thresholding is one of the most important parts in image analysis. There are many multi–thresholding methods proposed in the past. Boukharouba et al. [12] proposed an amplitude segmentation method using the intrinsic properties of the cumulative distribution function to threshold an image. The curvature of the distribution function is examined to obtain information regarding the threshold values. Wang and Haralick [13] presented a recursive technique for multiple threshold selection on digital images. After a pixel is classfied as an edge pixel or a nonedge pixel, the pixels can then be classified as being relatively dark or relatively light on the basis of its neighborhoods. A histogram of the gray levels is obtained for those edge pixels which are relatively dark, and another histogram for those edge pixels which are relatively light. A threshold is selected based on the gray level intensity value corresponding to one of the highest peaks from the two histograms. To get multiple thresholds, the procedure is recursively applied using only those pixels whose intensities are smaller than the threshold first and using only those pixels whose intensities are larger than the threshold.

Character extraction is one of the most important parts in document analysis. Fujisawa et al. [15] presented a pattern–oriented segmentation method that leads to document structure analysis. Connected pattern components are extracted, and spatial interrelations between components are measured to group them into meaningful character patterns.

Tsujimoto and Asada [16] presented a character segmentation and recognition method which is robust against touching characters. By accumulating the number of black pixels vertically in the image after an AND operation is performed between neighboring column of the image, the break cost can be calculated by evaluating the degree of contact. The possible break points are found by finding the local minima in a smoothed break cost function. The character segmentation accuracy is 99.6%.

Gyohten et al. [10] presented a method for extracting printed Japanese characters from an unformatted document image. This research exploits format–free knowledge about characteristics of character shape, regularity in character arrangement and attributes of character lines. The proposed character extractor works in a multi–agent scheme where each agent is assigned a single character line and tries to extract characters from the character line with the format–free knowledge.

Hertz and Schafer [14] proposed a multilevel thresholding method using edge matching to solve the problem of thresholding images which contain several objects of different brightness or reflectivity. The idea is that if the shape and geometric information have been preserved in the process of thresholding, the edge image should remain virtually unchanged. The edge matching technique provides a direct method of adjusting multiple thresholds so that the edges of the thresholded image closely match the edges of the original gray–tone image.

In this paper, we propose a multi–thresholding method to extract Chinese characters in a map. Our system consists of two phases. The first phase uses the difference property of gray values to extract Chinese characters. The second phase finds simple components from the image. By removing long simple components, which may be road lines, Chinese characters can be extracted.

We assume that the Chinese characters in a map are square. The proposed system cannot extract numerals and handwritten Chinese characters well. The index table and the head line regions of a map will not be processed either.

There are four processes in the first phase, named thresholding, blurring, connected component extraction and rotation angle detection. The four processes are performed repeatively. At the beginning of each iteration, the threshold is increased by a fixed amount. Then the blurring operation is performed to reduce the resolution of the thresholded image. The blurring operation can connect broken strokes in Chinese characters to a certain degree. Connected components of the blurred image are then found and possible Chinese character candidates are located. The strategy for detecting the rotation angle of an extracted Chinese character is detection by recognition. An input character is rotated and recognized. If the character can be recognized by a statistical character recognition module, then the rotation angle is what we want to find and is recorded.

In the second phase, we extract simple components from the map with extracted character portion being set to blank by the run–length method. After simple components have been extracted, the long components, which may be road lines, are removed. Then character extraction operations in the first phase are performed on the resulting map to extract the other Chinese characters. The simple component extraction operation is performed twice in both vertical and horizontal directions. The Chinese characters extracted are also sent to the recognition module.

The remainder of this paper is organized as follows. The multi–thresholding scheme is described in Section 2. The details to extract Chinese characters are stated in Section 3. Section 4 describes the simple component extraction method. Experimental results and some analyses are presented in Section 5. Finally, the conclusions of the paper are stated in Section 6.

2. Multi–thresholding scheme

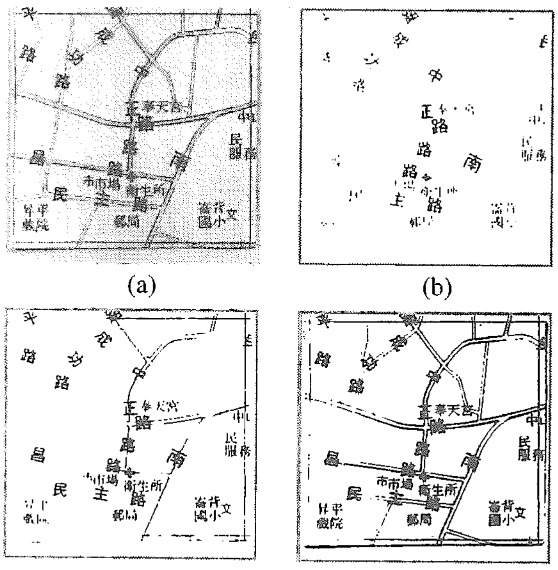
In a map, gray values information conveys much knowledge for the objects in the map. Advanced compilation information which may be stored into a database system may be obtained from the grayscale image. In this section, we will describe the multi–thresholding scheme which we use for extracting Chinese characters in a map.

To extract characters from a document, we usually find an optimal threshold to convert a digital gray level image to a binary image. But this technique does not work well for a map since characters and other objects such as roads in a map often have similar gray values. In the following, we show the difficulty of extracting Chinese characters in a grayscale map.

Figure 1(a) is a grayscale road map image which is digitized by a scanner at a resolution of 300 dpi (dot per inch). We can find that Chinese characters seem to be darker than roads. We can use this phenomenon to extract Chinese characters. We try to binarize the original map image with different thresholds. Figure 2 shows the results of thresholding with thresholds 80, 120 and 160. Note that the gray values 0 denotes black and the gray value 255 denotes white. In Figure 1(b), some Chinese characters, like "中" and "南", are perfectly seperated out from the original map. But some Chinese characters are broken into many pieces and some disappear. This is because that the selected threshold is too low. If we increase the threshold, we can find that more complete Chinese characters appear as shown in Fig 1(c). This phenomenon is favorable for our task. However, some road boundaries appear too. These road boundaries will obstruct the extraction of characters since they touch Chinese characters seriously. The obstruction becomes more severe when the threshold is increased, as shown in Fig. 1(d).

A small threshold results in broken or disappeared Chinese characters, while a large threshold also extract road boundaries, which may touch Chinese characters seriously. To extract characters correctly, we investigate the multi–thresholding scheme.

In the multi–thresholding scheme, dark Chinese characters are possible first extracted from the thresholded image with a low threshold via some character extraction operations to be described in Section 3. In this way, road boundaries which are whiter than the characters will not interfere with our character extraction process. Once Chinese characters are successfully extracted, they are substracted from the original map; that is, the gray values in the region of the extracted character are set to those of the background. The binarization and character extraction processes are executed repeatively with increased thresholds until the threshold is large enough. The whole multi–thresholding process is shown in Fig. 2.



(a) (b) (c) (d)

Figure 1 The original grayscale road map and its thresholded results. (a) The original map. (b) Thresholded result with threshold 80. (c) Thresholded result with threshold 120. (d) Thresholded result with threshold 160.

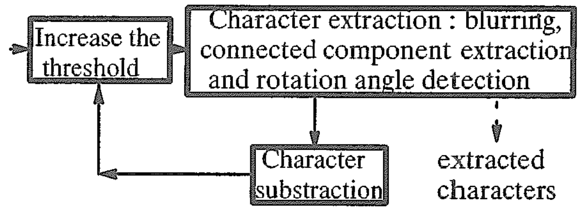


Figure 2 The multi–thresholding process.

It is almost impossible to use some training maps to generate the thresholds in our scheme since the training maps may have different characteristics from those of the others. In our experiments, we select the thresholds as the following $\{T_{ini}+INC|T_{ini}$ is 80, and INC is 0, 20, 40, . . . , 120.$\}$.

3. Character extraction

After thresholding the map image with a given threshold, character extraction operations are performed. There are three main procedures used in our character extraction operations, named blurring, connected component extraction and rotation angle detection.

3.1 Blurring

Although many efforts have been made at extracting characters in English documents, few efforts have been done at extracting characters in Chinese documents. Among methods for extracting English characters, finding connected components is the most commonly–used technique. After finding connected components, the next step is to design some features to judge whether touching characters exist among these components and to segment touching characters if they exist. These methods work well in the most part of English characters since English characters are inherently connected.

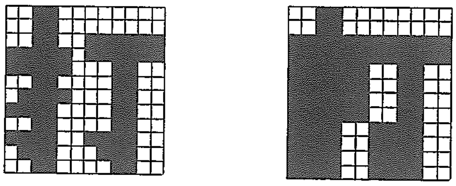
In Chinese characters, these methods cannot work well since Chinese characters are usually disconnected. A Chinese character is composed of radicals which are made up by strokes. In order to connect disjoint parts in Chinese characters, we introduce the blurring operation, which is stated as follows:

1. Partition the input digitized image into many square cells of size $B_i * B_i$, where B_i denotes the blurring factor.

2. For each cell, all pixels of the cell are filled with "black" if there is one "black" pixel in the cell.

Figure 3 illustrates the blurring operation with blurring factor = 2. The blurring operation is similar to the dilation operation[22] in mophological operations. The blurring operation is easy to implement and has the effect which we desire.

Figure 3(a) is a Chinese character "打", which has disconnected left and right parts. Figure 3(b) shows the left and



(a) (b)

Figure 3 The blurring operation with blurring factor= 2. (a) The input image. (b) The blurred image.

right part of the Chinese character "打" are connected each other. After the blurring operation, we can apply the connected component extraction operation to extract the character.

The blurring factor B_i is an important parameter in the blurring operation. It influences the blurred result directly. To decide the blurring factor, we must consider the following effects.

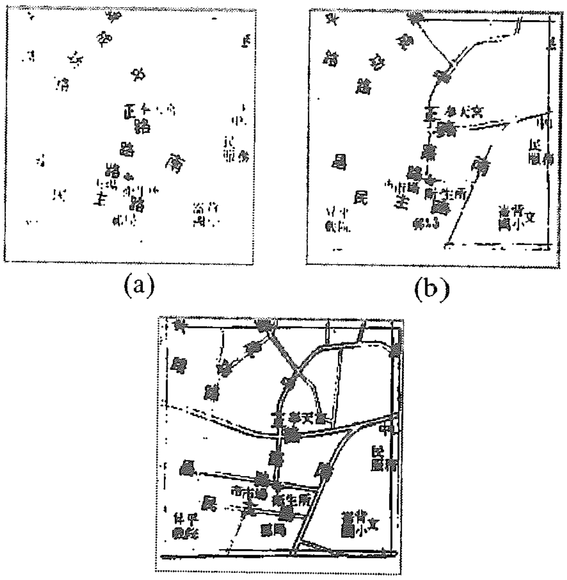
1. If the blurring factor is so large as to connect one character with the other, we can not extract the character successfully.

2. If the blurring factor is too small, strokes of a Chinese character will not connect together by this way. We may not extract the whole parts of the character.

3. The blurring operation has the side effect of thickening the strokes of a Chinese character. The larger the blurring factor is, the less precise the region of the extracted character is.

In Chinese documents, the distance between strokes of a Chinese character is not necessarily smaller than the distance between strokes of distinct Chinese characters. Thus, there does not exist an optimal blurring factor which connects different strokes of a Chinese character but does not connect one character with the other. In our experiments, we use one and two as our blurring factors; the blurred image with blurring factor equal to one is the original image.

Now we illustrate the blurring operation perfomed on practical cases. Three examples are shown in Figures 4(a)–(c), corresponding to the input image obtained from Figures 1(b)–(d). In Figure 1(b), characters "中", "正" and "南" are connected and can be extracted directly from the input image. Due to this reason, we take the value one as one of our blurring factors. After blurring with the blurring factor two, as shown in Figure 4(a), some disconnectivities in strokes of Chinese characters are connected, as shown on Chinese characters "背" and "國" in the bottom–right part of Figure 4(b) and on the Chinese character "平" in the bottom–left part of Figure 4(c). However, blurring still cannot connect all disconnected strokes of Chinese characters, like "小" in the bottom–left part of Figure 4(c). The undesirable effect of touching characters is also introduced via the blurring operation. Three cases are



(a) (b)

(c)

Figure 4 The blurred images of (a) Figure 1(b), (b) Figure 1(c), and (c) Figure 1(d) with blurring factor = 2.

shown on the region between Chinese characters "戲" and "院", the region between Chinese characters "市" and "場", and the region between Chinese characters "崙" and "國" in Figure 4(c).

3.2 Connected component extraction

After the blurring operation, the connected component extraction operation is performed on the blurred image to extract connected components. These extracted connected components are then checked to see whether they are Chinese characters or not. In this subsection, we explain the technique of connected component extraction and the features we used to check whether a connected component is a Chinese character or not.

The features for each connected component are given as follows:

1. Squareness. The squareness S of a connected component is defined by

$$S = \frac{min(\Delta x, \Delta y)}{max(\Delta x, \Delta y)}$$

where Δx and Δy denote the width and height of a connected component.

2. Density of black pixels. The density of black pixels of a connected component is defined by

$$D = \frac{BN}{\Delta x \times \Delta y}$$

where BN represents the number of black pixels in a connected component.

The criteria which we use for checking Chinese characters are listed as follows:

1. The number of black pixels of a Chinese character *BN* cannot be too small.

2. A Chinese character must be square.

3. The density *D* of black pixels of a Chinese character cannot be too small.

4. The width and height of a Chinese character in a map cannot be too large.

Based on the criteria stated above, the following rules are applied:

1. $BN > T_1$

2. $S > T_2$

3. $D > T_3$

4. $\frac{\Delta x + \Delta y}{2} < T_4$

In our experiments, we set T_1, T_2, T_3 and T_4 equal to 80, 0.8, 0.15 and 150, respectively.

The connected components which satisfy the four rules are shown in Figure 5, which are Chinese characters.

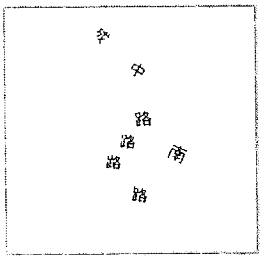


Figure 5 The result of applying the four rules to Figure 1(b).

3.3 Rotation angle detection

Chinese characters which are extracted from a map by the method stated in the previous two subsections are sent to the character recogniton module to be recognized. If the recognition process is successful, the recognition module returns an integer indicating the label of the recognized Chinese character. If the recognition module fails to recognize the Chinese character, label "0" is returned which indicates rejection. Rejection could occur because the extracted Chinese character is rotated. Since most of Chinese characters in a map are not rotated, we detect the rotation angle of a character when it is rejected by the recognition module.

In this paper, we propose a method to detect the rotation angle of the extracted Chinese character. In this method, the rotation angle of an extracted Chinese character is completely determined by the recognition result. We iteratively rotate the extracted Chinese character with a preset fixed degree clockwise and counterclockwise and sent the rotated extracted Chinese character to the character recognition module to check the recognition result. If the recognition result is not rejection, we stop the rotating process and take the rotation angle to be the rotation angle of that extracted Chinese character. The preset fixed degree and the angle range are set to 5 degree and 30 degree in our experiments.

The method of rotating an object can be easily found in many books. (For example, see [19].) Here we state a common method described in [19]. We want to find the location of a pixel (x, y) after it has been rotated by an angle Q around a point (x_0, y_0). Let r be the length of the vector joining (x, y) to (x_0, y_0). This does not change during the rotation and therefore we have the following sets of equations (see Figure 6 for the notation).

$$x-x_0=r\cos\Phi \qquad y-y_0=r\sin\Phi \tag{3.1}$$

$$X-x_0=r\cos(\Phi+\Theta) \qquad Y-y_0=r\sin(\Phi+\Theta) \tag{3.2}$$

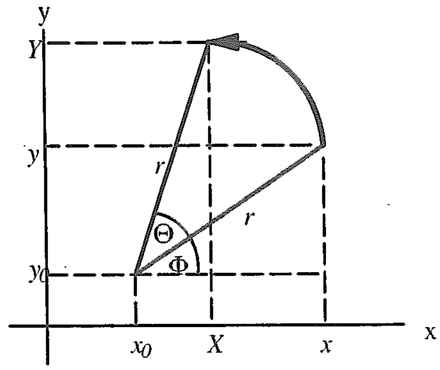


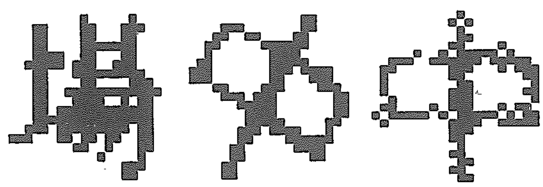
Figure 6 Symbols used for the expression of the new coordinates (X, Y) of a point in terms of the old ones (x, y) following a rotation by an angle Θ around a point (x_0, y_0).

Expanding the cosine and sine functions in Equation (3.2) and then substituting from Equation (3.1), we find that the new coordinates (X, Y) are given in terms of the old ones by the following equations:

$$X=x_0+(x-x_0)\cos\Theta-(y-y_0)\sin\Theta \tag{3.3}$$

$$Y=y_0+(x-x_0)\sin\Theta+(y-y_0)\cos\Theta \tag{3.4}$$

Unfortunately, some of the extracted Chinese characters are small (about 20*20). Thus they are sensative to noises and thus become difficult to be recognized. Moreover, if the Chinese character is rotated, it will be broken and its boundary will zigzag. Available character recognition modules cannot handle these problems. We show some examples in Figure 7.



(a) (b) (c)

Figure 7 Some extracted Chinese characters. (a)−(b) An extracted Chinese character. (c) The result after rotating (b) by 25 degree counterclockwise.

4. Simple component extraction

After the operations described in the previous two sections have been performed, most Chinese characters in a map are extracted based on the differences of gray values. However, there are some Chinese characters that cannot be extracted because the surrounding objects have gray values similar to these Chinese characters. In this section, we present a method to solve this problem.

We use a run–length based method to extract simple components from the remained map with the area of the extracted Chinese characters being set to the background. After simple components have been extracted, the long components, which seem to be road lines, will be removed. Then character extraction operations described before are performed again to extract the remained Chinese characters.

In the remained map, Chinese characters usually touch lines and thus cannot be extracted. We try to extract these Chinese characters by removing the lines. To remove the road lines, we segment the black pixels of the remained map into many components (we call them "simple components"). In these simple components, the long components seem to be road lines and thus can be removed. Now, we explain our definition and the process of the extraction of simple components.

We first scan the whole image to get all black runs before extracting simple components. After getting black runs, we group the black runs together to form simple components according to the following grouping rule.

If (run i and run $i+1$ are overlapped), $(L_i/L_{i+1} > \lambda)$ and $(L_{i+1}/L_i > \lambda)$ then run i and run $i+1$ belong to the same simple component.

After simple components have been extracted, long components will be removed. Now we decribe the method and effect of removing long components.

While simple components are extracted, the maximum and minimum values of the y–coordinates can be recorded simultaneously, denoted by y_{max} and y_{min}. The height H of a simple component is calculated as:

$$H = y_{max} - y_{min} + 1.$$

The component i can be removed if its height H_i is greater than a threshold T. In our experiments, we set λ and T to be 0.6 and 20, respectively.

The long components removal operation is performed twice, one for the vertical direction and the other for the horizontal direction. Thus we can extract the simple components in both directions. The result image is sent to the character extraction module for further processing.

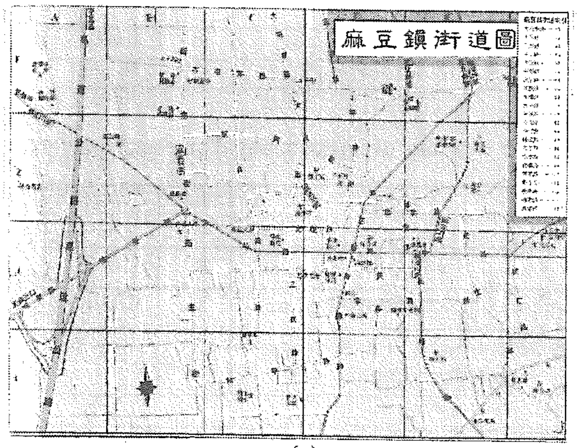
5. Experimental results and analyses

The proposed system is implemented by UNIX–C language and executed on the Sun Sparc–10 workstation. The original test maps are scanned at a resolution of 300 dpi (dot per inch). The test maps of our experiment are randomly selected from a Taiwan tour book. The total test maps contain two big maps and five small maps. The sizes of big and small maps are 2062*1462 and 375*375, respectively. Figure 8 shows some of the test maps.

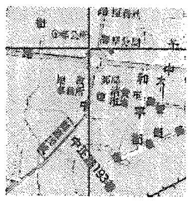
The criterion which we use to evaluate our system is the extraction rate. It is defined as :

$$\text{Extraction rate} = \frac{\text{Number of extracted Chinese characters correctly}}{\text{Number of total Chinese characters}} \quad (5.1)$$

There are totally 571 Chinese characters in our test maps. Among them, 471 Chinese characters are correctly extracted. The number of incorrectly extracted Chinese characters is 60, and the number of unextracted Chinese characters is 40. The extraction rate for our system is 82.31%.



(a)



(b)

Figure 8 Some of our test maps. (a) A big map. (b) A small map.

Table 1 Number of extracted patterns in each iteration

	Number of extracted patterns	Percentage
Phase 1: T=80, B = 1	69	11.29%
T = 80, B = 2	47	7.69%
T = 100, B = 1	58	9.49%
T = 100, B = 2	44	7.20%
T = 120, B = 1	53	8.67%
T = 120, B = 2	63	10.31%
T = 140, B = 1	49	8.02%
T = 140, B = 2	52	8.51%
T = 160, B = 1	54	8.84%
T = 160, B = 2	31	5.08%
T = 180, B = 1	31	5.08%
T = 180, B = 2	7	1.15%
T = 200, B = 1	28	4.58%
T = 200, B = 2	9	1.47%

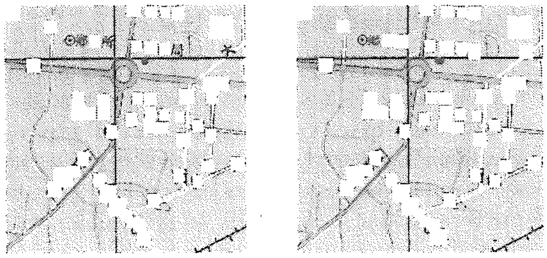
Subtotal	595	97.38%
Phase 2: T=180,B = 1	13	2.13%
T = 180, B = 2	3	0.49%
Subtotal	16	2.62%
Total	611	100%

Table 2 Reasons of extracting Chinese characters incorrectly in the proposed system.

	Number	Percentage
Total	60	100%
Stroke disconnectivity	25	41.67%
Non−uniform intensity of gray values	19	31.67%
Touching Chinese character	6	10.00%
Chinese character touching lines	10	16.66%

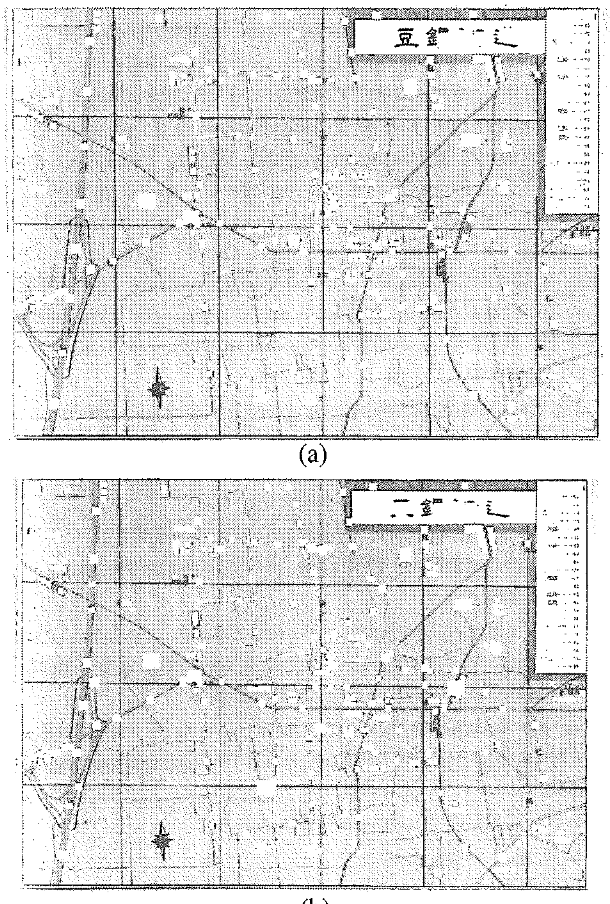
Table 3 Reasons of unextracting Chinese characters

	Number	Percentage
Total	40	100%
Chinese character touching lines	39	97.50%
Chinese characters touching geographic symbols	1	2.50%



(a) (b)

Figure 9 The experimental results of Figure 8(b). (a) The intermediate map after Phase 1 has been performed. (b) The final result.



(a)

(b)

Figure 10 The experimental results of Figure 8(a). (a) The intermediate map after Phase 1 has been performed. (b) The final result.

The number of extracted patterns in each iteration is listed in Table 1. From this Table, we can see that there are patterns extracted in all iterations. This phenomenon shows that each iteration we performed has contributed to extracting Chinese characters and is not redundant. When the threshold approaches 200, the number of extracted patterns becomes small. Thus we stop our iteration on the threshold 200. Note also that most extracted patterns come from Phase 1. Just 2.62% of extracted patterns come from Phase 2. This confirms that Phase 2 just plays a role to remedy the weakness of Phase 1.

The reasons of extracting Chinese characters incorrectly are listed in Table 2. Among all the reasons, stroke disconnectivity plays the majority. Although the blurring operation has been performed, the inherent disconnectivity of strokes of Chinese charaters is still the most severe problem. The non−uniform gray values also take a considerable percentage. Other problems are due to touching lines or other characters. Table 3 shows the reasons of unextracting Chinese characters in our system. Most unextracted Chinese characters are caused by touching lines. This reason shows that the touching problem is very difficult to solve.

Some experimental results are given in Figure 9 and Figure 10. In Figure 9 (b), we can see that most of the Chinese characters are extracterd. However, there are still some Chinese characters which are not extracted successfully. In the top part of Figure. 9 (b), the Chinese character "鄉 " is not extracted due to touching the geographic symbol. The Chinese characters "街 " appeared in the bottom−right part and "中 " apperaed in the middle part of Figure 9 (b) are not extracted successfully due to non−uniform intensity of gray values.

6. Conclusions

In this paper, we have proposed a multi−thresholding method to extract Chinese characters in a map. Our system consists of two phases. The first phase uses different gray values to extract Chinese characters. The second phase removes long components of the remained image which may be road lines and extracts other Chinese characters.

There are four processes in the first phase, named thresholding, blurring, connected component extraction and rotation angle detection. The four processes are performed repeatively. At the beginning of each iteration, the threshold is increased by a fixed amount. Then the blurring operation is performed to reduce the resolution of the thresholded image. The blurring operation can solve the stroke disconnectivity problem in Chinese characters to a certain degree. Connected components of the blurred image are then found and possible Chinese character candidates can be obtained. The strategy for detecting the rotation angle of an extracted Chinese character is detection by recognition. The extracted Chinese chatacters are finally sent to a statistical character recognition module to be recognized.

In the second phase, we extract simple components from the remained map by the run–length based method. After simple components have been extracted, the long components, which may be road lines, are removed. Then character extraction operations in the first phase are performed on the removed map to extract the remained Chinese characters. The simple component extraction operation is performed twice in both vertical and horizontal directions. The extracted Chinese characters are also sent to the recognition module.

The test maps of our experiment contain two big maps and five small maps. There are totally 571 Chinese characters in our testing sample maps. Among them, 471 Chinese characters are correctly extracted out. The extraction rate for our system is 82.31%, which shows the system we have proposed is rather effective. However, the execution time in our current implementation is rather long. How to reduce the computation load while maintain a certain extraction rate is left for future research.

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