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3—10 License Plate Recognition Using Associative Matching Based on Clique-Finding

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Abstract

In this paper, we propose a new method to separate the characters on the license plate using associative matching based on clique-finding. 180 digital images are tested by the prototype system. The correct separating rate for each kind of characters have been increased significantly. The experimental results also show that this method is not only robust against zooming, skewing, variety of illumination and noise, but also effective to deal with Japanese Hiraganas, Chinese characters and small numerals, which are very difficult to be obtained by the conventional sequential image segmentation method.

Keywords: License Plate Recognition, Clique, Matching, Computer Vision

1 Introduction

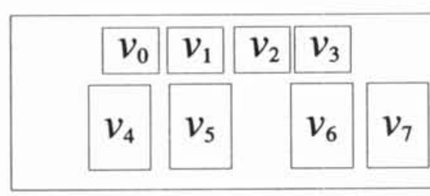
The license plate recognition systems are widely used in monitoring traffic, controlling access to parking areas, and finding stolen cars. However, in most of the license plate recognition systems ever developed [1], [2], [3], the process for separating characters on the plate is usually carried out by two steps. At first the plate is separated into two lines up and down, then 1-dimensional feature such as projection histogram is used to separate the characters in each line. They are not robust with zooming, skewing, variety of illumination and noise. Besides, some Japanese Hiraganas and Chinese characters such as "い", "川", and "." make character segmentation be a difficult task.

We propose a new method which employs associative matching based on clique-finding to separate the characters on the plate. The maximal clique of association graph is found to provide the "best match" between an image segmentation and the standard mask of the plate, so that the missing characters on the plate can be located.

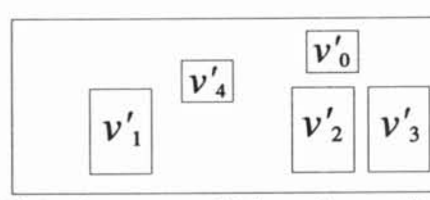
2 Associative Matching Algorithm

At first, the candidates for the plate which are detected in the car front-view image by region-growing method are segmented to get the candidates for the characters, then the association graph is constructed with the information of their size and relative position.

We define the standard mask of the plate as shown in Fig. 1(a), where the set of elements on the plate is $V\{v_i\}$, and the normalized size of each element is the property $P\{p_i\}$. The binary relation is defined as $R\{r_{ij}=(d_{ij}, a_{ij})\}$, where d_{ij} and a_{ij} is the length and the angle of the vector from the center of v_i to v_j's respectively. For a plate entry V' shown in Fig. 1(b), let their normalized size be the property $\{p_{i'}\}$, and the binary relation $\{r_{i'j'}\}$ between $v_{i'}$ and $v_{j'}$ can be calculated from the 2-dimensional coordinates of their centers.



(a)The Standard mask with two Chinese characters(Hiragana is not used here)



(b)A plate entry which needs matching

Figure 1. Standard mask and an entry of Japanese license plate

To get the "best match" between V and V', according to the relationship of (V, P, R) and (V', P, R), we can make an auxiliary data structure called association graph G [4] as follows:

(1) For each v_i in V and $v_{i'}$ in V', construct a node of G labeled$(v_{i-i'})$ if v_i and $v_{i'}$ have the same properties [$p_i \approx p_{i'}$].

(2) Connect two nodes $(v_{i-i'})$ and $(v_{j-j'})$ of G if the pairs satisfy the same predicates [$d_{ij} \approx d_{i'j'}$ and $a_{ij} \approx a_{i'j'}$].

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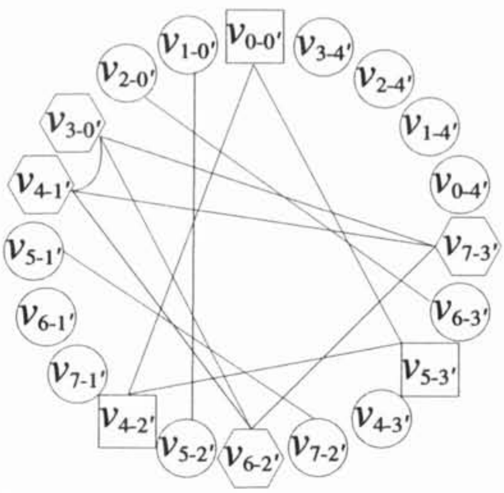
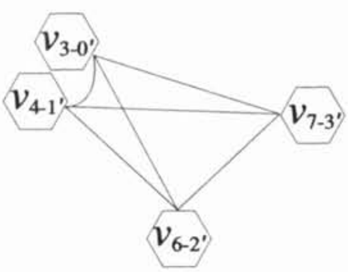
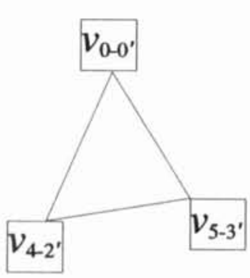


(a)The association graph for Fig.1(a) and Fig.1(b)



(b)The maximal clique of association graph



(c)Another clique but is not maximal

Figure 2. An example of Clique-Finding matching

Fig. 2(a) shows the association graph for the entry of Fig. 1(b) and the standard mask(Fig. 1(a)). For example, since $p_3 \approx p_{0'}$ and $p_4 \approx p_{1'}$, we should construct the nodes of $v_{3-0'}$ and $v_{4-1'}$, furthermore because $d_{34} \approx d_{0'1'}$ & $a_{34} \approx a_{0'1'}$, nodes $v_{3-0'}$ and $v_{4-1'}$ can be connected. Although we also construct the node $v_{0-0'}$ because of their similar property, $v_{0-0'}$ and $v_{4-1'}$ can not be connected, because (d_{04}, a_{04}) and ($d_{0'1'}$, $a_{0'1'}$) are quite different.

Then the "best match" can be obtained by finding maximal clique(Fig. 2(b)) of the association graph. From all above, we can say our method works in 2-dimension using the distance and the angle between each element at the same time. Therefore the matching is robust with zooming, skewing and the failure in segmentation.

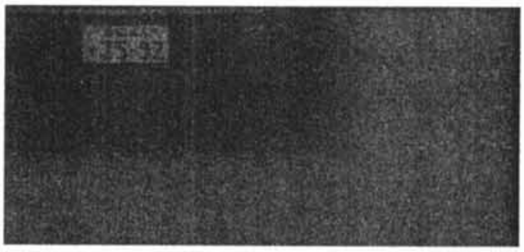
By temporal character recognition of the matched characters, relatively reliable elements on the plate can be obtained. Based on these characters(regions), the rest of the characters are located refering to the standard mask. In this way, the missing characters due to segmentation failure can be found. Also the false regions will be excluded through the matching and the temporal character recognition. If there is nothing matched or all of the matched regions are rejected by character-recognizer, we can conclude that this candidate plate is not a correct one. Then we should deal with the next candidate with the same procedure.

3 Performance evaluation

The test images of moving vehicles on road are taken by CCD camera. The gray-level is 256 and the size is 1024x512. The illuminating condition is towards light during daytime. After applying 3×3 filtering operation for edge detection, we can select up to three prospective regions of license platė where pixels are clustered in the edge image.

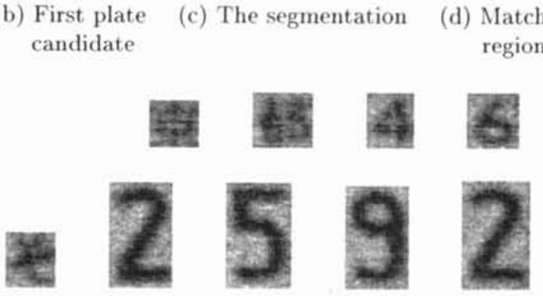
Fig. 3 - Fig. 6 show the images which are captured quite differently, but our method can detect and separate the characters successfully.

In the case of low illumination(Fig. 3), severe noise causes many false regions in the segmentation. Our procedure excludes them by matching.



(a) Original image

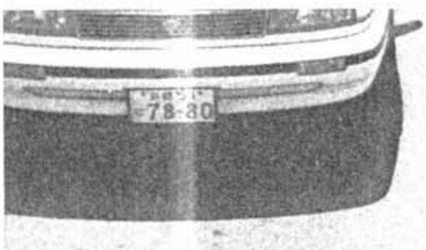
(b) First plate candidate (c) The segmentation (d) Matched regions



(e)Located characters

Figure 3. The case of low-illumination and severe noise

In the case of high illumination(Fig. 4), since the camera gets over-loading, a bright-bar appears and covers some characters which can not be detected by segmentation. However, our procedure finds them by association.



(a) Original image

(b) First plate candidate (c) The segmentation (d) Matched regions

(e)Located characters

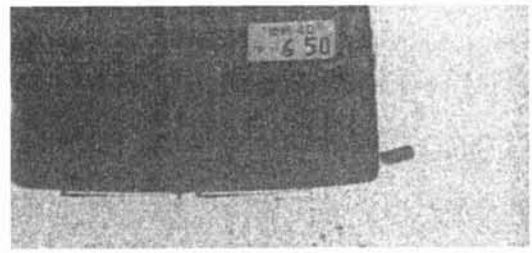
Figure 4. The case of high-illumination and over-loading

Fig. 5 shows the case of skewing and a "." being included; In Fig. 6, our procedure rejects a plate-like string. Although it can match with the large numerals on plate and "I" may be read as "1", there is no characters above them which can be read as the small numerals.

We evaluate the accuracy and speed of this procedure on Sun Ultra10 296MHz workstation with 180 test images. The recognition rate is shown in Table 1. and Table 2. The average processing time is about 1.8 sec/image.

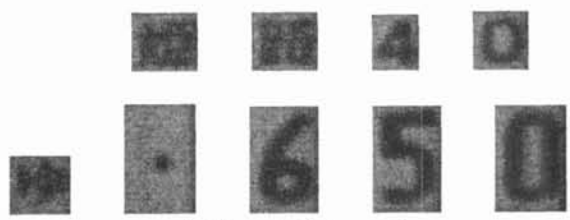
Table 1. Hit rate in the best 3 candidates for the plate

Test samples	Hit in the best 3 candidates	Failure
180	163	17



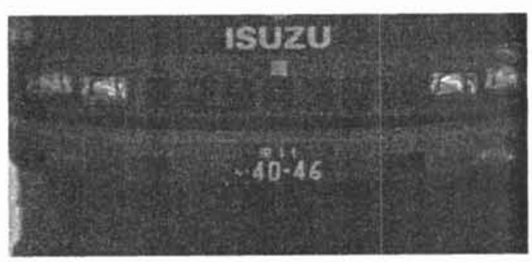
(a) Original image

(b) First plate candidate (c) The segmentation (d) Matched regions



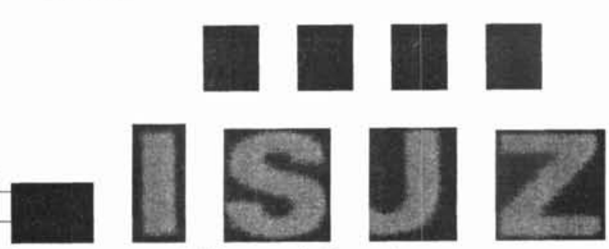
(e)Located characters

Figure 5. The case of skewing and having "."



(a) Original image

(b) First plate candidate (c) Matched regions (d) Second plate candidate



(e)Located characters

Figure 6. An example for rejection

Table 2. Separating & Recognition rate for the characters

Correct rate		Large Numeral	Small Numeral	Chinese Character	Japanese Hiragana
Number of characters		652	326	348	163
Without Association	Separating	95.70	89.88	83.62	84.66
	Recognition	92.64	87.73	79.89	82.82
With Association	Separating	99.85	98.77	91.38	100.00
	Recognition	99.85	96.93	89.66	98.77

4 Conclusion

Although there are some failure in selecting candidates for the plate and binarization for character recognition, our procedure is very effective to improve the correct separating rate.

The experimental results show that our procedure is not only robust against zooming, skewing, variety of illumination and noise, but also effective to deal with Japanese Hiraganas, Chinese characters and small numerals, which are very difficult to be obtained by the conventional sequential image segmentation method.

The proposed method can also be used in some object-recognition systems which have fixed structure just like the license plate. For example,the serial number recognition for container, train, etc. .

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