REAL-TIME AUTOMATIC VEHICLE MANAGEMENT SYSTEM USING VEHICLE TRACKING AND CAR PLATE NUMBER IDENTIFICATION

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ABSTRACT

This paper proposes a real-time vehicle management system using a vehicle tracking and a car plate number identification technique. The system uses two cameras: one for tracking vehicles and another for capturing LP (License Plate). We track the vehicles by applying the CONDENSATION algorithm over the vehicle’s movement image captured from the first camera. To render the CONDENSATION algorithm more effective, we build a discrete vehicle shape model by training vehicle patterns with a SOM (Self Organizing Map), which makes the system suitable for real-time application. Next, we take the probabilistic dynamic model such as HMM (Hidden Markov Model) to reflect the temporal change in shape of various vehicles. When a vehicle reaches the designated target line, a signal is sent to the second camera for capturing the vehicle’s front side. The captured image is transferred to an LPR (Vehicle LP Recognition System) which recognizes the vehicle’s category and LP. LPR system detects the vehicle LP using the only the vertical edge of the captured vehicle image, and effectively accomplishes the character segmentation of the LP region using the geometric transformation without respect to the position and angle of the CCD camera. The segmented characters are recognized using the SVM.

1. INTRODUCTION

Background subtraction method is a general method to segment and track moving objects in a real-time surveillance application. Ismail [1] used the background subtraction method for segmenting human beings in the real-time surveillance system W4. However, the background subtraction method has been influenced by changes of illumination or shadow. To minimize the effect of illumination or shadow, Gao et. al. [2] introduced the background estimation method. This method can miss some objects because it detects the objects by merging the detected regions. The real-time multiple people tracking was proposed as one application of the CONDENSATION algorithm [3]. This method proposes discrete shape model which is learned by SOM to be suitable for real-time application and appropriate object tracking.

LPR has the several steps-extraction of LP’s region, segmentation of each characters, recognition of each characters. To LP extraction in color image are proposed using the appointment colors of the LP [4]. However, it is very difficult because vehicle has the variety of color and there are similar colors to the LP. In other method, There is the method that uses only vertical edge in gray-level to extract the LP [5]. This method that it is useful to use for extract LP not all edges but only vertical edge. The segmentation of each characters in extracted LP uses the histogram of LP’s region [4, 5]. However, it is difficult to segment when the LP is inclined by the position and angle of camera. In this paper, effectively accomplishes the character segmentation of the LP region using the geometric transformation. The segmented characters are recognized using the SVM.

This paper is organized as follows. Section 2 explains our proposed method for the vehicle tracking. Section 3 describes our proposed method for LPR. Section 4 shows some simulation results that vehicle tracking and LPR. Finally a conclusion is presented.

2. VEHICLE TRACKING

For making the CONDENSATION algorithm more effective, we build the discrete vehicle shape model by training some vehicle patterns with SOM, which makes the system suitable for real-time application. Next, we take the probabilistic dynamic model such as HMM that can reflect the temporal change of variously shaped vehicles [3].
2.1. Create shape templates using SOM

To learn a shape model for vehicles, we should extract shape vectors from training image sequences taken by a stationary camera. Large connected regions in the foreground image provide ordered sets of boundary points of vehicle silhouettes, which have a sufficient number of control points for B-spline approximation. Enumerating the control points of the spline will make up a shape vector. SOM is used as VQ(Vector Quantization) to provide a set of shape templates. Shape vectors extracted from training image sequences are presented to SOM. We assign weight vectors between the input layer and each output nodes to template vectors. Also we define the distance between two templates as lattice distance between the corresponding output nodes. Fig. 1 shows the VQ result of 16 × 16 SOM.

![Figure 1: Vehicle front shape template at output nodes](image)

2.2. Tracking algorithm

The CONDENSATION algorithm is a probabilities tracking algorithm based on factored sampling[7]. Let \( x_t \) and \( z_t \) represent the state parameter and features of an image at time \( t \). The CONDENSATION algorithm can be summarized as follows:

- **Sampling**: Sample \( s'_{t-1} \) from the density \( p(x_{t-1}|z_{t-1}) \) represented by sample set \( \{s_{t-1}, \pi^t_{t-1}\} \).

- **Prediction**: Predict new sample \( s'_t \) using probabilities dynamical model \( p(x_t = s'_t|x_{t-1} = s_{t-1}) \).

- **Measurement**: Compute \( \pi^t_t = p(z_t|x_t = s'_t) \). Continue with sampling step with a new sample set \( \{s'_t, \pi^t_t\} \).

We should define a dynamic model to apply the discrete shape model to the CONDENSATION algorithm. We proposed to use the HMM to predict the shape transition more precisely. The shape transition probability is give as follows:

\[
p(x_t = s_t|x_{t-1} = s_{t-1}) = \frac{p((s_t-1, s_t)|HMM)}{\sum_s p((s_{t-1}, s_t)|HMM)} \tag{1}
\]

We have to measure and compute the weights for new samples estimated from the dynamic model. The measurement density is given by

\[
p(z|x) = \exp\left(-\frac{1}{M} \sum_{i=1}^{M} d^2(z_i, I)\right) \tag{2}
\]

where \( M \) is the number of the measurement points, the \( z_i \)'s are the measurement points along the B-spline contour, \( I \) is the feature image data, and \( d(z_i, I) \) denotes the distance between \( z_i \) and the closest feature of same type in \( I \). To reduce clutter in the scene, we use the moving edge map[6]. Fig. 2 shows the resulting two edge segmentations. There, the moving edge is more powerful that the edge map in the case of object movement.

![Figure 2: Feature extraction](image)

3. VEHICLE LICENSE PLATE RECOGNITION

3.1. License plate extraction

If we can detect the two vertical edges correctly, we can extract the licence plate exactly[5]. For a gray-level image \( \{G_{i,j}; 1 \leq i \leq N, 1 \leq j \leq M\} \), We apply a sharpening mask to obtain a more accurate vertical edge. Only the vertical edges of input image are used to extract license plate, which are represented as follows.

\[
F_{i,j} = \frac{1}{3} \sum_{k=i-1}^{i+1} |G_{k,j} - G_{k,j+1}|, \tag{3}
\]

\[
B_{i,j} = \begin{cases} 1 & \text{if } F_{i,j} \geq T \\ 0 & \text{otherwise} \end{cases} \tag{4}
\]

where \( F_{i,j} \) is vertical edge intensity function of the input image at pixel \((i,j)\), \( B_{i,j} \) denotes the binary vertical edge image and \( T \) in Eq.(3) is a threshold given below:

\[
T = \frac{1}{N \times M} \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} G_{m,n} \tag{5}
\]

Fig. 3(b) shows the vertical edge images. We also apply the dilation morphological operator to remove noise from the edge images.

In a binary image, a region is defined as a set of eight connected with each other. To filter the image, each region is browsed by using the size-and-shape filtering algorithm[5].
If the measured features of a certain edge region does not satisfy the predefined features of the interesting object, the region is removed as noise. Otherwise, the region is kept and its information is recorded for post-processing. Fig.3(c) shows the result of size-and-shape filtering.

The ratio of width over height of Korean LP ranges from 1.4 : 1 to 2.5 : 1, and the ratio of the heights between two vertical edges ranges from 0.8 to 1.4 depending on the viewing angles. If a pair of edge regions satisfies the above two conditions, it is regarded as the possible vertical edges of the LP. Korean LP have a regular pixel variation range of vertical pixel and horizontal pixel in LP. That is, horizontal pixel variation has about from 10 to 20, vertical pixel variation has about from 6 to 17. Thus, the region, which has a maximum variation value, is selected to satisfy this condition in the possible vertical edges of LP.

3.2. License plate segmentation

After the LP has been extracted, it is normalized into a 200×100 gray-level image \{P_{i,j}\} and is then transformed into a binary image \{L_{i,j}\}. In Korea, the LP is classified into personal car LP and business car LP. Their backgrounds are green and yellow, while the characters are white and dark blue, respectively. Therefore, segmentation is slightly different. For personal car plates where the characters have a higher intensity than the background, the segmentation is represented by

\[
L_{i,j} = \begin{cases} 
1 & \text{if } P_{i,j} \geq T_p \\
0 & \text{otherwise} 
\end{cases}
\]  

(6)

where 1 ≤ i ≤ Y, 1 ≤ j ≤ X, the Y and X denote vertical and horizontal size of LP, respectively. Also, the threshold \(T_p\) is using defined by \(T_p = P_{\mu} - P_{\sigma}\), in which the two terms are

\[
P_{\mu} = \frac{1}{Y \times X} \sum_{i=1}^{Y} \sum_{j=1}^{X} P_{i,j},
\]

(7)

\[
P_{\sigma} = \frac{1}{Y \times X} \sum_{i=1}^{Y} \sum_{j=1}^{X} |P_{i,j} - P_{\mu}|.
\]

(8)

For business car plates, the threshold \(T_b\) is defined by \(T_b = P_{\mu} + P_{\sigma}\). To distinguish between the personal car private plates and the business plates, each binary LP image is created by applying the threshold value \(T_p\) and \(T_b\) to the normalized gray-level plate. After applying the size-and-shape filtering into each binary plate image, the plate which has a greater amount of white pixel is selected.

For character recognition, each character should be segmented. The extracted LP can be tilted due to the difference of viewing angles between the car and the camera. As Fig.3(d), segmentation using a histogram is not suitable in the case of the tilted LP. To improve segmentation and recognition performance, we used the geometric transform[8] for LP restoration. Geometric transform can be performed by using the top and bottom point of each vertical edge used for LP extraction. Fig.3(e) shows restored LP images by geometric transform. It provides the correct segmentation and better recognition performance than the tilted LP. After geometric transform, LP is segmented into two regions horizontally and segments several regions vertically, combined with the knowledge of standard character’s position on a LP.

3.3. License plate character recognition

In Korea LP, there are two rows of characters in a plate. The upper row contains two Korean characters and one or two numerals. The lower row contains one Korean character and four numerals.

For accurate feature selection and efficiency of computation, Korean characters and numerals in the upper row are divided into 20×10, 7×9, respectively, while Korean characters and numerals in the lower row are divided into 10×10, 7×11, respectively. Four different SVMs-based character recognizers are used for recognizing the upper characters, the upper numerals, the lower character and the lower numerals, respectively. They take a one-against-the-rest approach to classify multi-classes characters.

4. SIMULATION RESULT AND DISCUSSION

A real-time vehicle management system integrates the vehicle tracking and the LPR described earlier. 2 CCD camera, 2 image processing board and 1 PC are used. The vehicle track uses the 320×240 size of images and the LPR uses the 640×480 size of images. Input image sequence are
30fps and TCP/IP is used for communication between two cameras to indicate the start of capturing the vehicle’s front side. Shape vectors were obtained from the training image sequences using $B$-spline approximation. We used 40 control points for $B$-spline approximation. Templates were built using $16 \times 16$ SOM. To obtain the training shape transition sequences, the dynamic model was defined as Eq.(1). The number of samples for each tracker is $N=100$ samples. Table.1 shows the performance improvement by geometric transformation for 100 tilted images. As Table.1, the tilted LP images generate poor segmentation, which decreases the performance of character recognition.

<table>
<thead>
<tr>
<th>Accuracy rate(%)</th>
<th>LP Extract</th>
<th>Segmentation</th>
<th>Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>100</td>
<td>83</td>
<td>63</td>
</tr>
<tr>
<td>(b)</td>
<td>100</td>
<td>100</td>
<td>99</td>
</tr>
</tbody>
</table>

Table 1: Result of geometric transform: (a)No geometric transform (b)Geometric transform.

![Vehicle tracking and LP recognition](image.png)

Figure 4: Example of vehicle management system.

For LP recognition based on SVM, we used 450 training images and 300 test images. Among test images, 50% are tilted LP images. Recognition rate is 99.3% and the average recognition time for one license plate is about 1.5 seconds. Misrecognized images are distorted and the character paint is peeled away, are impossible to recognize even with the naked eye. For experiment of real-time application, we examine our system in the entrance of parking lot. Fig.4 shows the vehicle tracking(Fig.4(a)) and LP recognition result(Fig.4(b)) of vehicle management system. Here, the capture signal has been occurred at the 863th frame and the capture image(the top of Fig.4(b)) is sent the LPR. This vehicle management system perform vehicle tracking successfully and recognizes the vehicles LP robustly without any influence of position of CCD camera.

5. CONCLUSION

This paper describes the vehicle management system that consists of the vehicle tracking and LPR. General vehicle management system uses the hardware such as sensors for vehicle detection. However, such hardware devices are expensive, and can be activated by all moving objects. Proposed vehicle management system detects only vehicle, can be possible to recognize the LP insensitively to the position of CCD camera. Also, it is cheaper than the existing vehicle management system.

6. REFERENCES


