Vehicle License Plate Detection Method Based on Sliding Concentric Windows and Histogram

Kaushik Deb, Hyun-Uk Chae and Kang-Hyun Jo
Graduate School of Electrical Engineering and Information Systems, University of Ulsan, Ulsan, Korea
Email: {debkaushik99, hwchae, jkh2008}@islab.ulsan.ac.kr

***Abstract*— Detecting the region of a license plate is the key component of the vehicle license plate recognition (VLPR) system. A new method is adopted in this paper to analyze road images which often contain vehicles and extract LP from natural properties by finding vertical and horizontal edges from vehicle region. The proposed vehicle license plate detection (VLPD) method consists of three main stages: (1) a novel adaptive image segmentation technique named as sliding concentric windows (SCWs) used for detecting candidate region; (2) color verification for candidate region by using HSI color model on the basis of using hue and intensity in HSI color model verifying green and yellow LP and white LP, respectively; and (3) finally, decomposing candidate region which contains predetermined LP alphanumeric character by using position histogram to verify and detect vehicle license plate (VLP) region. In the proposed method, input vehicle images are commuted into grey images. Then the candidate regions are found by sliding concentric windows. We detect VLP region which contains predetermined LP color by using HSI color model and LP alphanumeric character by using position histogram. Experimental results show that the proposed method is very effective in coping with different conditions such as poor illumination, varied distances from the vehicle and varied weather.**

***Index Terms*— Vehicle license plate detection (VLPD), HSI color model and histogram.**

I. INTRODUCTION

With the rapid development of highway and the wide use of vehicle, people start to pay more and more attention on the advanced, efficient and accurate intelligent transportation systems (ITSs). The task of recognizing specific object in an image is one of the most difficult topics in the field of computer vision or digital image processing. VLPD is also very interesting in finding license plate area from vehicle image. The vehicle license plate detection is widely used for detecting speeding cars, security control in restricted areas, unattended parking zone, traffic law enforcement and electronic toll collection. Last few years have seen a continued increase in the need for and use of VLPR. The license plate detection is an important research topic of VLPR system. Because of different conditions such as poor illumination and varied weather, it is important and interesting how to segment license plate fast and perfectly from road images which often contain vehicles.

The focus of this paper is on the consolidation of a new image segmentation method implemented in a VLPD system. Specifically our contribution in image segmentation is unique as:

Image segmentation method named as sliding concentric windows (SCW) used for analyzing road images which often contain vehicles and extract LP from natural properties by finding vertical and horizontal edges from vehicle region.

Furthermore, color verification for candidate regions by using HSI color model on the basis of using hue and intensity in HSI color model is verified by green and yellow LP and white LP, respectively. Finally, decomposing candidate region which contains predetermined LP alphanumeric character by using position in the histogram to verify and detect vehicle license plate region is performed.

The rest of this paper is organized as follows. The next section composes a review of similar researches that have been implemented and tested for vehicle license plate detecting. In Section III, the specific features of Korean VLP to be considered are described. In Section IV, the proposed VLPD algorithm is described. The three primary stages of the proposed VLPD algorithm, i.e. detecting candidate regions, authenticating candidate region color and character extraction of LP region are discussed in details in Section V. In Section VI, experimental results are reported. Finally, some conclusions are given and future work is proposed in Section VII.

II. REVIEW OF OTHER METHODS

This section provides a descriptive summary of some methods that have been implemented and tested for VLPD. As far as detection of the plate region is concerned, researchers have found many methods of locating license plate. For example, a method based on image segmentation technique named as sliding windows (SW) was also proposed for detecting candidate region (LP region) [1], main thought of image segmentation technique in LP can be viewed as irregularities in the texture of the image and abrupt changes in the local characteristics of the image, manifesting probably the presence of a LP. A conventional statistical classifier based on the k nearest neighbours rule is used to classify every pixel of a test image to obtain a pixel map where group of positive samples probably indicates the location of a license plate. In this system, time exhausting texture analysis is presented in [2], where a combination of a "kd-tree" data structure and an "approximate nearest neighbour" was espoused. The computational resource demand of this segmentation technique was the main drawback, taking an average of 34 seconds in processing of single image. In [3], the pulse coupled neural network (PCNN) is proposed and implemented for LP identification.

Fuzzy logic has been applied in detecting license plates. Authors made some intuitive rules to describe the license plates and gave some membership functions for fuzzy sets e.g. "bright," "dark," "bright and dark sequence," "texture," "yellowness" to get the horizontal and vertical plate positions [4]. Prior knowledge of LP and color collocation is used to locate the license plate in the image [6] as part of the procedure of location and segmentation. Hough Transform (HT) for line detection was proposed on the assumption that the shape of license plate is defined by lines in [7].

A modified color texture-based method for detecting license plate in images was presented in [8]. A support vector machine (SVM) was used to analyze the color and texture properties of LPs and to locate their bounding boxes applied by a continuous adaptive mean shift algorithm (CAMShift). The combination of CAMShift and SVMs produces efficient LP detection as time-consuming color texture analysis for less relevant pixels is restricted, leaving only a small part of the input image to be analyzed.

In addition, finding candidate areas by using gradient information, it is verified whether it contains the plate area by introducing a template of the LP in [9]. A region-based license plate detection method was presented in [10], which firstly applies a mean shift procedure in spatial-range domain to segment a color vehicle image in order to get candidate regions. Other approaches for segmentation of vehicle plates such as edge image improvement to detect a number of car plates in [11] and an approach using mathematical morphology method to detect license plate area [12] were also proposed.

Currently, some researchers prefer a hybrid detection algorithm, where license plate location method based on corner detection, edge detection, characteristics of license shape, character's connection and projection is presented in [15, 17] and [16] is another method which is based on the color collocation of the plate's background and characters combined with the plate's structure and texture to locate the VLP. Image enhancement and sobel operator to extract out vertical edges and finally search plate region by a rectangular window was presented in [18].

In this paper, an algorithm enforcing a new image segmentation method (SCWs), recursive connected component labeling and filtering is regarded for detecting candidate region. Additionally, color verification for candidate region by using HSI color model and finally, decomposing candidate region by using position in the histogram to verify and detect VLP region.

III. Specific Features of Korean VLP

In this section, the color arrangement of the plate and outline of the Korean VLP that are considered in this study are discussed.

A. *Color arrangement of the plate*

Assorted styles of license plates found on vehicles in South Korea are shown in Table I. Each style is associated with a particular class of vehicle. The classes include private automobile, taxi, truck, bus and government vehicles. Each style has a different foreground (character) and/or background (plate) color. However, in all only five distinct colors (white, black, green, yellow and deep blue) are utilized in these license plates. We shall pay attention to three different plate colors when searching for LP in an input image. Color arrangements for the Korean VLPs are shown in Table I.

TABLE I.
Styles of license plates.

Vehicle type	Plate color	Character color
Private automobile	White	Black
	Green	White
Taxi, truck and bus	Yellow	Deep blue
Government vehicle	Yellow	Black

Other types of vehicles, such as diplomatic cars and military vehicles, are not addressed since they are rarely seen.

B. *Outline of the Korean VLP*

Standard LP contains Korean alphabets and numbers which are shown in Fig. 1. Few LP contains Korean alphabets and numbers in two rows, in future this kind of LP is supposed to be converted into a single row. Where plate color is white and character color is black, they contain seven alphanumeric characters written in a single line. Fig. 1 shows, where plate color is green and character color is white, they contain Korean LP in two rows. The upper row consists of two small Korean characters of region name followed by one or two numbers of class code or two numbers of class code and a usage code of one syllable (Korean character). The lower row is usage code of one syllable (Korean character) and four big numbers serial code or only four big numbers to indicate the usage and serial number respectively. When plate color is yellow and character color is black, some LP contains all alphanumeric characters written in a single line, and another type of yellow LP is found and they contain Korean LP in two rows. The upper row consists of two small Korean characters of region name followed by one or two numbers of class code or two numbers of class code and a usage code of one syllable (Korean character). The lower row is usage code of one syllable (Korean character) and four big numbers serial code or only four big numbers to indicate the usage and serial number respectively.

IV. Proposed Algorithm

In the author's previous work [5], a parallelogram and histogram based vehicle license plate detection (VLPD) was presented. We propose in this section an enhanced version of VLPD algorithm. As shown in Fig. 4, the extracted features using a recursive algorithm is implemented for connected component labeling (CCL) operation and during this step main geometrical property of LP candidate such as aspect ratio is computed. This parameter is used to eliminate LP-like object from candidate list. In addition, we are segmenting each predetermined alphanumeric character after using position histogram.

The proposed VLPD algorithm consists of three main stages: (1) detecting candidate regions (2) authenticating candidate region color and (3) character extraction. General scheme for detecting LP region is shown in Fig. 2.

Typical color images are represented as red (R), green (G) and blue (B) or RGB images. Using the 8-bit monochrome standard as a model, the corresponding color image would have 24-bits per pixel – 8-bits for each of the three color bands (red, green, and blue) but a grey scale image (referred to as monochrome) only contains the brightness information but not color information [14]. In order to improve image processing speed, input vehicle image (RGB) is converted to grey-level image.

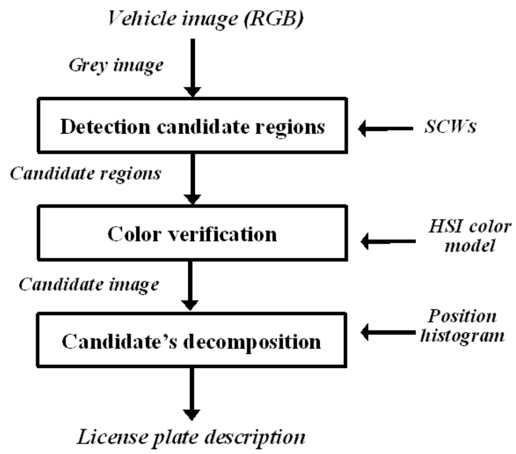

Figure 2. General scheme for detecting license plate region.

V. License Plate Detecting Module

A. Detecting candidate regions

Edges are usually displayed irregularities in intensity or color of the image. It is supposed that, if abrupt changes in such local characteristics of the image are found, it provides evidence for presence of a possible edge. Hence, we can assume that without irregularities in intensity or color in the local region, no edges should be present. On the basis of this observation, an algorithm has been developed in order to describe the local irregularities in the texture of the image. This idea is transferred to software steps where the standard deviation value of a processing block should vary with the standard deviation value in the neighboring blocks in the case of presence of an edge in the image.

Based on the above, using segmentation technique named as sliding concentric windows (SCWs) a new approach is being proposed in this paper to analyze road images which often contain vehicles and extract license plate from natural properties by finding vertical and horizontal edges from vehicle region.

The SCWs are based on the statistical measurement of standard deviation. While working with this method, all pixels in the image are examined one by one in terms of fulfilling a similarity rule about the standard deviation values of neighboring areas. The algorithm was developed and implemented as follows:

1. Creation of two concentric windows A and B of size $(X1)\times(Y1)$ and $(X2)\times(Y2)$ pixels; respectively. Those two concentric windows are shown in Fig. 3.

2. Calculation of the standard deviation of the pixels in windows $A(std_A)$ and $B(std_B)$.

3. Definition of segmentation rule: if the standard deviation ratio of the two windows exceeds a threshold set by the user, then the central pixel of the windows is considered to belong to a vertical and horizontal region. Following that, the pixel in the new image is set to 1; otherwise it is set to zero.

Accordingly, let x, y be the coordinates of the observed pixel in input vehicle image *I*. The pixel value in the respective coordinates $x^{'}$, $y^{'}$ of the resulting image I_1 is set either 0 (no edges) or 1 (edges) according to the following equation:

$$I_1(x^{'},y^{'}) = \begin{cases} 0, & \text{if } \frac{std_B}{std_A} \leq T \\ 1, & otherwise \end{cases} \tag{1}$$

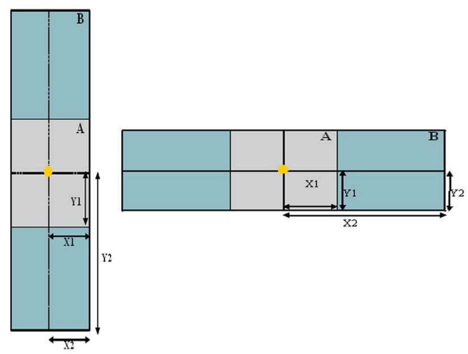

Figure 3. Concentric windows for detecting vertical and horizontal regions.

Figure 1. Outline of the Korean license plate.

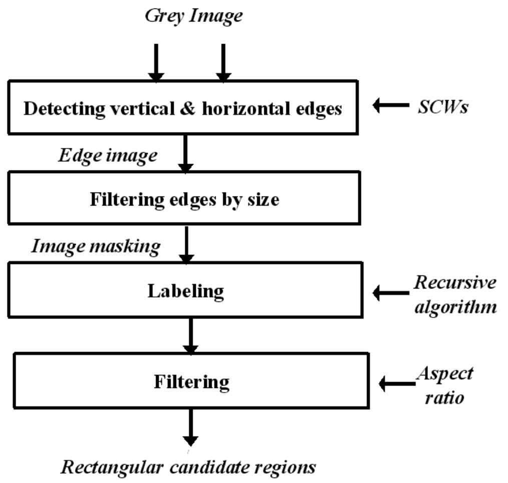

Figure 4. Candidate regions detection.

The two windows move all over the pixels of the image from left to right, until the entire image is covered. SCWs are used for faster detection of regions of interest (ROI), operating in different natural backgrounds and algorithmic sequence handling plates of various size and positions.

In the proposed method, the input to this module is a grey-level image. The resulting image after the SCW method is the binary image. After finding vertical and horizontal regions (ROI), the mask is used in the OR masking operation for finding rectangular candidate area. According to the prior knowledge of vehicle LP inspection, all license plates must be rectangular and have the dimensions as well as have all alphanumeric characters written in a one or two rows in LP region. Under the practical environments, the inclined angle is constant.

Next step of proposed algorithm is labeling the connected components. Connected components labeling (CCL) is a well-known technique in image processing that scans an image (binary and gray-level) and labels its pixels into components based on pixel connectivity. In other words all pixels in connected components share similar pixel intensity values and these components are actually connected with respect to either the 4-neighborhood or the 8-neighborhood definition. Once all groups have been determined, each pixel is labeled with a value according to the component to which it was assigned.

In the proposed method, a recursive algorithm is implemented for connected components labeling operation. Recursive algorithm [13] works on one component at a time, but can move all over the image. On this step we extract candidate regions which may include LP regions from the binary mask obtained on the previous step. During this step main geometrical property of LP candidate such as aspect ratio is computed.

The aspect ratio (also called elongation or eccentricity) can be found by scanning the image and the minimum and maximum values on the row and the columns, where the object lies [14]. This ratio is defined by:

$$r = \frac{(c_{max} - c_{min}) + 1}{(r_{max} - r_{min}) + 1} \tag{2}$$

where c and r indicates column and row, respectively. Those objects whose measurements fulfill the criteria between (1.0 $<$ Aspect ratio $<$ 2.0) for green LP, (1.0 $<$ Aspect ratio $<$ 3.0) for white LP and for yellow LP (1.0 $<$ Aspect ratio $<$ 3.0) are considered as candidate plate regions. The aspect ratio parameter is used in filtering operation to eliminate LP-like objects from candidate list. Filtering operation is based on geometrical property of LP regions.

Fig. 5 shows the steps for candidate region detection (green back ground LP): (a) initial image, (b) grey image, (c) detecting vertical edges, (d) detecting horizontal edges, (e) after image masking operation, (f) after inverse operation, (g) after labeling detecting sub candidate region and (h) candidate region detection.

Figs. 6 and 13 show the steps for candidate region detection (white back ground LP): (a) initial image, (b) grey image, (c) detecting vertical edges, (d) detecting horizontal edges, (e) after image masking operation, (f) after inverse operation, (g) after labeling detecting sub candidate region and (h) candidate region detection.

B. Authenticating candidate region color

Many applications use the HSI color model. Machine vision uses HSI color space in identifying the color of different objects. Image processing applications such as histogram operations and intensity transformations are performed on an image in the HSI color space.

The RGB color space consists of the three additive primaries: red, green and blue. Spectral components of these colors combine additively to produce a resultant color. RGB model is represented by a 3-dimensional cube with red, green and blue at the corners on each axis.

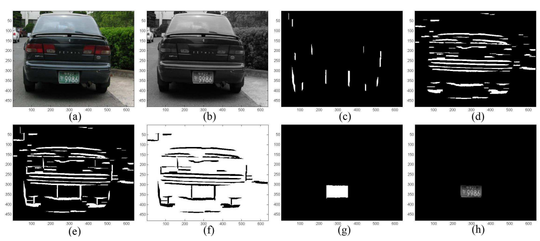

Figure 5. Steps for candidate region detection (green back ground LP).

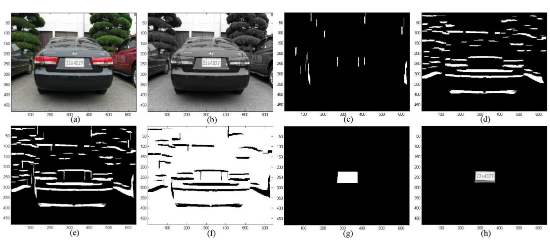

Figure 6. Steps for candidate region detection (white back ground LP).

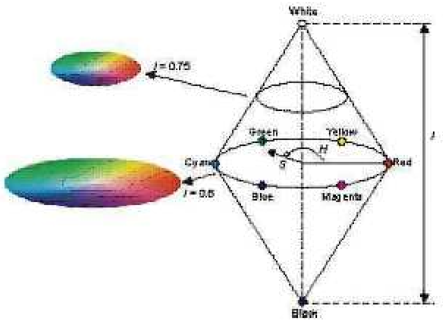

Figure 7. HSI color space.

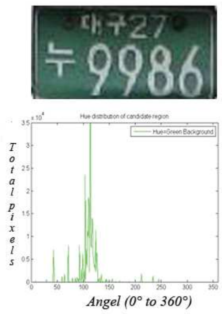

Figure 9. Hue distribution of candidate region.

Typically HSI colors are not described on the basis of percentages of primary colors, but rather by their hue, saturation and intensity. The saturation is the “pureness” of the color, the hue is the color itself and the intensity describes the brightness of the color. The HSI model separates all the color information, described by hue and saturation, from the intensity component. The color space in the HSI model is not represented by a cube as is done in the RGB color model, because the components are not orthogonal. The color space is represented by the diamond as in Fig. 7.

The hue H is represented as angle *0*, varying from *0*° to *360*°. Adjusting the hue the color will vary from red at *0*°, through yellow at *60*°, green at *120*°, blue at *240*° and back to red at *360*°. Saturation S corresponds to the radius, varying from 0 to 1. When S = 0, color is a grey value of intensity 1. When S = 1, color is on the boundary of top cone base. Intensities I vary along Z axis with 0 being black and 1 being white.

Using hue in HSI color model, verifying green and yellow LP and analyzing our database we find different illumination and in varied weather conditions hue value changes in specific range. Using intensity in HSI model we verify white license plate. The transformation from (R, G, B) to (H, S, I) [14] is

$$\begin{aligned} H &= \cos^{-1}\left\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{\frac{1}{2}}}\right\} \\ S &= 1-\frac{3}{(R+G+B)}[min(R,G,B)] \qquad (3) \\ I &= \frac{(R+G+B)}{3} \end{aligned}$$

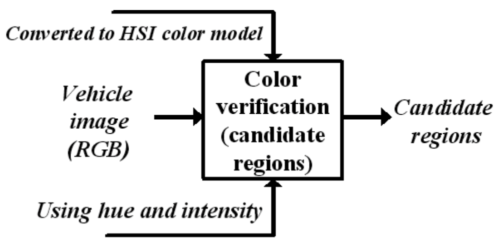

Figure 8. Color verification using HSI color space.

C. Character extraction

Information extracted from image, intensity histograms play a basic role in image processing, in areas such as enhancement, segmentation and description. In this section, verification and detection of the VLP region as well as character segmentation, are considered and discussed in this study.

Once the candidate area is binarized the next step is to extract the information. At first, regions without interest such as border or some small noisy regions are eliminated, the checking is made by height comparison with other plate characters height.

Following procedure is performed when LP color is green and yellow: first we proceed by performing horizontal position in the histogram, two objects are found where each object corresponds with one row. Then the rows are isolated and processed separately. As mentioned before in Section III, two types of plate are considered.

Processing of the upper row: firstly filter phase is performed to eliminate the regions without interest. Then vertical position histogram is processed. The upper row also has two different types as we mentioned in Section III. As it can be observed, usually in the upper row we can find two plate fixing dots as shown in Fig. 1. The right plate fixing dot does not even appear in the binarization process due to the fact that it is printed green. The left plate fixing dot is also eliminated. The checking is made by height comparison. From the vertical position in the histogram we can find isolated alphanumeric characters.

Processing of the lower row: firstly filter phase is

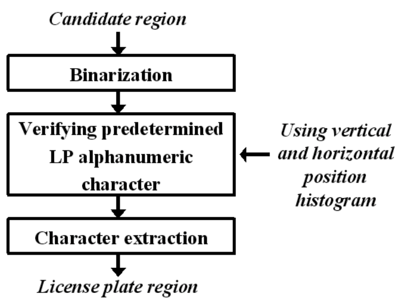

Figure 10. Detect license plate region.

performed to eliminate the regions without interest. Then vertical position histogram is performed and from the vertical position histogram the alphanumeric characters are isolated.

Fig. 12 shows the results for verifying predetermined alphanumeric character (green back ground LP): (a) extracting candidate region, (b) horizontal position histogram without LP border, (c) row extraction after binarization and (d) character extraction.

According to the prior knowledge of vehicle LP inspection, all white LPs contain seven alphanumeric characters as well as written in a single row. The following procedure is performed for character segmentation: After eliminating border area, vertical position in the histogram is performed for segmenting predetermined alphanumeric characters. As it can be observed, usually we can find also two plate fixing dots in upper area of plate region. The right plate fixing dot or both plate fixing dots do not even appear in the binarization process due to the fact that it is printed white. The left plate fixing dot is also eliminated; this checking is made by height comparison.

Fig. 14 shows the results for verifying predetermined alphanumeric character (white back ground LP): (a) extracting candidate region, (b) vertical position histogram with LP border, (c) horizontal position histogram without LP border, (d) view of binarization candidate region after removing border and noisy area, (e) vertical position histogram (seven peaks for predetermined seven alphanumeric characters in LP region) and (f) character extraction.

VI. Experimental Results

All experiments were done on Pentium IV 2.4 MHz with 1024 RAM under Matlab R2008a environment. In the experiments, 40 images were employed and the size of the images is 640*480 pixels. For these images, all of them were taken by digital camera (canon 570 power shot A570 IS) from various scenes and under different lighting conditions of the real world, varied distances from the vehicle and varied weather. The distance between the camera and the vehicle varied from 3 up to 7 meter and the camera focused in the expected plate region. The satisfactory result has been obtained; the success of detection rate of license plate is up to 82.5%. In this method, most mislocated plates happened when vehicle images were taken in following cases: (a) from different viewpoints, (b) containing some special objects (with stickers or stamps attached on their surface) (c) complex scenes (where several objects look like LPs) and (d) environment conditions (the strong sun light or under gloomy light).

Figure 11. Example images: (a) frontal view and (b) back view.

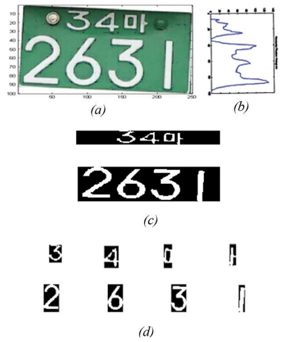

Figure 12. Detect license plate region.

VII. Conclusion

In this paper, we adopt a new method in image segmentation technique named as sliding concentric windows (SCWs) based on extract candidate regions by finding vertical and horizontal edges from vehicle region; and then color verification for candidate regions by using HSI color model on the basis of using hue and intensity in HSI color model verifying green and yellow LP and white LP, respectively. Finally, candidate region which contains predetermined LP alphanumeric character by using position in the histogram to verify and detect vehicle license plate (VLP) region was decomposed.

During the experiment, different illumination conditions and varied distances between vehicle and camera often occurred. In this case, we confirm that the result is very effective when the proposed approach is used. However, the proposed method is sensitive to the angle of view, physical appearance and environment conditions, e.g. the plate of car license are defiled, with stickers or stamps attached on their surface etc.

These problems can be solved by using image processing operation as like as histogram equalization, high dynamic range imaging (HDR) and so on. To improve the edge detection algorithms for progressive performance of vehicle license plate detection may be followed for other research direction.

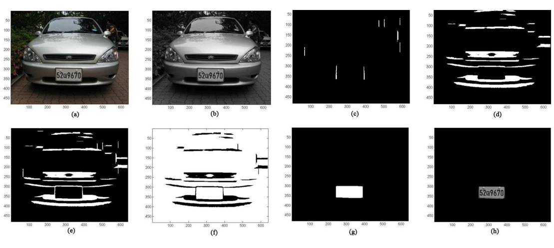

Figure 13. Steps for candidate region detection (white back ground LP).

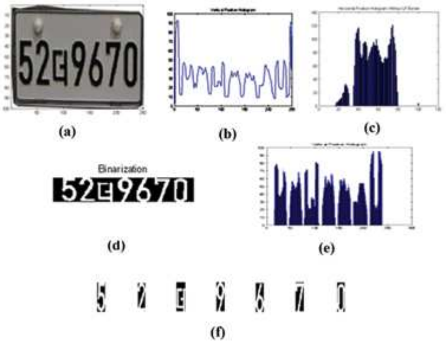

Figure 14. Detect license plate region.

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Kaushik, Deb received the B. Tech. and M. Tech. degrees from Department of Computer Science and Eng. of Tula State University, Tula, Russia, in 1999 and 2000 respectively. Since 2001, he has been serving as a faculty member in Department of Computer Science and Eng., Chittagong University of Engineering and Technology, Chittaong, Bangladesh.

He is currently a candidate for Ph.D. at the Graduate School of Electrical Eng. and Information Systems, University of Ulsan, Ulsan, Korea. His research interests include computer vision, pattern recognition, intelligent transportation systems (ITSs) and human-computer interaction.

Hyun-Uk Chae received his B.E. degree in University of Ulsan, Korea in 2007.

He is currently a student of Masters course at the Graduate School of Electrical Eng. and Information Systems, University of Ulsan, Korea. His research interests include computer vision and human-computer interaction.

Kang-Hyun Jo received the B.E. degree in Mechanical and Precision Eng. from Busan National University, Korea and M.E. and Ph.D. degrees in Computer-Controlled Machinery Eng. from Osaka University, Japan, in 1989, 1993, and 1997, respectively.

He is currently Professor at the Faculty of Electrical Eng. and Information Systems, University of Ulsan, Korea. His research interests include computer vision, human-computer interaction, robot applications in town and healthcare and intensive intelligent systems. He is actively participating as a member of variety of professional research societies, like IEEE, IEEK, ICROS, KRS, KIPS, KIISE and KSAE.