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LICENSE PLATE EXTRACTION METHOD FOR IDENTIFICATION OF VEHICLE VIOLATIONS AT A RAILWAY LEVEL CROSSING

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ABSTRACT−The primary cause of most railroad accidents is vehicle entry into railway level crossings despite warning messages. To identify drivers who violate railway level crossing regulations, vehicle license plate recognition can be applied at railway level crossings. The purpose of this paper is to present an effective method for extracting the license plate region from vehicle images taken at railway level crossings. The method proposed in this paper uses the variation in the gray-level values across the image of a license plate. For license plate region extraction, the character region is first recognized by identifying the character width and the difference between the background region and the character region. The license plate region is then extracted by finding the inter-character distance in the plate region. In addition, the license plate type is identified by the difference in the gray-level value between the background region and the character region. The proposed method is effective in solving the current challenges in extracting the license plate region from the damaged frames of license plates issued for domestic use, including new types of license plates. According to the experimental results, the proposed method yields a high extraction rate of 99.5% for vehicle license plates.

KEY WORDS : Railway level crossing, License plate extraction, Digital image processing

1. INTRODUCTION

The number of vehicles on the road continues to increase dramatically, which has led to heavy traffic congestion that can be blamed for the growing number of car accidents. Particularly serious accidents can occur because of violations of railway level crossing regulations. Many researchers have proposed schemes to prevent railway level crossing accidents. However, more intelligent technology is required to prevent accidents at railway level crossings. Figure 1 shows architecture that employs an intelligent system at a railway level crossing (Cho *et al.*, 2008). Hereafter, we refer to this architecture as the intelligent railway level crossing system.

The intelligent railway level crossing system provides warning information to train and roadside traffic adjacent to a railway level crossing using a wireless two-way communication link for the purpose of preventing accidents and reducing damage.

Railway level crossing events (like warning messages) and video information about obstacles trapped on the crossing gate (vehicles, pedestrians, etc.) are transmitted to a train from the railway level crossing, and information related to the train (direction, velocity, estimated time of arrival, etc.) is sent to the railway level crossing.

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The video information transmitted from the railway level crossing is displayed on the monitoring equipment of the train cab so that the train driver can stop the train before approaching the railway level crossing if necessary.

The integrated server estimates the time of arrival using information from the train and provides this arrival time to roadside display units and to the road traffic signal control equipment of the intersection adjacent to the railway level crossing. This information keeps drivers and pedestrians apprised of the approaching train and encourages them to clear the railway level crossing quickly.

The main components and functions of the intelligent railway level crossing system are as follows:

− Obstacle Detection System using Image Processing
This system diagnoses the condition of the crossing gates, detects any trapped obstacles and tracks the movements of obstacles in real time.

− Wireless Transceiver
This device allows wireless two-way communication between the train and the railway level crossing. Warning messages and visual information are continuously transmitted from the railway level crossing to the train, and the location and velocity of the train are sent to the integrated server. The wireless transceiver should be designed while taking into account the maximum velocity of the train at the

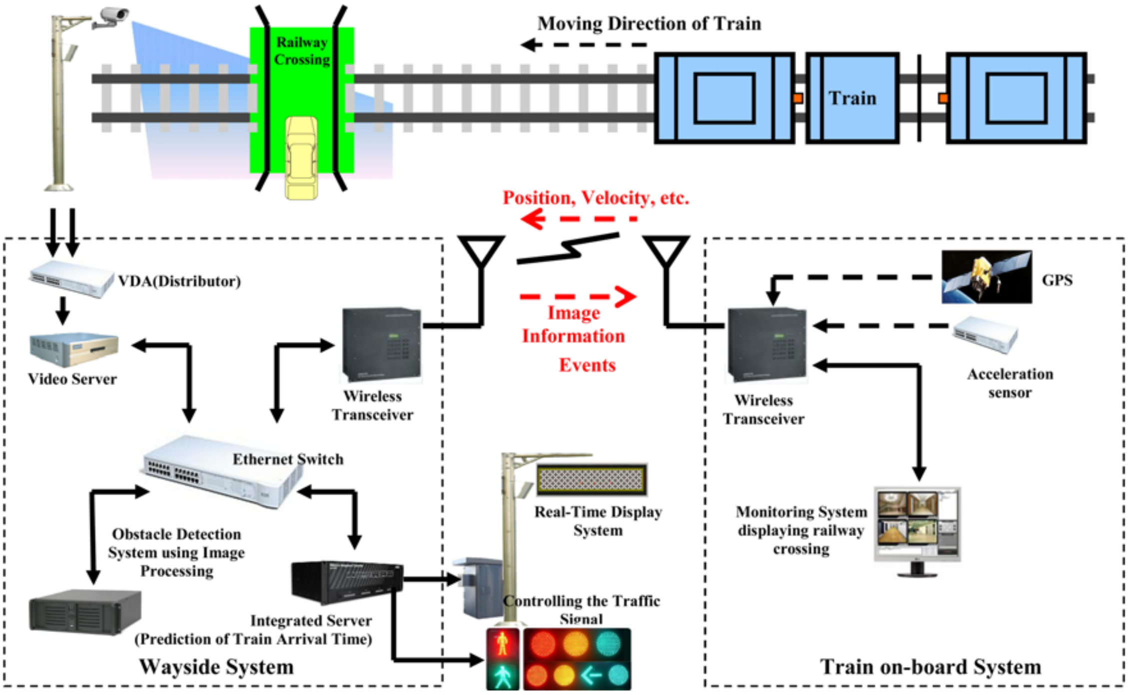

Figure 1. Architecture of the intelligent railway level crossing system.

railway level crossing (150 km/h), the railway level crossing warning time (30 sec), the wireless transmission distance (over 1,250 m) and a redundancy structure for high availability.

– Monitoring System on Train
This system is installed in the cab of the train. Warning messages and real-time video of any obstacles are provided to help the train driver notice obstacles and stop the train before the railway level crossing. If the train driver fails to react appropriately, this system is designed to immediately deploy the emergency brake.

– Real-Time Display System (Variable Message Signs, VMS)
An LED visual display device is installed between the railway level crossing and the adjacent road intersection to apprise vehicle drivers of accidents at the railway level crossing, and to provide information about approaching trains such as the direction of the moving train, and the estimated time of arrival. The VMS indicates the presence of vehicles on the railway level crossing and the approach of trains in real time to vehicle drivers for the purpose of reducing accidents on the railway level crossing.

– Road Traffic Signal Control Unit
In urban areas, long lines of vehicles on road intersections adjacent to railway level crossings can occupy railway level crossings and cause accidents. If a railway level crossing is near a road intersection, the vehicles leaving the railway level crossing for the road intersection shall be given priority for the traffic signal. In other words, when a train is approaching, it is necessary to stop vehicles attempting to enter the railway level crossing and to allow vehicles already on the railway level crossing to quickly exit the railway level crossing. In this way, accidents can be prevented.

– Integrated Server
The integrated server monitors the condition of each subsystem in the intelligent railway level crossing system and estimates the time of arrival for the approaching train; information regarding the time of arrival is then used by the real-time display system and the road traffic signal control unit (Ryu *et al.*, 2008).

Analysis of railway level crossing accidents shows that the main cause of such accidents is drivers who ignore the stop signal and proceed to cross despite the presence of warning barriers. A real-time display system and a road traffic signal control unit can reduce such accidents significantly, but many car drivers may still ignore the rules (Choi, 2008). To deter such breaches, drivers who do not observe the rules should be penalized. In this paper a license plate extraction technology to recognize and fine drivers who violate railway level crossing regulations is proposed and experimentally verified.

Studies on vehicle license plate recognition are categorized into three key areas of focus: license plate region segmentation, extraction of individual characters from the segmented license plate region, and recognition of extracted individual characters (Wei *et al.*, 2001; Yu and Kim, 2001; Yu and Kim, 2000; Kang, 2009).

License plate region segmentation is important because its accuracy determines the overall recognition rate; only when the license plate region is accurately segmented can each character in that region be extracted and properly recognized.

As various types of license plates become available, it is quite difficult to accurately segment license plate regions of different sizes and colors as a means of recognizing license plates.

The method proposed in this paper addresses this problem by segmenting the license plate region in an accurate and real-time manner through the use of digital signal analysis, regardless of damaged license plate frames, standard license plates of different sizes and colors, and irregular gray levels.

This paper consists of five sections. Section 2 describes an overview of existing studies on license plate region segmentation. In Section 3, the license plate region segmentation method is proposed. Section 4 provides experiments, results and analysis. Finally, Section 5 concludes the paper.

2. RELATED WORK

This study involves segmenting the license plate region in a vehicle image. Studies conducted so far on license plate region segmentation have proposed methods that use (1) the geometric features of a license plate (Yu *et al.*, 2000), (2) color information commonly allocated to the license plate region, (3) varying features of gray-level values that are generated by the characters and background of the license plate region (Yu and Kim, 2000; Jun and Cha, 2006; Jawahar *et al.*, 2000; Ohta *et al.*, 1980), and (4) neural network algorithms (Wei *et al.*, 2001; Kim *et al.*, 1999; Parisi *et al.*, 1998).

(1) For the method that uses the geometric features of license plates, the Hough transform-based license plate frame extraction method performs pretreatment for an inputted vehicle image and obtains an edge image for binarization through the use of edge operators like Sobel. In addition, this method performs a Hough transform for the binarized image before finding the desired horizontal and vertical lines and then extracts the license plate region using the features of the license plate. However, this method has the drawback of failing to perform real-time image processing due to the necessity of processing the entire image set. In particular, there is no feasible solution if the license plate frame is damaged. Another disadvantage is that this method results in low license plate region recognition rates if there is a big difference in size between the window and the license plate. This difficulty arises because the Sobel edge operator has windows with fixed sizes.

(2) The method for using color information commonly allocated to the license plate region is based on a color region segmentation technique (Chun and Yoon, 1993) that detects the license plate region with ease by locating a region with uniform background color in the license plate. However, if a vehicle license plate has various color features, and if the vehicle and its license plate have the same color, then there is a high likelihood that the license plate region will not be detected. In addition, this method requires longer processing time compared to processing black and white because it deals with the great deal of information inherent in color images. There are two types of color models that can deal with this problem: an RGB color model and an HSI color model. The problem with the RGB color model is that the RGB color value of pixels forming an image is keenly affected by variations in gray level due to changes in environmental conditions. The HSI color model, on the other hand, is able to overcome the problem posed by the RGB color model because it does not take into account the element I, which is affected by surrounding gray values, among individual HSI color elements forming pixel colors. However, the HSI color model has the disadvantage of requiring a great amount of processing time to calculate HSI color values.

(3) For the license plate region segmentation method that uses varying gray-level features generated by the characters and background of the license plate region, the main advantage lies in its ability to be less affected by loss of information due to exposure to light and to process images in a faster manner. However, this approach has the drawback of mistakenly recognizing a target region as the license plate region (Kim *et al.*, 2000) if the target region exists within a non-license plate region where a given gray-level variation threshold is met and its features are similar to those found in the license plate region.

(4) The neural network-based algorithm method has the advantages that it uses widely-known neural network learning algorithms instead of estimating complex filter parameters and that it is less sensitive to noise due to the nature of neural networks. However, this approach has some disadvantages. First, if the accuracy decreases in the region where the neural network and the license plate overlap, it is processed as a mistakenly extracted region. Another drawback is that if a vehicle image is blurred, the license plate region extraction rate decreases significantly (Kim *et al.*, 1999).

This paper proposes a method for extracting new types of car license plates based on digital signal analysis that solves the failure of license plate region segmentation that arises due to the color similarity between the car and license plate. The proposed method also overcomes some problems facing existing methods, such as license plate region segmentation that occurs when no license plate frame appears, having to consider standard license plates of different sizes and colors, and gray-level irregularities that occurring mainly at night. In addition, license plate region extraction conditions for different types of license plates are presented in this paper.

3. LICENSE PLATE REGION SEGMENTATION METHOD

3.1. Vehicle License Plate Region Features

As shown in Figure 2, the color features of license plates currently available for domestic use are categorized into intermediate type and old type for private cars with white letters on a green background, old type for commercial cars with blue letters on a yellow background, new type for private cars with black letters on a white background, and new type for commercial cars with black letters on a yellow background (MOCT, 2007). In addition, their size features are divided into the size of intermediate type and old type and the sizes of two new types.

The proposed method uses an image with 256 gray scale and finds the varying features of the gray-level values of a license plate region as well as the clustering features of gray-level values as a means of segmenting the license plate region and determining whether the license plate region is of an intermediate type or of new or old types. What follows involves some prior knowledge about the license plate region, which the proposed method uses for the purpose of this paper.

(1) The character-string region in the standard license plate has a standardized character width and gray-level variation.
(2) In the license plate region, gray-level variations along the horizontal axis are greater than those observed in other regions.
(3) Each character region in the license plate has uniform waveforms that are uninterruptedly distributed on a regular basis.
(4) In the case of old and intermediate type of license plates, the width-to-length ratio is 2:1.
(5) While old and intermediate types of license plates consist of a two-line character string, new types of license plates consist of a one-line character string.
(6) As illustrated in Figure 2, the height of the target region that needs to be detected from license plates by type is related to a four-digit registration number on the license plate. The target region height is 89 mm for an intermediate type, 65 mm for old types, 74 mm for a new short type, and 77 mm for new long types.

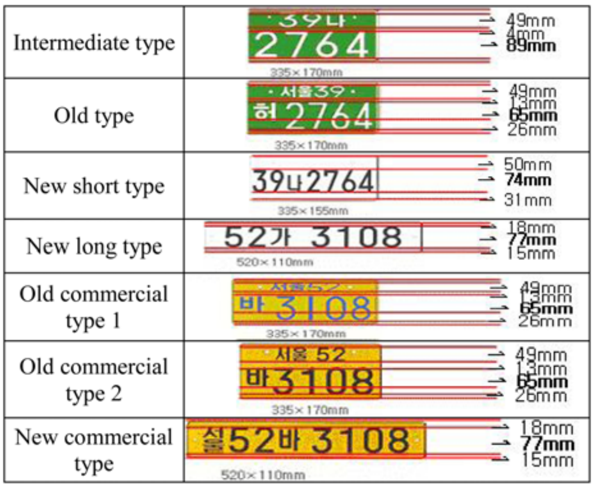

Figure 2. License plate types.

3.2. Vehicle Plate Region Segmentation Method

Figure 3 shows the overall process that the proposed method uses to perform segmentation on intermediate types of license plate regions. The camera is installed on the catenary protection beam, which is 4.5 m high and used to prevent the vehicle from coming into contact with power lines. The traffic road crossing the railway is usually a one-way lane, and one camera for each lane is set up. As shown in Figure 3-1, when a vehicle violation is found at a railway level crossing, the proposed scheme takes a picture of the vehicle and thereby obtains an image of the vehicle, as shown in Figure 3-2. To ensure the license plate region is segmented from the vehicle image, segmentation is uniformly performed at regular spatial intervals along the Y-axis in the image, as illustrated in Figure 3-3. For uniform segmentation, the regular spatial intervals are referred to as the Scan_Interval, and the Scan_Interval is obtained by Equation (1).

$$\text{Scan\_Interval} = \frac{(\text{HeightMinPlatNum} \times \text{HeightRegNum})}{\text{HeightStdPlatNum}} \quad (1)$$

Here, HeightMinPlatNum refers to the height of the minimum license plate on which characters are recognizable from the 640-by-480-pixel image; HeightRegNum refers to the height of the registration number region that needs to be detected from a real license plate to extract a license plate candidate region, as shown in Figure 2; and HeightStdPlatNum refers to the height of a standard license plate. The value of Scan_Interval for the intermediate type is calculated as 39 from Equation (1) in the following way:

$$\text{Scan\_Interval}(=39) = \frac{(\text{HeightMinPlatNum}(=75) \times \text{HeightRegNum}(=89))}{\text{HeightStdPlatNum}(=170)}$$

As described in Figure 2, target registration number regions of different license plate types have different heights. The process of obtaining HeightMinPlat Num (=75), the height of a recognizable minimum license plate, is based on prior knowledge that a character-recognizable minimum license plate has a width of 150 pixels and that, if it is of an intermediate or old types, its width-to-length ratio is approximately 2:1.

A Scan_Interval value means a string of numbers on the license plate are placed at least once on the horizontal axis if the Y-axis in the image is divided by an interval of 39 pixels and a horizontal line is drawn along the X-axis. The horizontal line is referred to as the ScanLine. The number of ScanLines for a 640 × 480-pixel image is 12 (round off of 480/39). In this case, the ScanLine is placed at least once

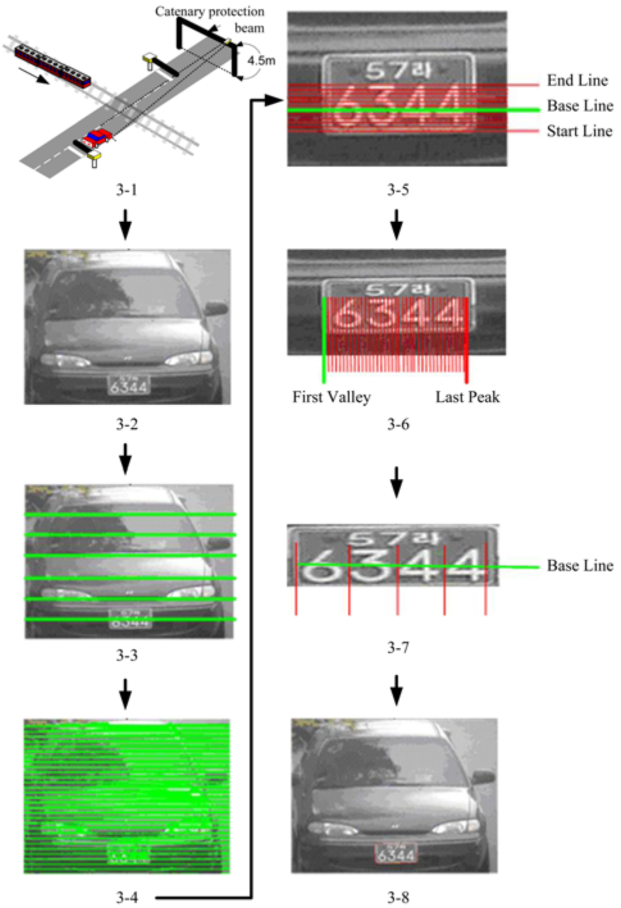

Figure 3. Vehicle license plate region segmentation process.

on the registration number region of the license plate, but twelve scan lines are not sufficient in a real situation. We employed 2.5 times 12 (30 ScanLines), as shown in Figure 3-4. The factor of 2.5 was determined by experience. The graph, as shown in Figure 3-4, consists of the displacement of the X-coordinates along the X-axis, and the 256 gray scale values normalized for the target coordinate (x, Scan_Interval) along the Y-axis. Along each ScanLine, digital signal analysis is performed.

Figure 4 shows peaks and valleys in the ScanLine graph. The number of registration characters over which the Scan-Line of each license plate extends are four for intermediate types, five for old types, and seven for new types. As shown in the figure, there are peaks within the range of inter-character spaces: 6 to 9 peaks for an intermediate type, 8 to 11 for old types, and 11 to 14 for new types. Using these features, different types of license plates (i.e., intermediate, old, and new) are identified.

The license plate candidate region segmentation process is performed in a two stages. First, the graph showing variations in gray-level values for each line is inputted to determine the presence of characters in the registration number region. Then, inter-character intervals are obtained in the registration number region, which is judged as the character region, prior to verifying the license plate candidate region.

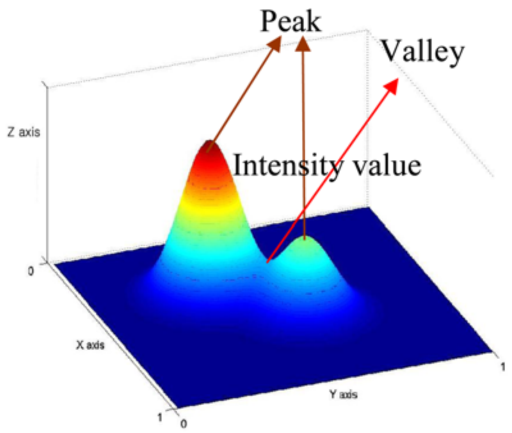

Figure 4. Peaks and valleys.

In the first stage, the difference in the gray-level value between the background region and the character region as well as the inter-character width in the registration number region are identified. Figure 3-4 shows a graph consisting of normalized 256-gray scale intensity levels. The Y-axis value at the Valley position refers to the GPeak, the gray-level value of the background region, and the Y-axis value at the Peak position refers to the GValley, the gray-level value of the character region. Thus, the value obtained by subtracting GValley from Gpeak is the difference in the gray-level between the character region and the background region. If the difference in the gray-level is greater than the threshold of the gray-level difference between the background and the character regions, the gray-level difference condition for the character region is met. In addition, the difference between Peak and Valley is half the length of a character width, as shown in Figure 3-4. Therefore, when multiplied by 2, it becomes a single character width. If the character width is greater than its minimum threshold and smaller than its maximum threshold, the character width condition is met. When both of the above conditions are met, the proposed method verifies that the character region is present.

In the second stage, scanning is performed to locate the region in the license plate where characters are clustered at regular intervals before determining the license plate candidate region. The characters aligned at regular intervals are judged as the license plate candidate region. Characters with small inter-character intervals are first integrated into the license plate candidate region. Then, character integration is performed if their size is smaller than the maximum size threshold specified for the license plate. Otherwise, no integration is performed. For the characters to be judged as the license plate candidate region, the number of inter-character spaces in the license plate should be 8 to 11 for an old type, 6 to 9 for an intermediate type, and 11 to14 for new short and long types.

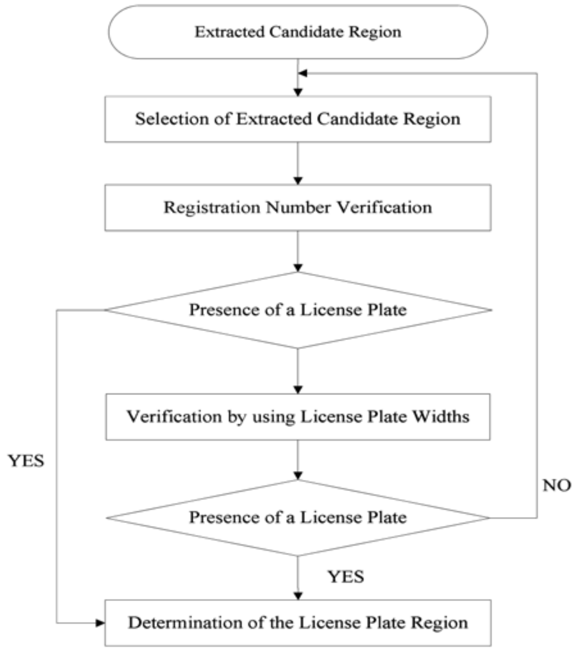

Figure 5. License plate area verification method.

In the extracted license plate candidate region, waveforms (i.e., a radiator grill or a signboard with a trade name) similar to the license plate might be included. Thus, verifications should be performed on the extracted license plate candidate region to confirm that they are the license plate region. To prevent license plate region extraction from failing due to verification failure, two rounds of verifications are performed on the extracted license plate candidate region, as shown in Figure 5. The license plate candidate region targeted for verification is selected from the top down among the peak-clustered candidate regions because the license plate in the vehicle image is highly likely to be positioned at the bottom of the image.

Verification is performed repeatedly in such a way as to allow a pixel to move horizontally in search of the license plate candidate region. Scanning is performed downwards to find the bottommost end of a number string, and, when the bottommost end of a number string is detected, scanning is conducted upwards to find the uppermost end of the number string. As described in Figure 3-5, if the distance between the START LINE and the END LINE is in accordance with the number height, the candidate region is judged to be the license plate region.

More than 85 percent of license plate candidate regions are judged as the license plate region. However, there exist cases in which attempts to verify the registration number height fail due to images with a decolored number region or because of poor visibility. As a means of compensating for such weak points, the area-based license plate verification method is used, as shown in Figure 3-6.

As shown in Figure 3-6, the verification process is performed in such a way as to calculate the number of peaks while scanning across the candidate region and to find the leftmost and rightmost ends of the license plate. If the distance between the reference valley and the last peak corresponds to the license plate width, the candidate region is judged as the license plate region. Then, the area of each type of license plate is sized to fit different sizes of license plates currently in use. This license plate area verification method makes new European types and standard types of

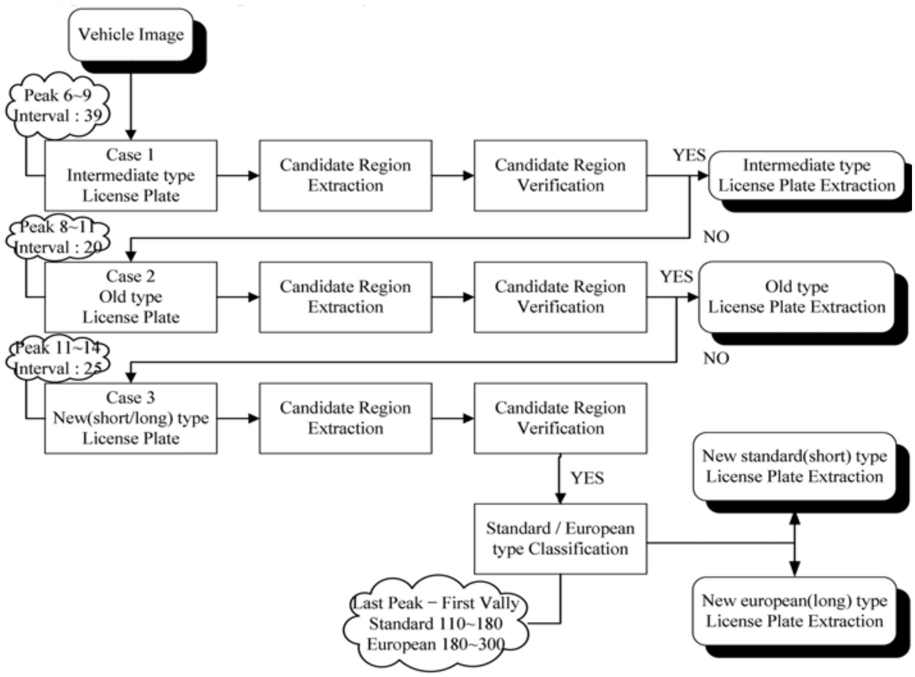

Figure 6. License plate region extraction method.

license plates recognizable.

Figure 6 provides a summary of the license plate region segmentation method featuring a three-stage process.

In the first stage, the Y-axis in the image containing intermediate, old, and new types of license plates is evenly segmented. In the second stage, based on each uniformly segmented position along the Y-axis, a ScanLine is drawn across the X-axis. In the final stage, a gray-level histogram is drawn for each ScanLine, as illustrated in Figure 3-4.

In the graph, the X-axis refers to X-coordinates and the Y-axis to the gray-level pixel value for the coordinate (x, Scan_Interval).

Pretreatment is conducted to make it easier to analyze the graph showing gray-level values for the ScanLine, and the number of peaks in the gray-level histogram for the Scan Line is calculated. According to the number of calculated peaks, candidate plates are classified as intermediate type of license plates (Case 1), old types of license plates (Case 2) or new types of license plates (Case 3).

In the second stage, candidate region segmentation for each case is conducted along the ScanLine by means of the number of peaks and the difference between peak gray-level values. Figure 3 shows an example of Case 1, an intermediate type of license plate. Along the ScanLine, as shown in Figure 3-4, license plate candidate region segmentation is performed based on the number of peaks and the difference between peak gray-level values.

In the final stage, license plate region verification is performed through the use of the registration number height verification method (refer to Figure 3-5) and the verification method that uses license plate widths (refer to Figure 3-6). As shown in Figure 3-7, final verification is performed through an inter-character comparison. Furthermore, for new types of license plates as in Case 3, the process of comparing area lengths is added to this stage to categorize license plates into European and standard types.

Through these three stages, the license plate region segmentation is completed, as illustrated in Figure 3-8.

4. EXPERIMENTS AND RESULTS

This section describes experiments to evaluate the proposed method and to verify the performance of the proposed method based on the results of the experiments.

The vehicle license plate recognition system consists of a vehicle detector, an image capture camera, and a license plate recognition device. When the vehicle detector detects a vehicle, it instantly sends a detection signal to the image capture camera so that the camera can take a picture of the vehicle. A small image taken of the vehicle offers an advantage in terms of broad visibility for the image capture camera. However, if the image of a vehicle license plate is small, it is difficult to recognize the characters and small numbers in the license plate. On the other hand, a large image of a vehicle license plate allows for easy recognition of the characters and small numbers in the license plate, but it is not sufficient to provide evidence to help keep vehicles under control. Therefore, the size of a vehicle image should be the minimum that is still within the recognizable range. Using a PGR color CCD and a Dragonfly®2 camera, images were taken from cars and vans at a resolution of 640 × 480. The camera was installed at 4.5 m from the ground. The angle of tilt was from 3.4 to 31 degrees.

Figure 7. License plate regions extracted in the experiment.

The hardware in the license plate extraction device consisted of a 2.6-GHz Pentium 4 PC with 512 MB of memory and Visual C++ 6.0, running under Windows XP. In this experiment, the processing time for extracting the license plate region was measured to be approximately 0.2 sec.

Figure 7 shows some of the images in the experimental data for different types of license plates. The initial image is an input image, which is uniformly segmented at regular intervals along the Y-axis. The middle image shows the gray-level values that are obtained by moving the line where a uniform segmentation point starts along the Y-axis. The number region and the background region are identified by analyzing each ScanLine chosen to obtain the variations in the gray-level values of the number region.

By comparing the gray-level differences and distances against the number region within the registration number, the license plate candidate region is segmented. In the segmented candidate region coordinates, the license plate region

Table 1. Experimental results.

Type \ Item	Experimental data	Num. of success	Extraction rate
Intermediate type	1,000	997	99.7%
Old type	1,000	995	99.5%
New short type	500	498	99.6%
New long type	500	495	99%
Old commercial type	1,000	997	99.7%
New commercial European type	500	495	99%

is segmented to verify the length of registration numbers and uses the license plate area segmentation method, which uses the license plate widths. For European types of license plates, long and short license plate regions are identified by means of the license plate width. Figure 7 shows the license plate region extracted by this process.

Experiments were conducted on images of various types of vehicles taken in real-life driving situations: 1,000 for intermediate types, 1,000 for old types, 500 for new short (standard) types, and 500 for new long (European) types. According to the experimental results, the majority of vehicle license plates showed a high extraction rate of 99.5%, except in the case of either severely damaged license plates or license plate regions shaded by passing cars.

5. CONCLUSIONS

A vehicle license plate extraction method for use at railway level crossings was proposed. The main cause of accidents between private passenger vehicles and trains at railway level crossings is the intrusion of passenger vehicles into railway level crossings after the crossing gates are deploy-ed. It is expected that if drivers are charged a penalty for violating railway level crossing regulations, then they may be less apt to violate railway level crossing regulations. To recognize drivers who violate crossing regulations, vehicle plate license recognition can be used.

Because the vehicle license plate system has become more diverse due to the introduction of new types of license plates, this paper proposed a method for segmenting all number plate regions of different types of license plates in a real-time manner. Existing license plate extraction methods require many steps for image processing and thereby cause loss of original information from images and take a long time. In addition, because there is no way to find out where the license plate is positioned, a binary threshold value can be determined that reflects no license plate region. There-fore, existing license plate extraction methods have failed to properly identify license plate regions. Furthermore, prior knowledge regarding the horizontal-to-vertical license plate ratio of 2 to 1 is not yet applicable to new license plates, and little research has been conducted with new license plates. Thus, it has not previously been possible to perform segmentation on new license plates.

The method proposed in this paper has three advantages. First, the proposed method allows a license plate region to be extracted in a real-time manner. Instead of dealing with all lines on the Y-axis in the image, the proposed method scans gray-level values for different lines along the Y-axis at regular intervals in such a way as to take into account, at least once, the registration numbers of different types of license plates. Second, the proposed method ensures reliability because it extracts license plate regions using original image data. Third, the proposed method makes new and old license plate regions recognizable by applying different scan intervals to different types of license plates.

Future research that focuses on building embedded intelli-gence into railroad crossings should involve monitoring vehicles in violation of the procedure for crossing railways and detecting a vehicle entrapped at a railway level cross-ing.

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