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Detection of Lane and Driving Vehicle License Plate Extraction for Specific Purpose in C-ITS Environments

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Abstract

Recently, an IoT (Internet of Things) environment is rapidly developing that provides an artificial intelligence service through a network in which intelligent objects are connected to each other through mutual communication between human beings and objects, and between objects and objects, by combining situational awareness based knowledge. Together with development of this kind of IoT, research to enhance the convenience and safety of drivers as well as traffic efficiency is being actively promoted by enabling efficient on-road driving for a moving vehicle at high speed. This is being achieved through sharing of such bi-directional information as car lane and license plate recognition, and detection of car accidents and road construction ahead. The information includes existing roadside infrastructure, and also other moving vehicles on the road in traffic infrastructure in a Cooperative Intelligent Transport System (C-ITS) environment. This paper seeks to determine whether vehicles can be allowed to drive in a bus-only lane in linkage with the traffic infrastructure, after recognizing a bus-only lane when driving on an expressway in the C-ITS environment, and a study was carried out on the follow-up measures that are required. More specifically, after grasping the location of a bus-only road through recognition of the bus-only lane, we try to recognize license plates of the accompanying vehicles in front and on the side, and present our findings on how to make the future traffic infrastructure recognize them, as well as the related test results.

Keywords: M2M, IoT, V2I, V2V, C-ITS, Bus-only lane, License plate recognition

I. INTRODUCTION

The diffusion of Internet networks along with the rapid supply of computers is binding innumerable computers into a network, and contributing to the advent of an era in which data can be sent and received remotely between computers through networks. At the same time, the explosive increase in the number of smart phone users and rapid expansion in the number of Internet networks has helped expand the range of the Internet, which was previously used mainly by computers, to the sphere of smart phones, making the mobile Internet a topic of everyday conversation by the 2000s. The prospect is that after undergoing a period of mobile Internet, a new era of M2M (Machine-to-Machine) communication, which denotes all technologies supporting wired and wireless communication between devices [1][2], and of the Internet of Things (IoT), which connects all things and binds them into a gigantic framework like the Internet, will be provided as a service from the 2010s [3][4][5]. Together with the development of the IoT, a Cooperative Intelligent Transport System (C-ITS) has also emerged. With the C-ITS, a network is forming as vehicles are combined with wireless communication technologies, enabling closer connection between drivers, vehicles, and roads, which network will potentially enhance stability, convenience, and traffic efficiency [6][7]. Based on the same Wireless Access in Vehicular Environment (WAVE) communication technology standard, the United States and Europe are aiming at the realization of C-ITS service. As an IEEE communication standard, WAVE communication technology denotes a concept supporting V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communication [8]. The WAVE communication standard has been developed in IEEE 802.11p and IEEE 1609 series. V2V networking provides safety service through cooperative driving, by using inter-vehicle communication to deliver real-time information. Such services as telematics service, automatic fare collection service, traffic information collection, and provisioning service are provided using V2I networking [9][10]. This paper proposes a system to determine whether a certain vehicle is in violation of bus-only lane regulation, using V2I networking technology in the C-ITS road environment, a cooperative intelligent transport system. The existing method of enforcement on violation of the bus-only lane rule on an expressway is characterized by the installation of fixed enforcement cameras at regular intervals along the expressway. This condition makes it very easy for the drivers of vehicles who use this expressway to often avoid enforcement, and the frequent and unlawful changes of car-lane by violating drivers to avoid the enforcement cameras pose a serious threat to the users of public transportation, and to other drivers and their passengers. The system proposed in this paper to address this situation is the installation of a black box in buses traveling on the expressway. These black boxes would facilitate the required enforcement by taking pictures of the violating vehicles along the entire sections of the expressway, and reporting the incidents of violation to the authorities concerned. However, this system is not free from the burden of additional work and human endeavor, as the recorded images need to be checked, before an attempt is made at enforcement. In this paper, we propose a system that can be used to identify the location of a bus-only road using a low-price video recording device installed in a car, like a black box or a mobile phone camera, instead of a high-price shooting equipment, in order to determine whether a vehicle can be allowed to drive on a bus-only lane by recognizing the license plates of the vehicles

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in the front as well as vehicles on the side. In the case that a vehicle running on the bus-only lane is not of the allowed type, the recorded images and recognized license plates taken through V2I networking are sent to the Traffic Center for appropriate action.

II. RELATED WORK

The IoT denotes an environment in which the definition of Internet users expands from human beings to myriad things, along with the development of diverse telecommunication technologies [11]. As the IoT is ubiquitously applied everywhere, development of the IoT is being carried out in much wider areas than commonly realized, and are already being used in various fields. An IoT-based system for providing emergency medical services [12], and an IoT-based agricultural production system made available through a correlation analysis of statistical information on crops and information on the agricultural environment [13] are prime examples of this kind. Besides, supply of the IoT that uses many other things, such as auto vehicle, building, parking lot, and home appliances, is also being expanded [4][5]. C-ITS refers to a transport system that provides transportation information and related services by grafting electronic control and communication technologies to the means and facilities of transportation, and enhances efficiency and stability by controlling the flow of transportation. As one of the core C-ITS issues, the development of V2V and V2I communication technologies is being actively promoted in major advanced countries, which enables an automobile to function not just as a means of personal transportation, but also to play its role as a form of social infrastructure. V2V can prevent a sudden traffic accident by sharing information on the location and speed of nearby auto vehicles. It brakes a vehicle if the distance from the vehicle in front is becoming too close [14], and it sounds an alarm if an unknown car suddenly 'cuts in' in front of the vehicle running next to the subject vehicle, or disappears from the vision of the driver [15]. Also, if a collision is expected, it helps the subject vehicle navigate by itself in order to avoid an accident [16]. As a result of research on V2V communication technology over the past several years, the United States government concluded that common traffic accidents other than those caused by drunk driving or by mechanical failure can be reduced by approximately 80%. This technology is currently being promoted as a major target for commercialization by 2017. Starting with the development of multi-hop style communication technology for vehicles, which is compatible with IEEE 802.11p standard [17][18], technologies are also being developed that include the means to predict collision with a vehicle in front through real-time wireless communication with other vehicles, and delivery of the information to the vehicle following behind, in order to prevent chain collisions; and a next generation intelligent transport system that automatically controls the road signal system and traffic flow of a city using a large-capacity computer [19][20]. Research for an image processing technology that is capable of handling the road situation, ambient environment, vehicle surveillance, and prevention of traffic accidents through image recognition using SIFT and neural networks [21] within a moving vehicle is also being carried out.

III. DETECTION OF A BUS-ONLY LANE

III.I Detection of Car Lane

In Korea, the color of the surface of a bus-only lane on an expressway is blue. In consideration of this fact, it is possible to recognize a bus-only lane using RGB colors. Fig. 1 shows the flow chart of bus-only lane recognition implemented in this research.

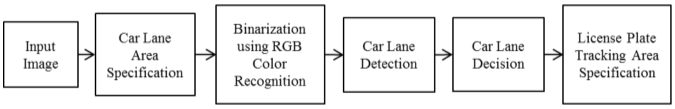

Fig. 1. Blockdiagram of Bus-only Lane Recognition

III.I.I Specification of Car-lane Area

The black box within a vehicle designated for the car-lane area is located in most cases at the center of the vehicle. For this reason, car-lane images of photos taken in a moving car appear at a particular location. Fig. 2 shows therefore that when an image is divided into 6 parts of equal size, it is possible to see that car-lanes are located at both ends of an image. In most cases, the left car-lane is shown in area ④, whereas the right car-lane is shown in area ⑥. In consideration of this fact, instead of carrying out a car-lane recognition algorithm using the entire area of an image inputted to find a bus-only lane, car-lanes of a square shape of regular height and width are designated on the right and the left of an image at equal distance from the center, and it is possible to identify the location of a bus-only road by judging whether a car-lane is discovered in this area.

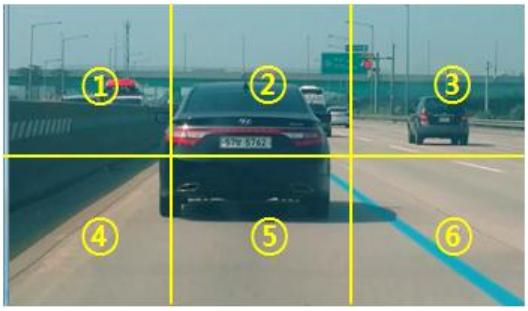

Fig. 2. Input images divided into six elements

III.I.II Binarization Using Color Recognition

Binarization of an image denotes the changing of color values that are widely distributed into RGB values of 0 or 255. This involves a conversion operation that first changes RGB color images to black and white images, and using a particular threshold value as standard, converts the excess value to 255, and the value below it to 0. However in this research, RGB color images were not converted to black and white images, as commonly practiced in a binarization method; instead an image is binarized using each of the R, G, and B color values. RGB is a color expression method that is widely used to signify a Red, Green, and Blue combination. Binarization is applied as follows. In the RGB color space, each of the three components expresses the intensity value of light as a number in between 0 and 255. Using this scheme, each R, G, B value that is used to designate a car-lane area is represented as a number between 0 and 255. The color of an expressway consists of white, yellow, and blue car-lanes over a dark-tone driving road. Table 1 shows the range of RGB color values for car roads and car lanes that constitute the expressway.

Table 1. RGB Values of Lanes and Lane-Dividing Lines

Classification	R Value	G Value	B Value
Blue Lane	0-30	140-180	180-245
White Lane	140-180	180-220	180-220
Yellow Lane	150-200	110-200	80-140
Traffic Lane	70-200	100-170	100-160

Using the result values of RGB color recognition, it is possible to know that the blue car lane that corresponds to a bus-only lane has low R value, in comparison to the other car lanes and car roads. With this realization, it is then possible to binarize images using a method that changes the value of the corresponding pixel to 255 when the R value of each pixel is 30 or below, and the color values of G and B satisfy the ranges of 140～180 and 180～245, respectively; and changes other pixel values to 0, when the corresponding pixel values are above 30, and the color values of G and B do not satisfy the specified respective ranges. When the binarization operation is carried out this way, only the blue bus-only car-lane area is extracted in white color.

III.I.III Car-lane Detection Using the Hough Transform

For the next stage of car-lane detection using the Hough transform, it is necessary to find out whether the white portion obtained from binarized images through RGB color recognition was binarized by the blue bus-only lane, or by a blue object other than a car lane. For this purpose, taking into account that car-lanes on the expressway are in the form of straight lines of regular width, a straight line is detected from binarized images using a Hough transform algorithm.

$$y = ax + b \quad (1)$$

$$b = x_i a + y_i \quad (2)$$

$$p = x\cos\theta + y\sin\theta \quad (3)$$

The Hough transform is a transform rule that extracts the most overlapped portion among straight lines that are composed of dots in an image. Equation (1) shows that all straight lines are represented by grades and y-intercepts. To put it another way, this means that, in the space of a, b parameters, they can be represented as shown in equation (2). However, since the grade in the above equation can approach infinity, processing is very difficult. To overcome this, a regular representation method as shown in equation (3) was used. In equation (3), θ has the range of [0, π], and ρ can have either a positive number or a negative number. In the coordinate system that is determined by ρ and θ, a straight line is represented by a dot. By this kind of equation, (ρ, θ) values that are detected from each pixel are added to an Accumulation Table, and of the accumulated values, if (ρ, θ) that has the maximum value is inversely transformed, a straight line can be extracted. When detecting a straight line from images of a binarized car-lane area using RGB color recognition, the thicker the thickness of a car-lane of the binarized image, the greater the number of straight lines that are detected. Accordingly, before detecting straight lines through the Hough transform, straight lines are detected after a pre-processing work using a contour extraction and a dilation operation. Fig. 3 shows a flow chart for the detection of straight lines.

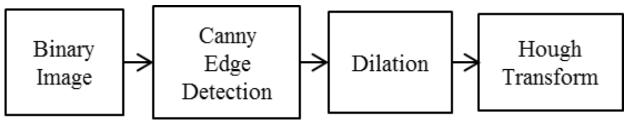

Fig. 3. Blockdiagram of a straight line detection

For straight line detection, the contour line of a car lane is extracted using the canny edge algorithm. As the contour line so extracted cannot be distinguished by the naked eye, gaps of pixels that constitute a straight line can be disconnected. As the desired detection result of a straight line is not obtained, pixel values in between straight lines should be connected using a dilation operation. If a dilation operation and a canny edge extraction technique are used in this way, pixel values in between the disconnected straight lines of a contour line can be reconnected. Straight lines are detected after a process of pre-processing using the Hough transform algorithm.

III.I.IV Car-lane Discrimination

Next, there is a need to discriminate whether the straight line that is detected through the Hough transform algorithm is a car-lane. As a car-lane that is longer than a certain length is located in a specified car-lane area, it should be discriminated as to whether the straight line detected by this kind of condition is really a car-lane.

$$l = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (4)$$

$$radian = tan^{-1}\frac{(y_2 - y_1)}{(x_2 - x_1)} \quad (5)$$

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Straight lines that were found through the Hough transform consist of a starting dot (x_1,y_1) and an ending dot (x_2,y_2). After obtaining the length of a straight line by applying these dots to equation (4) for the purpose, the straight lines that are 70% of the diagonal line of a specified car-lane area in length or shorter are eliminated through filtering. If the length condition of a straight line is satisfied by this criterion, the next move is to obtain the grade of the straight line. With this, it is possible to identify that a straight line drawn on an expressway is inclined at a set degree when seen from the position of the driver, as shown in Fig. 4.

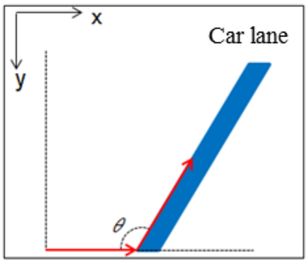
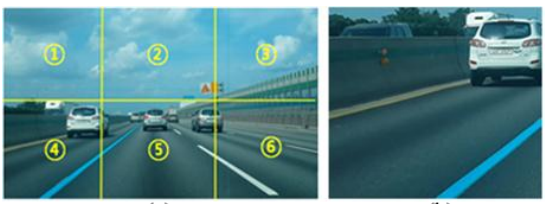


Fig. 4. Shape of the left lane-dividing line at the driver's eyesight

Straight lines that were found through the Hough transform consist of a starting dot (x_1,y_1) and an ending dot (x_2,y_2). After obtaining the length of a straight line by applying these dots to equation (4) for the purpose, the straight lines that are 70% of the diagonal line of a specified car-lane area in length or shorter are eliminated through filtering. If the length condition of a straight line is satisfied by this criterion, the next move is to obtain the grade of the straight line. With this, it is possible to identify that a straight line drawn on an expressway is inclined at a set degree when seen from the position of the driver, as shown in Fig. 4.

III.II Specification of the License Plate Tracking Area

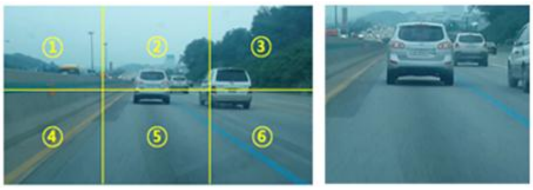
The specification of car-lane areas for the detection of a bus-only lane is made on two locations, one on the right and the other on the left of the position of a driver who takes the required pictures. This is to enable the driver of a car moving on the right side of the bus-only lane or the second lane to recognize the license plate of a vehicle in the front moving on the bus-only lane. In Fig. 5 (a), it is possible to see that the images photographed in a car running on the 2nd lane are divided into 6 parts of equal size.



(a) (b)

Fig. 5. Tracking Area of License Plate When Traveling on the Second Lane, (a) 2nd Lane Traveling Image, (b) License Plate Tracking Location ④

If the car road on which the car is running is the 2nd lane that is on the right side of the bus-only lane, as shown in Fig. 5 (a), the bus-only lane would be located on the left side of an image when seen from the position of the driver. In a case like this, area ④ that is on the lower left side of Image (a) would be the bus-only lane as can be seen in Fig. 5 (b), and recognition of a license plate to determine whether a violation of the bus-only lane rule has occurred would be required only in this area. Likewise, if the car road on which the car is running is the 1st lane, as shown in Fig. 6 (a), the bus-only lane would be located on the right side of an image when seen from the position of the driver.



(a) (b)

Fig. 6. Tracking Area of License Plate at the Time of 1st Lane Traveling, (a) 1st Lane Traveling Image, (b) License Plate Tracking Location

In a case like this, recognition of the license plate would be necessary only in the front area in between area ② and ⑤ to determine whether a violation of the bus-only lane rule has occurred. When this kind of method is used, not only can the car running on a bus-only road determine whether driving can be allowed by recognizing the license plate of a vehicle in the front, vehicles running on the 2nd lane or the car road on the right side of the bus-only lane can recognize a vehicle that is in violation of the bus-only lane rule.

IV. RECOGNITION OF VEHICLE NUMBER

The images used for license plate recognition are those taken while driving a car on an expressway of the target vehicle moving in front. As such, the images are often blurred by shaking, and are difficult to achieve in focus. Hence, the images are inferior in quality, in comparison to the pixels of the camera used. Also, those images are sensitive to sunlight, and in recognizing a license plate, these characteristics should be taken into consideration in the process of image processing. Accordingly, for the purpose, the license plate area should be extracted using a labeling method.

IV.I Binarization of Images

Images in a license plate tracking area should be converted to gray scale following the process described in the flow chart of the vehicle number recognition algorithm, before binarization can be implemented. The license plate area is extracted through labeling after binarization of images is completed, in accordance with the flow chart described in Fig. 7. In the case that the license plate area is not properly extracted, the process returns to the binarization stage, and repeats the required process. In the first stage of binarization, the Otsu's algorithm is used, but if this is not successful, an adaptive thresholding algorithm should be used instead.

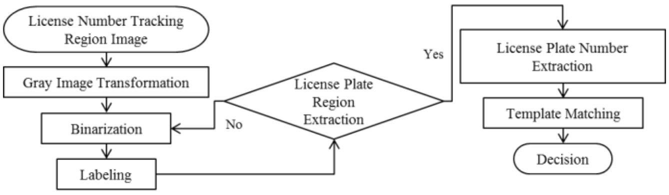


Fig. 7. Flowchart of Vehicle's License Plate Recognition Algorithm

If failure occurs again in the second stage, binarization should be carried out using a binarization algorithm. The reason why three methods are used like this is that the light and darkness contrast of inputted images varies, depending on the environment in which a vehicle is running on an expressway, and shade can affect the recognition of license plates. Hence, the recognition rate of vehicle numbers should be enhanced through proper binarization that suits a specific situation.

IV.I.I The Otsu's Thresholding Algorithm

Otsu's thresholding algorithm is a method of binarizing images using a midpoint as the dividing line when the histogram shape of inputted gray images constitutes a bimodal shape, as shown in Fig. 8.

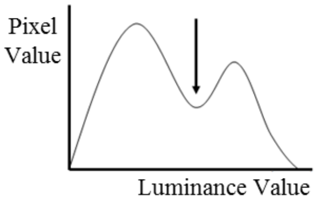


Fig. 8. Histogram of Input Image

This algorithm includes a statistical method that facilitates finding the best threshold value, as it provides two types of variance, within-class variance, and between-class variance. The first method, or the within-class variance, can be obtained using equation (6). Here, ω signifies the probability that a statistically t pixel value will appear. σ_i^2 denotes information on how widely the pixels are dispersed. The smaller the value, the more the pixels will be gathered together, making it easy to distinguish. In other words, the smaller this value, the better will be its performance as a threshold value.

$$\sigma_{\omega}^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t) \tag{6}$$

$$\sigma_b^2(t) = \sigma^2 - \sigma_{\omega}^2(t) = \omega_1(t)\omega_2(t)\left[\mu_1(t) - \mu_2(t)\right]^2 \tag{7}$$

$$\eta(T) = \left[\frac{\sigma_b^2(t)}{\sigma_{\omega}^2(t)}\right]_{max} \tag{8}$$

The second method, or the between-class variance, can be obtained using equation (7). If the weighted value of each class is multiplied by the value minus the variance value of each class, and the resulting value is multiplied by the squared value of the value minus the mean value of each class, the between-class variance can be obtained. As this method represents an inversion of within-class variance, the value that gives the largest of this value can be used as a threshold value. Equation (8) is derived using equation (6) and equation (7). When between-class variance is divided by within-class variance, the larger the resulting value, the better the threshold value that is obtained. With the resulting threshold value, binarization of images can be implemented.

IV.I.II Adaptive Thresholding Algorithm

The adaptive thresholding algorithm is a method that is used to obtain the threshold value for part of the histogram using part of the images, instead of using the histogram for the entire images. Entire images are divided into $m\times m$ small images, and histograms are examined for each of them, in order to determine the threshold value $T_{ij}(1\leqq i,\ j\leqq m)$ for each. Fig. 9 represents an adaptive thresholding algorithm.

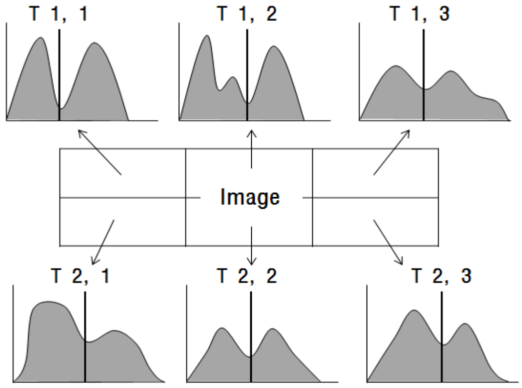


Fig. 9. Adaptive Binarization Method

In the case of an image whose brightness value changes gradually since there exists strong illumination or reflection, this method can be used with effect.

IV.I.III Binarization Algorithm

The most basic of all binarization algorithms, this algorithm is used to change a value that exceeds a particular threshold value specified as the base value to 255, and to change a value that is smaller than the base value to 0. The threshold value used here as the base was automatically set in a previous algorithm to fit the image, but there were still cases for which the license plate area could not be found. For such cases, this method directly determines the threshold value as a last resort. The threshold value is in between 200 and 40. Binarization starts with threshold value 200, to be reduced by 10 until it reaches 40, or the process is repeated, until the license plate area is extracted.

IV.II License Plate Area Extraction Using Labeling

License plates in Korea use black characters and numbers against a white background. When binarizing this kind of license plate, the background is binarized to pixel value 255 in white color. Therefore, groups in the 255 pixel value area are found through labeling, and the license plate areas are finally found through filtering. Labeling, which groups adjacent and similar pixels by attaching the same number, is carried out in the following sequence:

Sequence **A**: Labeling Process
Step 1: Examines up to the pixel value to be detected from images (255) in sequence
Step 2: Checks whether a label is attached to the pixels, and when not, stores current coordinates in stack
Step 3: Explores in all directions using the current coordinate as the base, and stores all pixels that are 255 and on which no label is attached in stack
Step 4: Receives the top-most coordinate in stack before erasing, attaches labels to received coordinates, and repeats Step 3
Step 5: Carries out this process until all stacks are empty

Pixel values of binarized input images are connected to one another by 0 or 255. For this reason, when the labeling operation described above is carried out, all areas whose pixel values are 255 will be found. But since areas other than the license plate areas are also detected in this process, a filtering operation that is intended to find labels for license plate areas to be recognized should be carried out separately. As license plates have a certain ratio of 520 × 110, labels for license plate areas should be found using the following conditions:

Sequence **B**: Label Filtering Process of License Plate Areas
Step 1: Remove labels whose horizontal length is 60% or longer than that of the inputted images (license plate tracking area).
Step 2: Remove labels whose vertical length is 30% or longer than that of the inputted images (license plate tracking area).
Step 3: Remove labels whose vertical length is 6 times longer than the horizontal length or more.
Step 4: Remove labels whose vertical length is 4 times shorter than the horizontal length or less.

Steps 1 and 2 represent a filtering process using the ratio of horizontal length and vertical lengths in between a found label (license plate area) and the inputted images (license plate tracking area). Steps 3 and 4 represent a filtering process of labels using the characteristics that the horizontal length of a license plate is approximately 5 times longer than the vertical length. Labels of license plate area are found from among many labels through a filtering operation, but verification is needed to make sure that they are actually license plates. As a vehicle number consists of 7 numbers and characters, in the process of labeling of license plate areas, 7 or more labels are found. Hence, a labeling operation is carried out once again in the label areas that turn out to be license plate areas. However, even in these areas, labels other than license plate labels are discovered during a labeling operation. Therefore, an extraction process of license plate labels should be carried out using the ratio between the horizontal and vertical lengths of license plate characters, and those of the license plate themselves, as per steps 1 and 2 presented below.

Sequence **C**: Filtering Process of License Plate Labels
Step 1: Remove license plate labels whose horizontal length is 20% of the horizontal length of a license plate area or longer.
Step 2: Remove license plate labels whose vertical length is 70% of the vertical length of a license plate area or shorter.

Fig. 10 provides explanations of the areas mentioned above. License plate tracking areas that correspond to dotted line areas are specified from among inputted images through recognition of bus-only car-lanes, and license plate areas within the solid line area are found from among these areas.

Fig. 10. Specified Area on the Input Image. (Dotted Line: License Plate Tracking Area, Solid Line: License Plate Region of the Vehicle)

If 7 or more numbers and characters are extracted from the detected license plate areas, these are finally judged as license plates of vehicles. The process described thus far describes operations that have been carried out to find license plate areas of vehicles. In the next stage, an operation will be carried out to extract the vehicle number from the detected license plate areas.

IV.III Extraction of Vehicle Number

In this section, an operation is carried out to extract vehicle numbers from the license plate areas found in the previous stage. Although vehicle numbers were extracted in the previous process, they were not used for template matching, because clearer images of license plate characters could be obtained when binarization was carried out with the license plate areas only, than those with images of the license plate location tracking areas. Due to the characteristics of vehicles running on an expressway, license plates are often in shade, and even after images are binarized, the desired images are not easily obtained. Fig. 11 shows the results of binarization of images covered in shade. Result (a) represents binarization results obtained using the Otsu's algorithm, Adaptive algorithm, and Binarization algorithm respectively. Result (b), which uses the Otsu's algorithm, shows part of the characters cut in comparison to the original images. Result (d), which uses the threshold value 100, shows characters that look thinner in comparison to the original images. In contrast, Result (c), which uses the Adaptive algorithm, shows characters whose thickness is similar to that of the original images.

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Fig. 11. Results of Binarization, (a) Input Image, (b) Otsu's Binarization, (c) Adaptive Binarization, (d) Binarization (Thresholding Value=100)

As can be seen in this comparison, when brightness and darkness comparison of the license plates is taken into consideration and the Adaptive algorithm is used, it is possible to more effectively binarize the license plate areas in gray images. These binarized license plate areas are used again in the operation that is carried out to find more than 7 numbers and characters through labeling and filtering. The vehicle numbers so detected are stored in image characters of 30×45 size for recognizing and distinguishing numbers through template matching.

IV.IV Character Recognition Using Template Matching

Template matching is the technique most widely used as a means of pattern recognition, in order to select the part that has the highest similarity as the detection area in image processing. In this paper, of the template matching methods, the Pearson correlation method is used instead of the more popular Normalized cross correlation, as the former is a matching algorithm that shows the characteristics of enhanced speed. The condition by which this algorithm can enhance speed is that the number of pixels of two images should be the same. First, when *X* and *Y* are pixel streams of the template area to be matched, the concept that is used to seek the Pearson matching coefficient, *r*, for each vector is as follows. The *r* is the degree value to which *X* and *Y* change separately divided by the degree value to which *X* and *Y* change together.

$$\overline{X} = \frac{1}{N}\sum_{n=1}^{N} x_n \, , \left(X = x_1, x_2, \ldots, x_n\right) \tag{9}$$

$$r = \frac{\sum\left(X - \overline{X}\right)\left(Y - \overline{Y}\right)}{\sqrt{\sum\left(X - \overline{X}\right)^2 \sum\left(Y - \overline{Y}\right)^2}} \tag{10}$$

When *X*□ and *Y*□ are mean values of *X* and *Y*, respectively, the *r* can be obtained using equations (9) and (10). This kind of template matching is often used for character recognition, fingerprint recognition, face recognition, and license plate recognition. Through this kind of license plate extraction process, recognition of numbers and characters can be carried out by applying the template matching explained above to vehicle number images that are stored in 30×45 size. 0~9 number templates are created in the same size of 30×45 that have been obtained through the vehicle number extraction process and stored first, and recognition of numbers and characters is carried out by one-by-one matching with extracted vehicle number images using the stored templates and equation (10). The focus of this research is placed on the judgment of whether an 8-person seater sedan that uses the bus-only lane can be allowed to drive on an expressway. Class signs of registered license plates vary depending on the vehicle model as 01～09 given to a sedan, 70～79 given to a van, 80～97 given to a truck, and 98~99 given to a special automobile, signifying that the first two digits of a license plate are the class signs of a vehicle. Using these characteristics, the first two digits of a vehicle number that were found during the previous template matching process are compared. When the numbers are not in between 70 and 79, the vehicle concerned is determined to be a vehicle that is not allowed to drive on the bus-only lane. On such occasions, informations on the vehicle running on the bus-only lane, such as images, vehicle number, and GPS information, are transmitted to the traffic infrastructure through V2I networking. V2I, which denotes communication between vehicles and the traffic infrastructure, is the delivery system of traffic information that was collected from vehicles to the infrastructure apparatus using WAVE communication, and finally to the Traffic Information Center using the Internet or private networks. When this kind of condition that changes in real time is transmitted by the infrastructure apparatus using V2I communication technology to the vehicles running on an expressway, the driver can determine whether the vehicle in question can be allowed to drive on the bus-only lane on an expressway.

V. EXPERIMENTS AND RESULTS

Videos were taken using a 12 million pixel rear-camera of a SM-N960NZBFKOO smartphone in 2220 × 1080 or 2960 × 1440 resolution in a car while driving on an expressway. Photo taking of the expressway was carried out by dividing the environment of the 1st lane, which is the bus-only lane, and the environment of the 2nd lane, which is on the right side of the 1st lane, and pictures were taken with the vehicles running in the front of both lanes as target. From the videos so created, images were processed using OpenCV version 3.4 in Visual Studio 2017 work environment for recognition of the bus-only lane and the license plates of vehicles involved.

V.I Detection of the Bus-only Lane

Fig. 12 shows the detection process of the bus-only lane from inputted images using the bus-only lane detection methods introduced in Chapter III. Fig. 12 (a) represents the location to be specified as the car-lane utilizing the videos taken on an expressway using a rear-end camera as input image, which is displayed as a square. Figures 12 (b) and (c) represent car-lane areas specified on the right and the left sides, respectively. Detection of the bus-only lane is carried out in this area. For the purpose, (b) and (c) were binarized using RGB color recognition into (d) and (e). Since there is no blue bus-only lane in (b), black binarized images were obtained, as shown in (d).

But since (c) has a blue bus-only lane, white binarized images were obtained from the bus-only lane, as shown in (e).

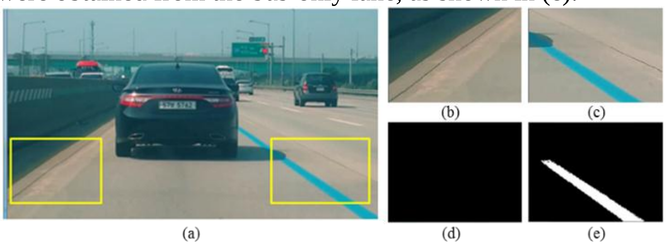

Fig. 12. Lane Area Binarization Through the RGB Color Recognition, (a) Car-Lane Area Specification, (b) Left Lane Area, (c) Right Lane Area, (d) Binarized Left Lane Region, (e) Binarized Right Lane Region

Next, an examination was carried out to ascertain whether the car-lane detected from the binarized images through RGB color recognition is the actual bus-only lane. For straight-line detection of binarized images (a) of the bus-only lane, Fig. 13 shows the process that undergoes (b) and (c) as a pre-processing process.

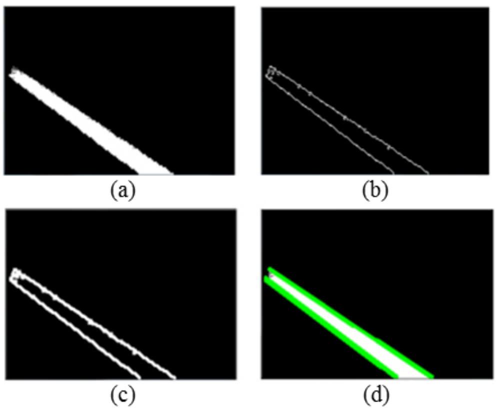

Fig. 13. Process of straight line detection, (a) Bus-only lane's binary image, (b) Edge detection, (c) Dilation of (b), (d) Straight line extraction

After undergoing an extraction operation, as shown in (b), the thickness of the contour line is adjusted through a dilation operation, as shown in (c). When this pre-processing process is completed, the result of straight-line detection can be obtained using the Hough transform algorithm, as shown in (d). The straight lines so detected can include straight lines other than the car-lane. So, in order to find straight lines that correspond to the car-lane, the following discrimination method was applied. In Fig. 13, it is possible to notice the car-lane occupies more than a regular length in the area where the car-lane is specified, and maintains a regular grade. The length and grade of detected straight lines can be detected using these characteristics. Of the straight lines obtained, those that do not satisfy the condition of length are removed. Additionally, the bus-only lane is finally determined from the straight lines that satisfy the conditions already established as set forth in Chapter III above to the effect that, when the car-lane is on the left side, the grade angle should be in the range of 110～130°, and when the car-lane is on the right side, the grade angle should be in the range of 40～60°. The white line, which an arrow points to in Fig. 14 (a), represents the bus-only car lane detected, and Fig. 14 (b) specifies the area of the vehicle that uses the bus-only lane determined by Fig. 14 (a).

Fig. 14. Detected bus-only lane and the specified tracking area, (a) Detected bus-only lane (red arrow), (b) Area of the specified car tracking region

As shown in this example, only a particular part of the input images is used to recognize the bus-only lane through image processing.

V.II Recognition of the Vehicle Number

An experiment was carried out regarding the process that is used to recognize the license plate of a vehicle that is using the bus-only lane in a specified vehicle tracking area to determine whether the vehicle can be allowed to use the bus-only lane. This experiment was implemented based on the vehicle number recognition algorithm that was explained in Chapter IV. Fig. 15 shows the result of the experiment implemented using the binarization algorithm.

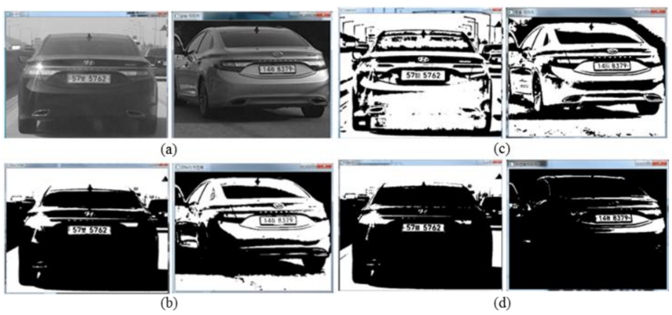

Fig. 15. Results of binarization method, (a) Image area of the license plate tracking region, (b) Results of Otsu's binarization, (c) Results of adaptive binarization, (d) Results of binarization (Thresholding value=140)

The binarization methods mainly used were the Otsu's algorithm and Adaptive algorithm, but the results showed that the performance of each method turned out differently, depending on the picture-taking environment of the input images. The Otsu's algorithm was useful in finding clearer license plate areas, and showed excellent performance when a vehicle of dark color entered as input images, as shown in the right side figure of Fig. 15 (b). However, when license plates were in shade, or when a vehicle of bright color entered as input images, binarization of the license plate areas did not turn out clearly. In comparison to the Otsu's algorithm, the Adaptive algorithm revealed clear license plate areas for input images covered in shade or for a vehicle of bright color; but for a

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vehicle of dark color or input images, binarized images in the form of the left side figure of Fig. 15 (c) were outputted. In contrast to the above two algorithms that showed less than satisfactory results in finding clear binary images of the license plate areas, the Binarization algorithm succeeded in finding much clearer binary images of the license plate areas with the adjustment of threshold values. Next, we carried out an experiment to extract license plate areas from the binarized images obtained using the Binarization algorithm through labeling and filtering.

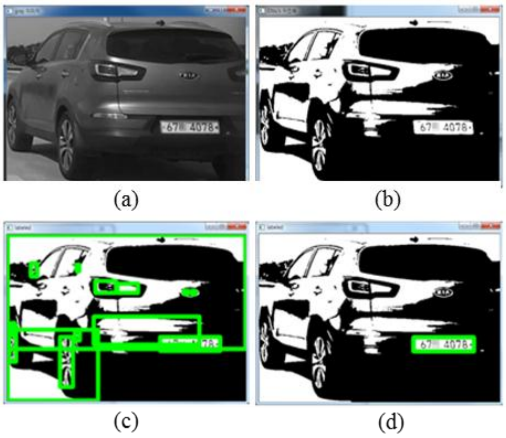

Fig. 16. License plate area extraction process through the labeling and filtering, (a) Input image, (b) Binarized image, (c) Results of labeling, (d) Results of filtering

As shown in Fig. 16, when a labeling operation is performed on (b) that binarized input images (a) of license plate tracking areas, the result would be something like (c). However, as labels other than those of license plate areas were also detected, we employed the process of label filtering of the license plate areas that was explained in Chapter IV to obtain result (d). To verify whether this result was actually the license plate, a new labeling operation was carried out over the labeling areas, using the condition that a vehicle number consists of 7 digits, and an examination was carried out to check whether there existing 7 labels. Using these methods, the license plate areas were finally determined. Next, we carried out an operation to extract vehicle numbers with the found license plate areas as target. Fig. 17 shows the process that was used to extract vehicle numbers. Groups that consisted of 255 pixel values like (c) were found from license plate areas (a) after binarization using the Adaptive algorithm through a labeling operation, and the 7 digits of the vehicle number were finally found through a filtering operation, as shown in (d).

Fig. 17. Process of License number extraction, (a) License plate region, (b) Adaptive binarization, (c) Results of labeling, (d) Results of filtering

The vehicle numbers so recognized were stored in 30 × 45 size to distinguish numbers through template matching. Vehicle numbers were finally recognized through a process of recognizing the extracted images of vehicle numbers as characters and numbers using template matching. For the purpose, matching was implemented with images of vehicle numbers that were obtained with the help of a camera using the templates that appear in Table 2.

Table 2. Numeric code table

Code Number Table										
Number	0	1	2	3	4	5	6	7	8	9
Code	0	1	2	3	4	5	6	7	8	9

Fig. 18 shows the results of recognition of 10 vehicle numbers through template matching. All results show that the recognition of vehicle license plates was properly carried out. Table 3 shows the results of bus-only lane recognition and vehicle license plate recognition.

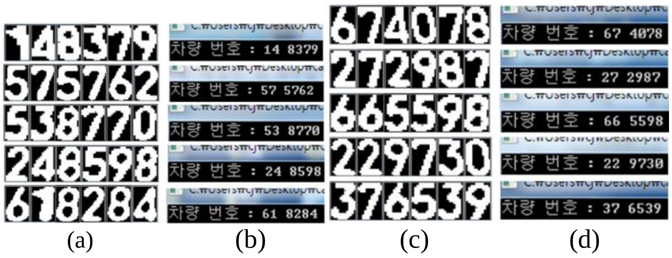

Fig. 18. Recognition results of numbers using the template matching, (a),(c): Acquired and binarized car's license plate numbers, (b),(d): Results of recognition of (a) and (c).

Table 3. Results of license plate recognition of vehicles on the bus-only lane (A: Direction, B: Car Number, C: Used Binarization Algorithm, D: Number Recognition, E: Whether it is possible to use bus-only lane or not)

A	B	C	D	E	A	B	C	D	E
Front	76○ 5725	Otsu's	○	○	Front	29○ 7793	Adapt.	○	×
	30○ 5192	Otsu's	○	×		16○ 3961	Adapt.	○	×
	52○ 5762	Otsu's	○	×		68○ 8023	Otsu's	○	×
	28○ 8393	Otsu's	○	×		33○ 1771	Bin.	○	×
	12○ 4783	Otsu's	○	×		20○ 2063	Adapt.	○	×
	39○ 3914	Otsu's	○	×		18○ 5873	Adapt.	○	×
	28○ 3717	Adapt.	○	×		24○ 2063	Adapt.	○	×
Sid	72○ 2063	Otsu's	○	○	Sid	67○ 3031	Bin.	○	×
	70○ 6811	Otsu's	○	○		56○ 8371	Bin.	○	×
	62○ 4365	Otsu's	○	×		25○ 5327	Otsu's	○	×
	37○ 7370	Adapt.	○	×		63○ 5217	Otsu's	○	×
	40○ 5485	Otsu's	○	×		22○ 9592	Bin.	○	×
	37○ 7330	Bin.	○	×		05○ 9567	Bin.	○	×
	20○ 4769	Adapt.	○	×		53○ 8770	Bin.	○	×
	18○ 8391	Otsu's	○	×		26○ 7297	Adapt.	×	×
	18○ 6572	Otsu's	×	×		24○ 8598	Otsu's	○	×
	14○ 8379	Adapt.	○	×		61○ 8284	Otsu's	○	×

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e	12○ 6360	Otsu's	○	×	e	23○ 1319	Bin.	○	×
	49○ 3682	Otsu's	○	×		13○ 9264	Otsu's	○	×
	27○ 2987	Adapt.	○	×		87○ 4984	Otsu's	×	×
	66○ 5598	Otsu's	○	×		26○ 4325	Otsu's	○	×
	31○ 3176	Otsu's	○	×		33○ 1757	Otsu's	○	×
	37○ 6539	Otsu's	○	×		28○ 8380	Otsu's	○	×
	22○ 9730	Adapt.	○	×		29○ 7315	Otsu's	○	×
	47○ 7862	Adapt.	○	×		37○ 5898	Adapt.	○	×
	50○ 8952	Otsu's	○	×		67○ 4078	Adapt.	○	×
	42○ 1227	Otsu's	○	×		90○ 4142	Bin.	○	×
	22○ 6026	Otsu's	○	×		91○ 7023	Otsu's	○	×

The bus-only lane was found through car-lane recognition, and recognition of the vehicle license plates was carried out using images of vehicles in the front while driving on the bus-only lane (1st lane), and using images of vehicles that were running on the left side when driving on the right lane of the bus-only lane (2nd lane). The resulting images of the experiment were divided into images that were taken of the vehicles in the front and the vehicles on the side, and were classified to reveal whether the vehicle concerned could be allowed to drive on the bus-only lane, which algorithm was used, and the status of license plate recognition. Videos that took pictures of the vehicles in the front revealed a 100% recognition rate. In contrast, videos that took pictures of vehicles on the side revealed a 92.8% recognition rate, failing at times to find license plate areas. The reason for this seems to be that the vehicles on the side were relatively far apart from the car from which the pictures were taken, in comparison to the vehicles running in front. Images of license plate areas for the former could not be recognized as clearly as those for the latter. Table 4 and Table 5 show the result of applying vehicle number recognition algorithms in this research to cases of varying illuminance depending on the date, time and weather.

Table 4. Vehicle's license plate recognition results in the front depending on the weather and time (lightness) (A: Weather, B: Classification, C: AM, D: Recognition, E: PM, F: Recognition, G: Evening, H: Recognition)

A	B	C	D	E	F	G	H
Sunny	Front	12○ 1405	○	23○ 7846	○	18○ 4174	○
		56○ 2725	○	68○ 2948	○	43○ 8905	○
		27○ 3927	○	13○ 2983	○	66○ 9537	○
		46○ 5332	○	14○ 7511	○	33○ 9460	○
		31○ 2779	○	25○ 6490	○	31○ 6839	○
		14○ 2607	○	20○ 8227	○	34○ 4915	○
		14○ 3327	○	41○ 9433	○	63○ 9148	○
		77○ 9701	○	24○ 3095	○	66○ 8390	○
		82○ 9150	○	17○ 1056	○	57○ 5281	○
		31○ 8134	○	68○ 4487	○	26○ 9111	○
		49○ 2172	○	56○ 6943	○	25○ 5037	○
		63○ 8213	○	14○ 1095	○	33○ 2579	○
		64○ 5486	○	55○ 8237	○	66○ 7299	○
		56○ 5117	○	64○ 9003	○	47○ 4800	×
		02○ 5987	○	53○ 2389	○	53○ 7949	○
Cloudy	Front	42○ 1452	○	38○ 8124	○	13○ 7223	○
		49○ 1522	○	23○ 5187	○	22○ 4773	○
		47○ 7358	○	36○ 3292	○	49○ 9596	○
		29○ 1480	○	13○ 9669	○	72○ 7580	○
		14○ 8166	○	48○ 7031	○	47○ 3479	○
		23○ 3442	○	14○ 7022	○	28○ 6945	○
		45○ 3735	○	79○ 2215	○	71○ 5396	○
		53○ 5350	○	50○ 9492	○	14○ 7909	○
		69○ 2041	○	22○ 7871	○	41○ 9738	○
		85○ 6393	○	26○ 3096	○	63○ 7760	×
		11○ 0951	○	12○ 5832	○	64○ 7802	○
		82○ 1721	○	33○ 9136	○	91○ 3891	○
		86○ 5711	○	46○ 1954	○	41○ 7991	○
		23○ 5784	○	15○ 3762	○	47○ 5133	○
		62○ 5829	○	66○ 1139	○	22○ 6309	○
Rainy	Front	14○ 1218	○	63○ 6373	○	35○ 8867	○
		16○ 8843	○	33○ 2643	○	53○ 6448	×
		43○ 9498	○	14○ 7596	○	47○ 8643	○
		14○ 8685	○	31○ 7403	○	19○ 7465	○
		27○ 9182	○	68○ 5948	○	34○ 7916	○
		18○ 1804	○	51○ 9724	○	66○ 1074	○
		69○ 2827	○	18○ 8215	○	33○ 5627	○
		16○ 5748	○	34○ 1296	○	58○ 5449	○
		32○ 9828	×	28○ 7885	○	17○ 7163	○
		41○ 2346	○	67○ 3399	○	20○ 6852	○
		33○ 7985	○	28○ 7802	○	82○ 5392	○
		73○ 6099	○	45○ 8398	○	24○ 8855	○
		55○ 8864	○	25○ 4789	×	66○ 6337	○
		25○ 8060	○	24○ 6665	○	09○ 6495	○
		35○ 5328	○	28○ 5518	○	69○ 3886	○

Table 5. Vehicle's license plate recognition results on the side depending on the weather and time (lightness) (A: Weather, B: Classification, C: AM, D: Recognition, E: PM, F: Recognition, G: Evening, H: Recognition)

A	B	C	D	E	F	G	H
Sunny	Side	85○ 8859	○	35○ 8637	○	27○ 3100	○
		96○ 4742	×	18○ 8008	○	41○ 3993	○
		49○ 2062	○	36○ 3994	○	19○ 3504	○
		58○ 6460	○	22○ 8903	○	24○ 8054	×
		22○ 7230	○	45○ 1873	○	51○ 6575	○
		51○ 6998	○	11○ 7977	○	30○ 4043	○
		62○ 5136	○	41○ 3985	○	65○ 8725	○
		55○ 2423	○	65○ 8264	○	15○ 6404	○
		37○ 2801	○	14○ 1319	○	57○ 1547	○
		49○ 5548	○	47○ 4530	○	69○ 2840	○
		46○ 4569	○	66○ 3010	○	40○ 1234	○
		11○ 5956	○	67○ 5036	○	38○ 7908	○
		26○ 1895	○	77○ 9853	○	12○ 8677	○
		62○ 4779	○	30○ 9957	○	27○ 7187	○
		70○ 4166	○	66○ 1256	○	27○ 6161	○
Cloudy	Side	31○ 5729	○	61○ 7273	○	11○ 1192	○
		54○ 7881	○	54○ 6701	○	37○ 6913	○
		61○ 9061	×	54○ 9311	○	18○ 8699	○
		19○ 8207	○	38○ 2809	○	68○ 1093	○
		62○ 9037	○	23○ 2810	○	66○ 7845	○
		28○ 9740	○	53○ 6378	○	45○ 8856	○
		12○ 7355	○	68○ 5201	○	26○ 9761	○
		17○ 3078	○	20○ 7426	○	74○ 4568	○
		66○ 1534	○	69○ 8077	○	64○ 6975	○
		83○ 3382	○	29○ 3035	×	47○ 5695	○
		57○ 9216	○	38○ 8275	○	68○ 6633	○
		68○ 7838	○	24○ 4555	○	33○ 4660	×
		37○ 6743	○	22○ 8538	○	43○ 5097	○
		97○ 7805	○	56○ 7925	○	72○ 2972	○
		70○ 1477	○	13○ 9134	○	79○ 7456	○
Rainy	Side	62○ 9065	×	63○ 6936	○	23○ 8373	○
		11○ 5310	×	24○ 3400	○	51○ 7242	○
		58○ 1887	○	37○ 9512	○	82○ 3069	×
		63○ 9420	○	60○ 2423	○	91○ 7862	○
		53○ 7986	○	18○ 1239	○	60○ 4890	○
		34○ 3907	○	25○ 9760	○	53○ 9120	○
		59○ 5763	○	26○ 6558	○	41○ 1461	○
		35○ 6747	○	49○ 9781	○	19○ 2574	○
		11○ 7281	○	49○ 9054	○	69○ 5003	○
		50○ 9622	○	59○ 4427	○	63○ 2961	○
		16○ 9287	○	40○ 2177	×	03○ 8345	○
		55○ 3908	○	52○ 5932	○	36○ 7737	○
		63○ 7223	○	68○ 2901	○	26○ 4041	×
		40○ 8249	○	50○ 3311	○	69○ 2202	×
		15○ 9102	○	27○ 3215	×	55○ 8924	○

For the purpose of data collection, the experiments were carried out between 6:00～7:00 a.m., between 12:00～1:00 p.m., and between 6:00 ～ 7:00 p.m. during the summer. Change in illuminance was measured separately, based on shiny, cloudy, and rainy days. Tests on bus-only lane recognition and license plate recognition were carried out accordingly. Table 4 and Table 5 show the result of the experiments carried out for 15 vehicles each in the front, and 15 vehicles on the side, on different dates, and at different times. The results on the status of license plate recognition were marked with ○ and ×. As it turned out, the results of license plate recognition were not affected much by weather and change in illuminance. It seems that poor recognition rate can be attributed to shaking when pictures of vehicles on the side were taken, data that was not sufficiently clear, and relatively low illuminance. Also, on rainy days, objects looked somewhat distorted by falling raindrops, not to mention the overall poor condition for taking pictures, displaying a relatively lower recognition rate in comparison to sunny or cloudy days. Table 6 shows the amount of sunlight (*lux*) and the plate recognition rate based on the weather and time as recorded in Table 4 and Table 5.

Table 6. Recognition rate of vehicle's license plates depending on the weather and time (lightness)

Weather			AM	PM	Evening
Sunny	*Lux*		8000-10000	↑10000	4000 - 7500
	Recognition Rate	Front	100%	100%	93%
		Side	93%	100%	93%
Cloudy	*Lux*		4000 - 7500	8000 -↑10000	2500 - 6500
	Recognition Rate	Front	100%	100%	93%
		Side	93%	93%	93%
Rain	*Lux*		1500 - 5000	6500 - 9500	500 - 2500
	Recognition Rate	Front	93%	93%	93%
		Side	87%	87%	80%

In other words, Table 6 shows the difference of license plate recognition of the vehicles in front and vehicles running on the side depending on the weather and time. On shiny and cloudy days when luminance was high (during the morning and afternoon), the recognition rate of license plates of vehicles running in front and on the side turned out to be between 93% and 100%, whereas during the evening hours of the same weather, the recognition rate turned out to be 93%. This seems to be attributable to the fact that the pictures of license plates were taken from the side when luminance was low, and the camera was shaken because of the moving car. When the weather was bad, the illuminance was also low. Because of this, the recognition rate of license plates obtained during morning hours and evening hours from the vehicles in front and from the vehicles running on the side were 93% or above, and 87% or above, respectively; whereas, the recognition rate that was obtained during evening hours was about 80%. Images of license plates obtained in this experiment include those of the vehicles running in front, as well as on the right, which were taken in a car following them from behind, at times at a high speed of 100 *km* per hour or faster. Also, there exist images of the license plates that could not be clearly recognized, due to lane change and severe shaking. However, those pictures taken when luminance was high always revealed a high recognition rate.

VI. CONCLUSION

This paper conducted research on the methods of recognizing a bus-only lane, and of managing and controlling vehicles running on an expressway in a C-ITS environment, and described the research results. For the purpose, special emphasis was placed on the environment where enforcement of the bus-only lane rule was implemented in real time in a moving vehicle using low price photo-taking equipment, such as a black box installed in a car or a camera, instead of using the fixed surveillance cameras installed along the expressway, as in the past. For this purpose, we used algorithms that were devised for recognition of the bus-only lane, and for recognition of vehicle license plates. The time for implementing the required tasks was reduced by setting up a Region of Interest (ROI) for bus-only lane recognition, and by carrying out the required image processing only within the ROI. Also, utilizing the characteristics that a car lane within the ROI has a regular length and grade, the final discrimination was made and ascertained. As for recognition of license plates, the Adaptive thresholding algorithm was employed, which enables recognition of license plates that suits the environmental factors, in consideration of the driving characteristics of the vehicles. The Adaptive algorithm method also allows recognition of vehicles not only in the front, but also on the sides, running in the forward direction. The vehicle numbers so recognized are finally used to discriminate whether certain vehicles are in violation of the bus-only lane rule, using the first two digits as classification signs for special use. The proposed enforcement method of the bus-only lane rule can be used against reckless drivers who willfully avoid the existing enforcement that relies on fixed enforcement cameras, and who keep changing lanes on an expressway. Since the new method can also be used to prevent accidents by such drivers, it is expected to improve the traffic environment. In future research, we plan to investigate the methods that can be used for sending and receiving the enforcement information described above using the WAVE communication technology of V2I communication.

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