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MATHEMATICAL IMAGE PROCESSING FOR AUTOMATIC NUMBER PLATE RECOGNITION SYSTEM

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ABSTRACT. In this paper, we develop the Automatic Number Plate Recognition (ANPR) System. ANPR is generally composed of the following four steps: i) The acquisition of the image; ii) The extraction of the region of the number plate; iii) The partition of the number and iv) The recognition. The second and third steps incorporate image processing technique. We propose to resolve this by using Partial Differential Equation(PDE) based segmentation method. This method is computationally efficient and robust. Results indicate that our methods are capable to recognize the plate number on difficult situations.

1. INTRODUCTION

A rapid motorization by an economic growth has brought not only positive aspects including convenience of living but also many negative aspects. The number of cars became increasingly faster than the extension of roads and parking spaces. This resulted in a traffic congestion, growth of the rate of car accidents, violation of the traffic regulations such as speeding and illegal parking, and a crime like car theft. To resolve these problems, we need the intelligent Transport System(ITS) to improve the environment and security of transportation by building intelligent system which can effectively operate transportation. The car recognition system is one of the essential components which are needed for the construction of the ITS. This is the system to intelligently obtain and analyze cars' information through automatically classifying and recognizing features, shapes and number plates. Among various car's information obtained by the car recognition system, the car number plate is the most distinguishing element which assigns a distinct identity to each car. For this reason, the Automatic Number Plate Recognition (ANPR) is the most fundamental requisite for the car recognition system. Figure 1 shows the general ANPR system which is composed of the following four steps.

i) The acquisition of the image

We obtain a car image from a high resolution camera or CCTV. The image deteriorates the resolution quality because of equipments and environmental influences.

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ii) The extraction of the region of the number plate

In this step, we use the intensity and the property of the location of the number plate considering the front or back sides of the car in the image.

iii) The partition of the number

The image processing is applied to separate the region of objects(letters and numbers) and backgrounds.

iv) The recognition

We recognize letters and numbers by the method of the pattern recognition from the partitioned numbers.

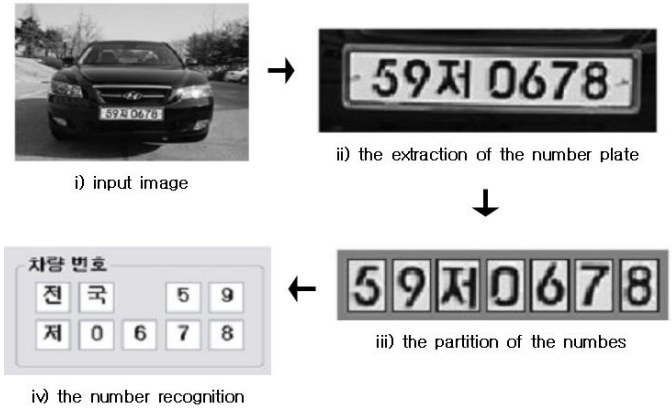

FIGURE 1. The outline of the Automatic Number Plate Recognition (ANPR).

ANPR could be used in various traffic and security applications, such as automatic charging system, automatic access and border control system, tracking of regulation-violating car, a criminal investigation and an intelligent traffic control system. we can expect the effect reducing costs and saving human resources. In spite of these advantages, ANPR system has been used only in the specific fields. This is, because the present technology can be applied to the high quality image. To get the high quality image, we need high-priced image-equipments and the broadband wire communication network. Ultimately, it increases the investment-cost of facilities and equipments. Especially, most of investment-costs of extending the ANPR system is the cost of building the wire communication network to transmit the image data stably. The more insufficient the infra is, such as the road in rural areas and a detached house, the higher the investment-cost is.

If we transmit the acquired image data from image-equipment through wireless communication network, we can save the investment-cost for constructing the wire communication network. However, there are several problems for building ANPR system using the wireless communication network. First of all, it is difficult to send the high resolution data through the

wireless communication network in real time. This is, because the wire communication network transmits the data using the wave. Wireless communication network has lower bandwidth and higher possibility contaminated with noise and interference than wire communication network. And if we use the wave in high frequency, we can send more data and transmit-distance can be longer. But the wave is weakened by the obstacles between a transmitting station and a receiving station having the lower diffractive property. So we need to use the suitable bandwidth, eventually, the data amount we can transmit are limited. There are two approaches to solve this problem. One is developing the wireless communication technology to transmit the high quality image data in real time. And the other is that we transmit the low quality data using the present wireless communication technology and equipment and then, make it the high quality data using the image processing technique properly. If, by using image processing technique, we can acquire the image data up to the level we can analysis, we don't need to try to get the high quality data and transmit it as it is. After we acquire image data using low resolution equipment, we transmit low quality data through wireless communication network. So after restoring the high quality data from the low ones using the image processing, we can build the system to analyze for the needed information. The above system saves the costs of constructing ANPR system and eventually, ANPR system can be applied to various application fields.

In this paper, we propose the method to improve the image quality. This method makes ANPR system more efficient. Using the low resolution equipment such as CCTV for road traffic information and crime prevention, and wireless communication network we can construct ANPR system that is useful and robust in the environment condition, such as light and atmosphere.

2. The Automatic Number Plate Recognition (ANPR)

The algorithm of the number plate recognition should not be sensitive to noise and variation because the obatined image is affected by environment. However, it is less complicated than the general recognition of images and letters since the number plate has the standard sort and size. We implemented for new cars' number plates among revised number plates of a private car(standard) but our experiments could be applied to other number plates. The size of number plate is 110 mm by 520 mm, so the proportion of length and width is about 1:5 and it plays an important role in the procedure to extract the region of number plate.

2.1. **The preprocessing.**

In our experiment, we first dealt with images without noise and will expand this conduction for noisy images later. When we preprocess the noisy image through using filters such as mean filter, median filter, and Gaussian filter to remove noise, the image rather deteriorate due to blurring effects. Later, we want to devise a method to minimize these preprocessing so that the noisy image doesn't worsen. We expect to resolve this by using Partial Differential Equation(PDE) based segmentation method.

2.2. **The extraction of vertical components.**

An ordinary car image rarely has vertical components except the region of the number plate. So we take the convolution of the following

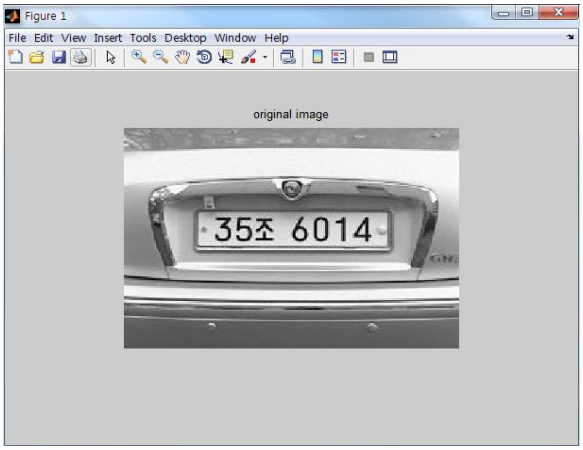

FIGURE 2. The input image.

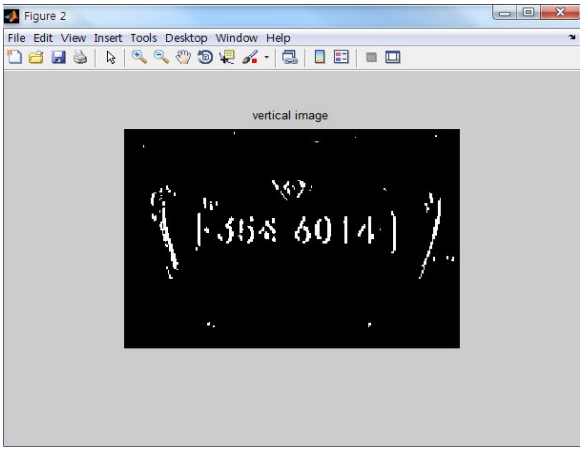

FIGURE 3. The binary image of vertical components.

mask M and the image to get only vertical components in the original image. Figure 3 shows the binary image obtained from gray-scale threshold for the image after the convolution.

2.3. **The projections of x and y axis.** Except in the case of images having many decorations around the number plate or complex designs, the region of the number plate can be easily extracted by the projections of x and y axis. Figure 5 shows the projections of x and y axis for the binary image. As you can see in this figure, the maxima of the red graph which represent the projection of y axis is located near the number plate.

-1	0	1
-1	0	1
-1	0	1

FIGURE 4. A mask M.

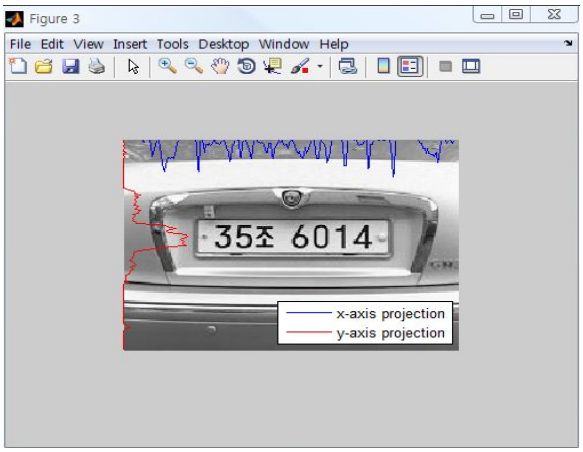

FIGURE 5. The projections of x and y axis.

2.4. **The extraction of the region of the number plate.** This is the most important part in the process of the number plate recognition. To extract the region of the number plate, we sort differential projected values of y axis in descending order. We choose the largest two sorted values and the coordinates are assigned to the criteria y_1, y_2 of y axis. For the projection of x axis, we carry out in similar ways. When we choose x_1 as the criterion of x axis according to the rule that difference of large x_1 and its adjacent values is greater than 6 times $|y_1 - y_2|$ and less than 7 times $|y_1 - y_2|$. Since y_1, y_2 are very close to numbers in the number plate, $|y_1 - y_2|$ is less than the vertical length of the number plate. From this and the information that the proportion of length and width of the number plate is about 1:5, we can choose x_1 and x_2 = x_1 + 6· *vertical length*. Figure 6 shows the extracted number plate by x_1, x_2, y_1, and y_2. As stated above, the information about the size of the number plate is used. Since the extraction method like this is very sensitive to the image, if the image has the complex background near the number plate, we cannot correctly extract the desired region. Therefore we want to devise the method which is less sensitive to the image by mathematical modeling.

2.5. **The segmentation of numbers.** From this step, we progress only for the small image which is obtained after the extraction procedure. Without any preprocessing like threshold, we

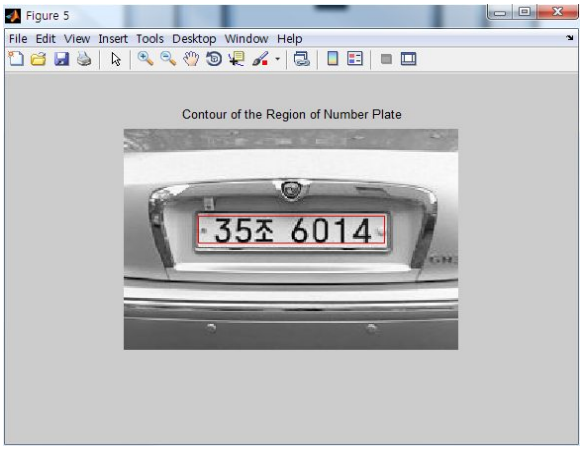

FIGURE 6. The extraction of the region of the number plate.

segment the image by using Gibou-Fedkiw algorithm. This algorithm is considered as 2-means clustering method by using level set function with c_p, c_n, where c_p is the average of positive level set values and c_n is the average of negative level set values. If we let ϕ be a level set function and I be the image which represent only the region of the number plate, the idea of Gibou-Fedkiw is as follows.

$$\begin{aligned} c_p(t) &= \text{average of}\{I(x,y) : \phi(t,x,y) > 0\} \\ c_n(t) &= \text{average of}\{I(x,y) : \phi(t,x,y) < 0\} \\ \frac{\partial \phi}{\partial t}(t,x,y) &= -\lambda_1[I(x,y) - c_p(t)]^2 + \lambda_2[I(x,y) - c_n(t)]^2 \end{aligned} \tag{2.1}$$

The Ordinary Differential Equation can be simply solved through the following algorithm.

Algorithm

i) Set initial $\phi = \pm 1$.
ii) $c_p = \frac{\Sigma I \cdot (\phi+1)}{\Sigma(\phi+1)}$, $c_n = \frac{\Sigma I \cdot (\phi-1)}{\Sigma(\phi-1)}$.
iii) $F = -[I(x,y) - c_p(t)]^2 + [I(x,y) - c_n(t)]^2$
$\phi = 1$ *if* $F > 0$ *or* $\phi = -1$ *if* $F < 0$.
iv) Repeat ii) and iii) until c_p *and* c_n *are not changed.*

In Figure 7, the red line in the first image denotes zero-level set of the initial level set function and the second image shows the level set values $\phi = \pm 1$ used in the first image.

Figure 8 shows the zero-level set and the level set function after applying the Gibou-Fedkiw algorithm.

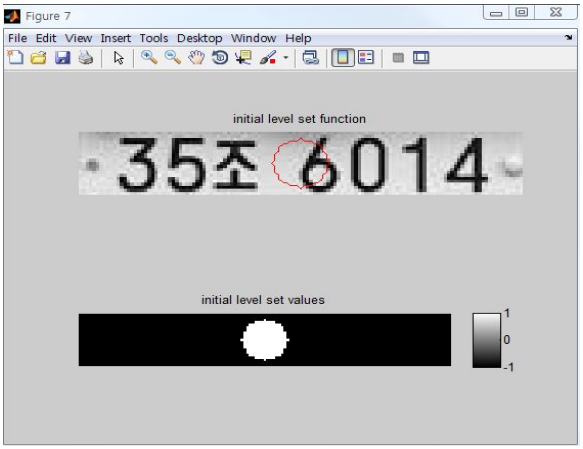

FIGURE 7. The initial level set function and its zero-level set.

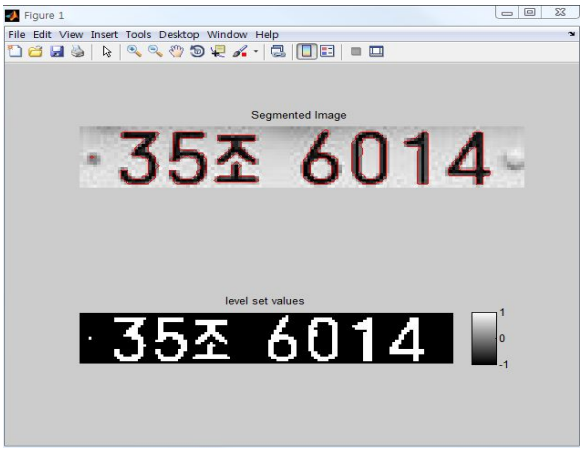

FIGURE 8. The zero-level set and the level set function after the segmentation.

2.6. **The extraction of the region of the each number.** We use the projection of x-axis to extract the region of the number plate as the first step to extract each number. Since the maxima of the projected values of x axis are located near numbers as you can see in Figure 9, we can get information about the locations of starting and ending points for each number from these maxima. Figure 10 shows the result for the extraction of the region of the each number.

2.7. **The segmentation of the each number and the acquisition of number images.** We segment each number in each region by using the Gibou-Fedkiw algorithm and then we get the binary images as seen in Figure 11.

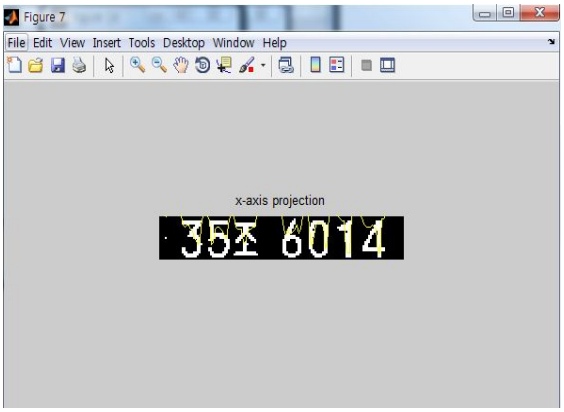

FIGURE 9. The projection of x-axis.

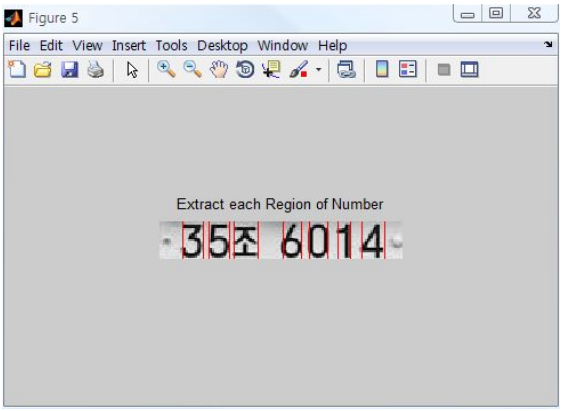

FIGURE 10. The extraction of the region of the each number.

2.8. **The normalization of number image.** We prune the up, down, left and right margin to recognize the number efficiently. Since the sizes of number images extracted from number plate image are different, their pixel sizes should be normalized. Each number is scaled to 42×24 pixel image. Figure 12 shows the number image pruned out the margin and normalized.

2.9. **Number Recognition.** Since the car number plate system has single-font and fixed size number/character, the template matching technique is useful. Number plate is composed of number and Korean character. As seen in Figure 11, among segmented images in the number plate, third image is a Korean character and six other images are numbers. Thus, when the image we want to recognize is a number image, we use the number-template and choose the most similar one. In the case of Korean character, we compare segmented Korean character image with the character-template. The recognition process is based on the computation of

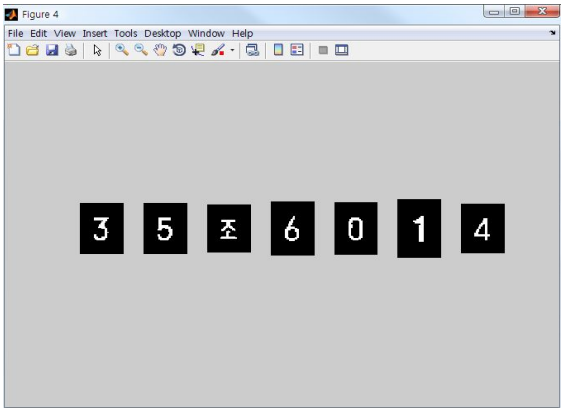

FIGURE 11. A series of number images.

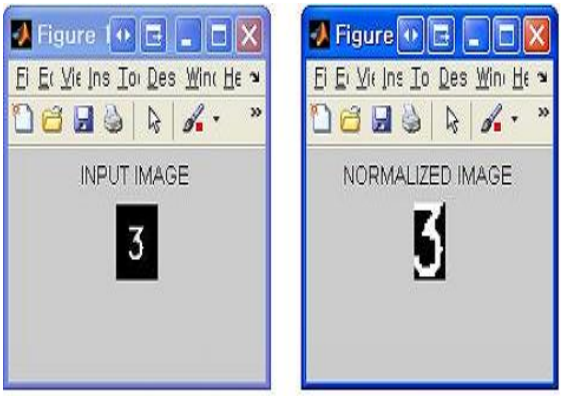

FIGURE 12. The normalized number

correlation values for each template over the extracted image. The Korean language made up of 28 phonetic signs(11 vowels and 17 consonants). The Korean characters are built up from two or more symbol. Some research has been done into segmenting the Korean character into individual symbols. But results have shown that this method has not produced results any better than those systems that don't segment the character into symbols. So segmentation of the character was not implemented. Since Korean character is composed of two or three symbols, there are many possibilities. And many of these combinations look remarkably similar. So Korean character recognition is more challengeable than number recognition. Although the Korean character used in car number plate system is limited, the recognition rate corresponding to the Korean character is much lower than one to number. So in the following study, we try to improve the recognition rate for Korean character.

FIGURE 13. Number Recognition.

3. CONCLUSION

In this paper, we applied the segmentation method using level sets to the automatic number plate recognition for simple cases. The results are quite good but this approach is very limited. In practice, we have various images such as blurry, noisy, and transformed images. For the ANPR system, the extraction of the region of the number plate is a very important procedure. Therefore, we expect better and stable results by replacing the use of the projections of x and y axis in this procedure with an approach to find feature points of the number plate.

ACKNOWLEDGMENTS

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