Motion estimation from sequential image using correlation

MOTION ESTIMATION FROM SEQENTIAL IMAGE USING CORRELATION

In Soo Kweon, Yue Bao, Naofumi Fujiwara

Kanazawa University

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In this paper, we take aim at a flexible and active vehicle following system. To realize the system, we use a license plate instead of the devices that receive and send signals. In order to gather information from a license plate, we propose three method, one method is that continuously tracks a license plate, another is that extracts the characters under conditions of changeable and uneven illumination, and the third is that calibrates the difference between the reference template image and the image selected by correlation. From these characters in a license plate, we can determine the relative distance and angle. The effectiveness of this system is shown by the experimental results.

1. Introduction

It is becoming more important to improve traffic safety by lightening the burden on the human driver in our society, especially with the growing population of elderly drivers worldwide. The autonomous vehicles are expected to increase traffic safety. Specifically, vision-based vehicle following systems are expected to play an important part in these autonomous vehicles. The following systems can improve a traffic safety and efficiency, and apply to the construction sites[1] and conveying the cargo for factory automation. Generally, they need the information on the preceding vehicle for the purpose of tracking. A variety of techniques have been proposed to get this information. These include techniques using a laser and corner cubes[2], as well as a specific figure of a black regular square against white plane[3]. But these techniques can be applied to only vehicles equipped with those systems. We describe a method that can apply to general vehicles, a method that automatically gets images of a moving object, a method that continuously tracks a license plate, and a method that extracts the characters under conditions of changeable and uneven illumination[4].

2. Correlation

The correlation coefficient represents a measure of the relationship between the members in two sets of quantities. Its use in image processing is to determine local similarity between two structured data sets. In this paper, it is applied to detect a license plate. By using this correlation, the image containing the license plate can be extracted from the entire image and the selected image is displayed by a bounding box on the screen. But if

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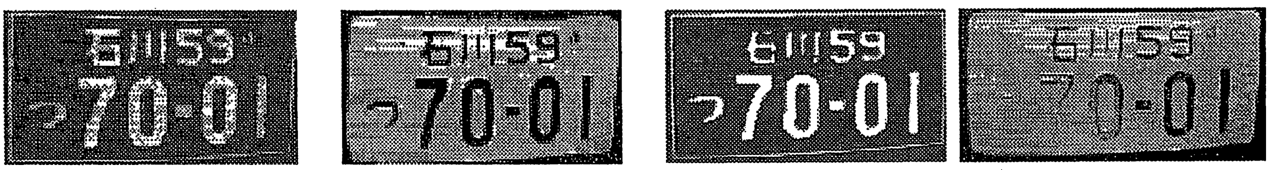
the object of correlation uses only one reference template, it cannot manage to extract a license plate that is too far away or too near by the preceding vehicle, since a license plate image on the preceding vehicle is too big or too small in comparison with the size of the license plate in the reference template. This problem can be resolved by sequential estimation, since a high correlation value between successive frames is expected.

Another problem that occurs when applying to this method is that the difference between the images selected by correlation and the reference template image increases as time goes by. Therefore, calibration by each measurement cycle is needed. To correct these differences, this system uses the characters on license plates.

3. Pre-processing module

The goal of this process is to extract characters from the license plate[5]. If the brightness of a license plate is uneven, the extraction of its characters through a spatially constant threshold value which is determined, for example, by a gray level histogram results in failure. Therefore, we use the minimum-maximum subtraction (MMS) method, since this method is not strongly influenced by shadows and uneven lighting, and makes it easier to extract the characters from the various colors of the background on the license plate. The experimental result of MMS method is shown in Fig. 1. After performing the MMS method, in order to facilitate the location of the characters on the license plate, a threshold technique could be applied. Obviously, when the images are uniformly illuminated and not too noisy, it is easy to find a optimal threshold that allows the characters to be isolated from the background. However, for most real images, it is often difficult to detect the valley bottom precisely, especially in such cases as the valley is flat and broad, imbued with noise, or the two peaks are extremely unequal in height, often producing no traceable valley. To select a optimal threshold, we make use of the Otsu method[6]. Although an image is processed by optimal threshold into binary image, much noise may keep to remain in the image. Noise occupies many memories in image processor and makes objects distorted in an image. Then dilation and erosion are used for salt and pepper noise removal in this paper.



(a) (b) (c) (d)

Fig. 1. (a) An image using MMS under normal illumination condition; (b) An binarized image under normal illumination condition; (c) An image using MMS under a partial uneven lightness; (d) An binarized image under a partial uneven lightness.

Dilation and erosion generally use a neighborhood operator. The next step is labeling operation.

Labeling operation performs the unit change from pixel to region or segment. The algorithm used in this paper assigns new labels to the first pixel of each component and attempts to propagate the label of a pixel to its neighbors to the left or above it: this paper uses 4-adjacency with a left-to-right and bottom-to-top scan order. Characters on a license plate are identified by the labeling. But their representative points are needed. Therefore, this paper decides these points with using the center of mass in characters. In the case of a spatially discretized *M*x*N* image, this is expressed by;

$$m_{pq} = \sum_{i=0}^{M}\sum_{j=0}^{N} i^p j^q f(i,j) \quad (1)$$

where *f(i,j)* is a gray level of an image pixel (i,j), p and q are p^{th} and q^{th} moment respectively.

All points *(i,j)* used in this computation are either boundary or interior points [(7)-(8)].

4. Calibration

This chapter proposes how to calibrate the difference between the template image and the image selected by correlation. The calibration method is as follows;

1)Find the standard point, which is the center of the preceding image, and the centers of the first and the fourth character from the bottom-right in the license plate of the preceding image(where a bar in the license plate isn't considered as a character).

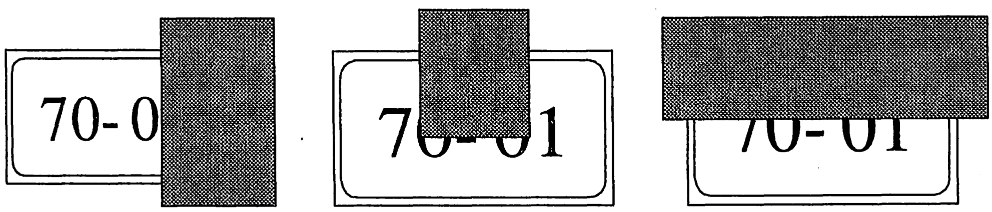
2) Find the centers of the first and the fourth from the bottom-right of the license plate image selected by the correlation in the present image (where a bar in the license plate isn't considered as a character).

3) Find the new standard point of the license plate in the present image by the relation between the points in 1) and 2).

The calibration is expressed by equation as follows:

$$m = \frac{y_2 - y_1}{x_2 - x_1} \quad (2) \qquad m' = \frac{y_2' - y_1'}{x_2' - x_1'} \quad (3)$$

$$k_1 = \frac{x_c - x_1}{|x_c - x_1|} \quad (4) \qquad k_2 = \frac{y_0 - y_c}{|y_0 - y_c|} \quad (5)$$



(a) (b) (c)

Fig. 2. (a) In case that more than one among the characters disappears; (b) In case that the part of the characters is cut by the obstacle; (c) In case of the more than one-third of the license plate is cut by the obstacle.

$$\begin{cases} x_c = \dfrac{my_0 - my_1 + x_0 + m^2 x_1}{m^2 + 1} \; (x_1 \neq x_2) \\ x_c = x_0 \qquad (x_1 = x_2) \end{cases} \quad (6)$$

$$\begin{cases} y_c = \frac{1}{m}(x_0 - x_c) + y_0 & (x_1 \neq x_2) \\ y_c = y_0 & (x_1 = x_2) \end{cases} \quad (7)$$

$$a' = \frac{l'}{l} a \quad (8) \qquad c' = \frac{a'}{a} c \quad (9)$$

$$\begin{cases} x_c' = k_1 \frac{a'}{\sqrt{m'^2+1}} + x_1' & (x_1' \neq x_2') \\ x_c' = x_1' + k_1 a' & (x_1' = x_2') \end{cases} \quad (10)$$

$$\begin{cases} y_c' = m'(x_c' - x_1') + y_1' & (x_1' \neq x_2') \\ x_1' = x_2' \; y_c' = y_1' & (x_1' = x_2') \end{cases} \quad (11)$$

$$\begin{cases} y_0' = k_2 \frac{c'}{\sqrt{m'^2+1}} + y_c' & (x_1' \neq x_2') \\ x_1' = x_2' \; y_0' = y_c' + k_2 c' & (x_1' = x_2') \end{cases} \quad (12)$$

$$\begin{cases} x_0' = x_1' & (x_1' = x_2') \\ x_0' = m'(y_c' - y_0') + x_c' & (x_1' \neq x_2') \end{cases} \quad (13)$$

If there are obstacles between the preceding vehicle and the following vehicle as shown in Fig.2, the shapes of the characters in license plate can be deformed or the characters may exist beyond visual field of either camera. Since an unexpected image may be decided by the incorrect character centers in these cases, the following vehicle compensates by reducing the speed or stopping until the obstacles disappear from the screen.

5. Distance and angle

The relative distance between the license plate and the baseline is determined by the parallax. Its principle is shown in Fig. 3.

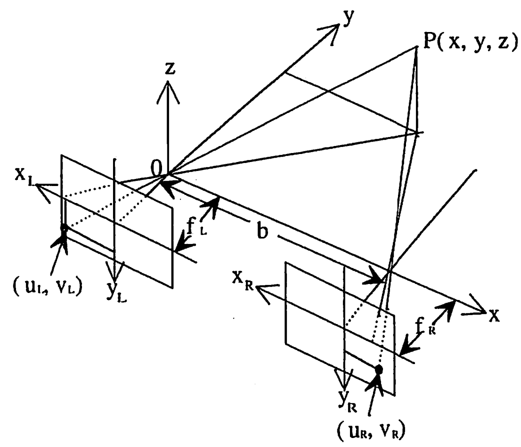


Fig. 3. Principle of calculating the Distance

When our proposal puts the standard coordinate system on the center of the left lens, the coordinates of the license plate can be derived from the equation (14).

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \frac{b}{u_L - \frac{f_L}{f_R} u_R} \begin{pmatrix} u_L \\ f_L \\ v_L \end{pmatrix} \quad (14)$$

When there is the standard reference of the two cameras on the left lens, a relative angle is defined as an angle between the line through the left lens surface center and the line along the license plate surface. Let m denote the distance from the left camera lens to the last character *1* in license plate, and assume *l* is the real distance from the first character *7* to the last character *1* as shown in Fig.4. Let *n* denote the distance from the left camera lens to the first character. Under these circumstances, the relative angle is determined by the trigonometry equation (15)• (19).

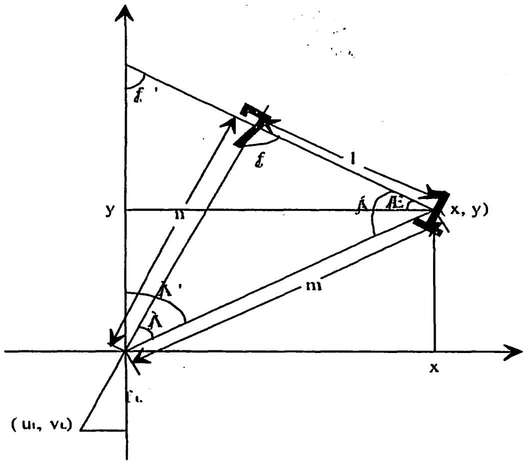


Fig. 4. Relative angle

$$\beta' = \tan\frac{u_L}{f_L} \quad (15) \qquad \alpha' = \alpha - (\beta' - \beta) \quad (16)$$

$$\alpha = \cos^{-1}\frac{l^2 + n^2 - m^2}{2 \cdot l \cdot n} \quad (17)$$

$$\beta = \cos^{-1}\frac{m^2 + n^2 - l^2}{2 \cdot m \cdot n} \quad (18)$$

$$\theta = 90 - \alpha' \quad (19)$$

6. Experiments

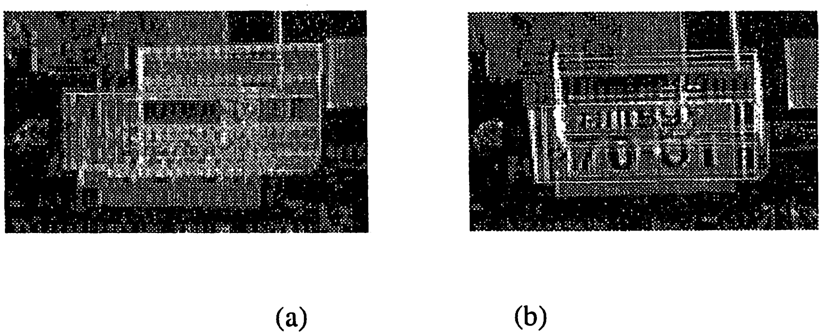
We have performed the experiments used two cameras (CCD-G100ST), DOS/V486 (66MHz) and Image Processor (CSC901) with 512x480 pixels.

Fig.5. shows the result of experiments where a single feature (the license plate) is tracked by boundary square. The experimental results have shown that before calibration, the license plate moves further and further outside of the bounding square with the passage of time as shown in Fig.5(a), but remains in the square in its entirety after calibration as shown in Fig.5(b). Fig6(a) show errors and standard deviations of angles from 2m to 4m, with the maximum error being 3.8°. Distance errors and standard deviations are shown in Fig.6(b) with the maximum error being 0.021m. We can estimate from these experimental results that this system is possible enough to be realized.

7. Conclusions

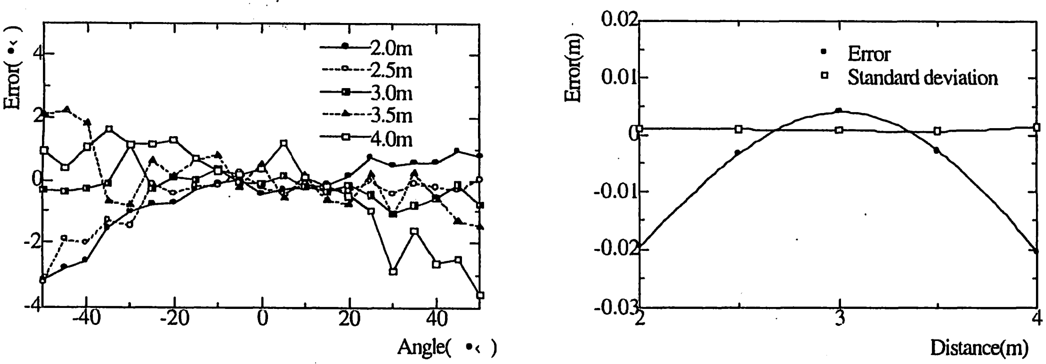
This paper is summarized as follows:

1) This paper suggests a novel tracking method using information taken directly from the license plate.
2) A license plate is extracted from unknown environment by using correlation.
3) This system can track a target image continually regardless of the size of the target image in a screen. It does this by using the preceding image instead of the specific image as an object of correlation.
4) If it is extracted by only correlation, the target



(a) (b)

Fig. 5. Tracked a license plate (a) Before calibration (b)After calibration



(a) (b)

Fig. 6. Error and standard deviation of each angle (a) in 2.0m• 4.0m (b) Error and standard deviation

boundary square with the passage of time. This system compensates for this problem by tracking the target image continually through calibration using characters on the license plate.

5)It becomes possible to extract the characters without being affected by shadows and uneven lighting using MMS method.

8. References

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