Nighttime Vehicle Distance Alarm System

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Abstract: - Keeping safe distance between two cars is an important topic for car accident prevention. This paper presents a practical nighttime vehicle distance measuring method based on a single CCD image. The method combines the image-based distance measuring system (IBDMS) with nighttime vehicle distance alarm system. To solve the nighttime feature extraction problem, the proposed method uses two taillights as the feature. Based on the proportionality of similar triangles, distance between a CCD camera and taillight of the vehicle ahead can be measured. The method focuses on detecting taillight and differentiating the targeted vehicle from others on the basis of partial image analysis instead of whole image processing. As a result, high-speed processing and simple configuration of the proposed method have been achieved as demonstrated in this paper.

1. Introduction

Non-contact measuring is a must to measure distance between two moving vehicles. Generally, traditional non-contact measuring methods can be categorized into two types: ultrasonic reflection [1]-[3] and laser reflection [4]-[6]. Many researches based on these two methods have been published [4]-[6] over the past years. It is well known that both ultrasonic or laser reflection methods are based on reflective theory and wave pulse counting for measuring distance. Theoretically, these two methods can be used at nighttime. It is very difficult, however, in finding a stable reflective surface on moving vehicles during the night. As a result, these two methods are generally used at low-speed reversing/maneuvering of vehicles.

There are many vehicle distance measuring systems based on image processing or pattern recognition [7]-[8] techniques. During the nighttime, however, the use of spot light is not allowed. Thus, the recognition of lane or vehicle's shadow based on these methods is difficult because clear images can not be obtained. Therefore, vehicle distance measuring systems based on image processing or pattern recognition methods are generally unreliable and even fail to work properly in the dark.

This paper presents an application of our previous researches [9]-[14]. With a new algorithm established in this paper, the IBDMS is used for night-time vehicle distance measuring. Because distance between two taillights is fixed, image size of these two taillights in images will be different at different shooting distances. The configuration of the system is established in such a way that a CCD camera is set at certain height so that its optical axis is parallel with the road. This will allow the two taillights' image locating somewhere around the middle scan line of the CCD image. As demonstrated in Figs. 1 and 2, we can identify the location of the taillights in images by analyzing color and intensity information over a particular region. With the knowledge of the taillight locations in the images, pixel number between two taillights can be determined for calculating the distance between two vehicles.

Fig. 1 Photo showing the measured distance of 442.8 cm while the actual distance is 415 cm.

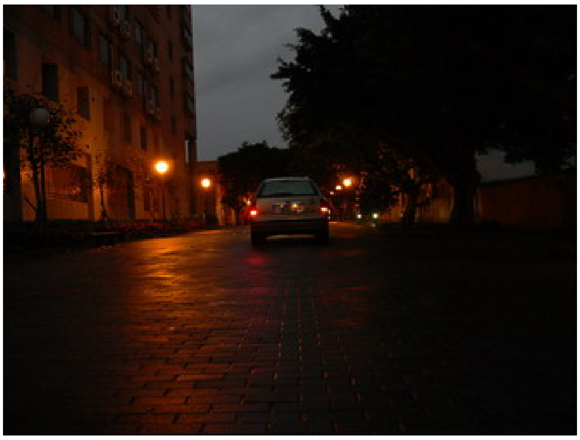

Fig. 2 Photo showing the measured distance of 994.3cm while the actual distance is 931 cm.

2. Theory of distance measuring

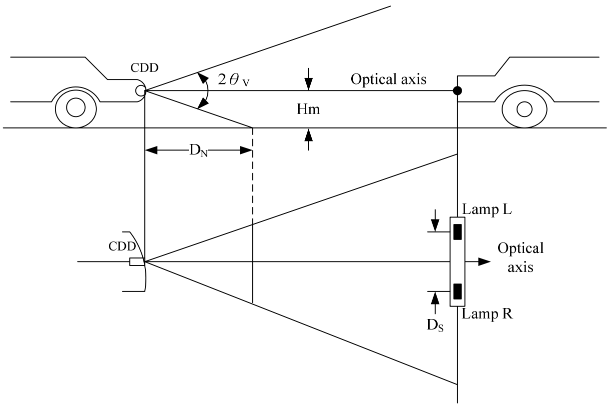

Fig. 3 Configuration of the proposed measuring system.

Figure 3 is the configuration of the proposed measuring system, depicting both the vertical and horizontal views, where the top of Fig. 3 shows the vertical view and the button shows the horizontal view. A CCD camera is mounted at height H_m with its optical axis parallel with the ground. By this structure, the taillights' image will appear around the scan line $1/2N_V(max)$ in the images. D_N is the minimum measuring distance. The distance between two taillights, Lamps L and Lamp R, is a constant D_S. The position of Lamp L and Lamp R in images is denoted as P_L and P_R, respectively, in Fig. 4. Pixel number between P_L and P_R is $N_{LR}(H_K)$. As demonstrated in our previous work [9]-[12], there is a direct proportional relationship between the horizontal pixels' counting and horizontal distance. For distance H_K with a view angle of $2\theta_H$, the maximal horizontal distance $D_{max}(H_K)$ covered by the view angle can be expressed as:

$$D_{\max}(H_K) = \frac{N_H(\max)}{N_{LR}(H_K)} \times D_S \qquad (1)$$

In Fig. 4, the shooting distance H_K can be expressed as:

$$\begin{aligned} H_K &= \frac{1}{2} D_{\max}(H_K) \times \cot\theta_H - hs \\ &= \frac{1}{2} \frac{N_H(\max)}{N_{LR}(H_K)} \times D_S \times \cot\theta_H - hs \end{aligned} \qquad (2)$$

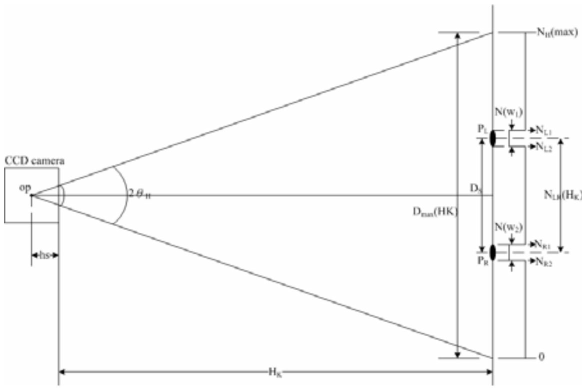

Fig. 4 Diagram illustrating the IBDMS.

The shooting distance H_K indicating the distance between two vehicles can be determined by (2) . θ_H is half of the horizontal view angle $2\theta_H$. hs is the distance between the optical origin and the front end of the CCD when the view angle is known as $2\theta_H$. The parameter θ_H can be determined through a proposed mechanism previously revealed in our researches [13]-[14]. By this mechanism, the view angle θ_H and hs can be ascertained for any brands of CCD cameras. When the position of the two taillights is identified, pixel number between two taillights in the image is $N_{LR}(H_K)$. By (2), the distance between two vehicles can be calculated. Note that the image size of the taillights in images varies depending on the distance and the brightness of the taillights in images might be up to the saturation level. Furthermore, the image might be affected by other cars or streetlamps. In these cases, pixel numbers N(w1) and N(w2) might be different. To solve this problem, pixel counting between P_L and P_R is decided by their image center.

3. Identification of taillight position in images

As shown in Figs. 1 and 2, image size of the taillights in the image frame varies depending on different distances. However, the taillight's image is still at the same region in the image. At first we eliminate the image outside the particular region, as shown in Figs.5 and 6. Subsequently, we use color and intensity information to analyze the remaining region for identifying the taillight position in the images. Because partial image analysis rather than whole image processing is required, computation time and cost can be significantly reduced.

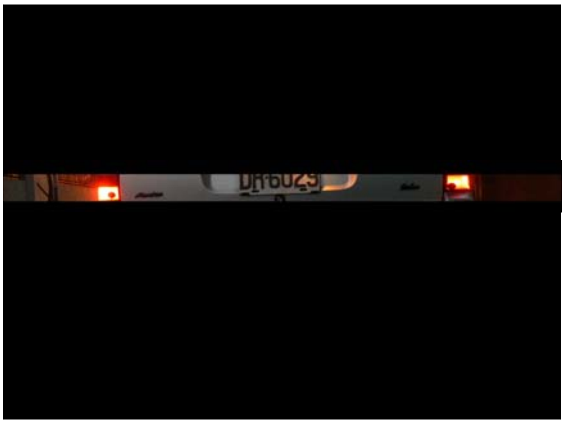

Fig. 5 Image showing the particular region at 415 cm

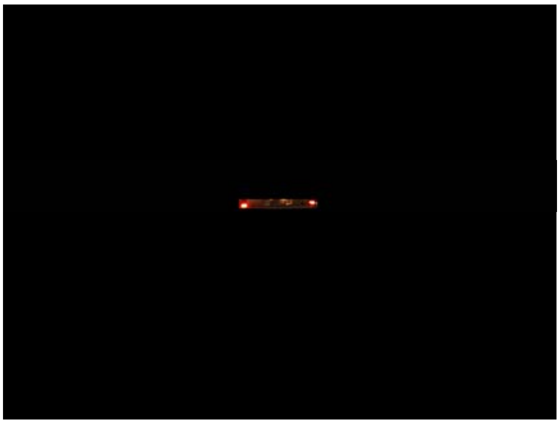

Fig. 6 Image showing the particular region at 931 cm

Figs. 7 and 8 show images of the two taillights after processing via a color and intensity decision function. After combining the scan line of the particular region by an OR operation, we can obtain the result as Figs. 9 and 10.

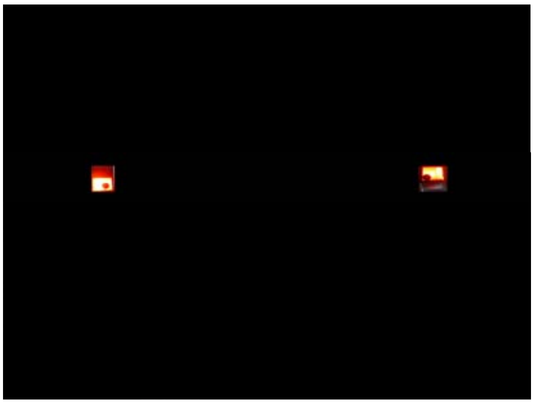

Fig. 7 Image of taillights at 415 cm

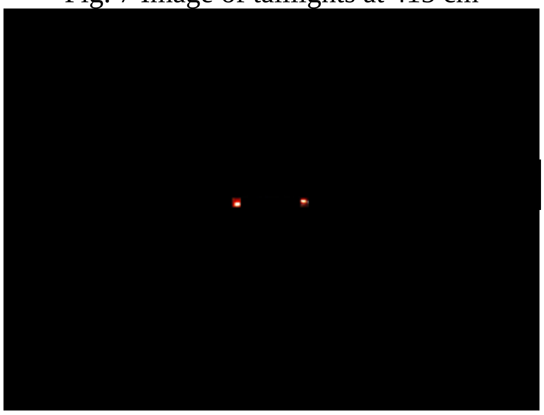

Fig. 8 Image of taillights at 931 cm

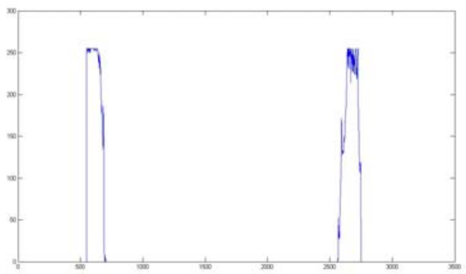

Fig. 9 Intensity signals at 415 cm after operation

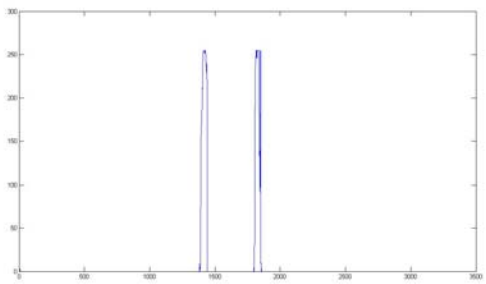

Fig. 10 Intensity signals at 931 cm after operation

After all the operations, the intensity signals of the right and left taillights are identified as shown in Figs. 9 and 10. Note that N(w1) and N(w2) in Fig. 4 might have different pixel numbers as revealed in Figs.7 and 8. Therefore, $N_{LR}(H_K)$ is calculated as the pixels counting between the center of N(w1) and N(w2).

$$N_{LR}(H_K) = \frac{1}{2} \cdot [(N_{L1} + N_{L2}) - (N_{R1} + N_{R2})] \quad (3)$$

4. Separate different cars from different lanes

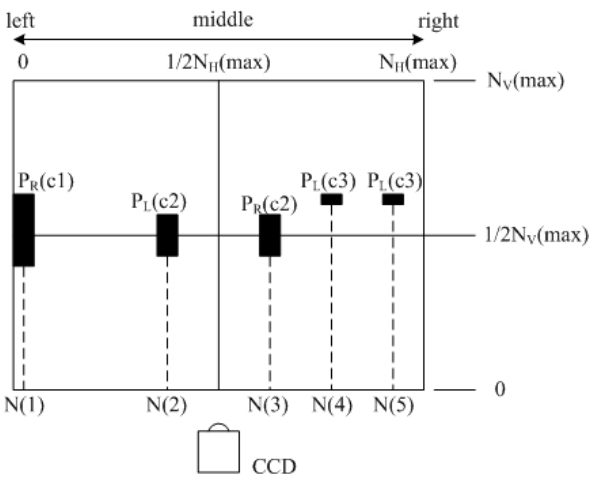

Fig. 11 Diagram illustrating vehicles in different lanes.

For vehicles moving in different lane, the alarm should not be activated. So we have to eliminate the image signals of cars which are not in the same lane from the image, focusing only on the vehicle ahead in the same lane. By this algorithm, the proposed measuring system is more suitable for fitting into practical situations.

With reference to Fig. 11, there are three cars in the image. $P_R(c_1)$ stands for a taillight of a car in the left lane driving in a short distance from our car. Therefore, only the right taillight is captured by the camera. $P_L(c_2)$ and $P_R(c_2)$ are images of the two taillights of the car ahead in the same lane. $P_L(c_3)$ and $P_R(c_3)$ are images of the two taillights of a car driving in a longer distance from our car in right lane. There are five taillight regions in total shown as N(1), N(2), N(3), N(4) and N(5), respectively.

$$\left[\frac{N(i)+N(i+1)}{2} - \frac{N_H(\max)}{2}\right] \leq \delta(i) \quad (4)$$

$$i = 1....N$$

$$\delta(i) = \left[\frac{N(i+1)-N(i)}{2}\right]^2$$

As long as (4) is proved valid, we have

$$N_{LR}(H_K) = N(i+1) - N(i) \quad (5)$$

As shown in Fig. 11, δ (i) has minimum value when i=2, which means $N_{LR}(H_K)$ =N(3)-N(2) by discarding N(1), N(4) and N(5). The implication is that taillights in different lane in the images will not be included in the procedure for counting $N_{LR}(H_K)$.

5. Experiment results

CCD camera adopted: PANASONIC Lumix DMC-FZ30.

Distance between Laser A and Laser B: (D_{min}) = 20 cm.

Camera resolution: N_H(max)= 3264 pixels, N_V(max)= 2448 pixels.

Intrinsic parameters: $\cot\theta_H$ = 2.11 , $\cot\theta_V$ = 2.81 , h_0 = 1.121 cm

Table 1 The measuring results

Distance between two cars	$N_{LR}(H_K)$	Measured distance	Error %
244	2096	260.3599	6.7
415	1221	442.7949	6.7
634	801	674.8938	6.5
931	542	994.2719	6.8
1244	406	1332.507	7.1
1572	329	1643.524	4.5

2000	250	2160.074	8.0
2370	212	2547.902	7.5

*In this experiment, we use Ford Mondeo as our test car. The distance between two taillights is D_S= 157 cm.

6. Conclusions

In this paper a novel distance measuring method incorporating the CCD-based distance measuring system and partial image analysis technique is presented for preventing car accidents at night. Based on the proposed method with a special structure, any brands of CCD camera can be used to measure distance between two vehicles. The partial analysis technique used in this paper has been proved to be effective in reducing the processing time. The problem of different lanes has been solved by our proposed method. Experiment results show that the error rate via the proposed approach is acceptable for car accident prevention. There are a lot of potential applications of the nighttime image based distance measurement. In the future, we shall consider fitting the method into real situation, such as numerous brands of cars, and implementing the proposed system on a SOPC embedded system to allow a faster and more accurate measuring.

Acknowledgment

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