A Real-Time Collision Warning System Based on TLC Computation

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Abstract. A real-time collision warning system based on TLC[1] computation is proposed. Multi-frame lane detection and analysis are adopted so that the TLC calculation algorithm is more reliable. Lane departure is analyzed and vehicle coordination is estimated. These parameters can be used in an intelligent vehicle for warning or lateral control. Experimental results show that the proposed algorithm, calculates TLC acceptably.

Keywords: Computer Vision, Time to Lane Crossing, Collision Warning System, Intelligent Vehicle

1 Introduction

The growing volume of traffic requires higher and higher level of traffic safety. Driver assistant system based on computer vision is helpful to reliving the contradiction between enhancement of traffic safety and increment of traffic density. The system can gather information on the environment surrounding the vehicle and detect dangerous condition [1].
Lane departure detection module is an important part in driver assistant system. It is used to warn the driver in dangerous condition or to control the vehicle's lateral position on the road. One of the methods to do this is to calculate the Time to Lane Crossing. TLC is defined as the time until the vehicle will cross either edge of the roadway, assuming both the vehicle's speed and font wheel steering angle remain unchanged.[2] Figure 1 is a visualization for TLC.
A warning is issued when TLC falls below a threshold. If the operation system is operational, another warning indicates when an intervention would begin.
The conditions are:

- Limited access highways, away from entrance and exit ramps where road-edge striping is intentionally interrupted
- White striping in good condition
- Daytime, non-shadowed, illumination
- Pavement free of water, snow, or other contaminants

The real-time property of our algorithm makes it different from the similar TLC calculation algorithms [3, 4]. To test the proposed algorithm, we have used the data of the GOLD system [5]. An experimental land vehicle, which is shown in figure 2, gathers this data.

[1] Time to Lane Crossing

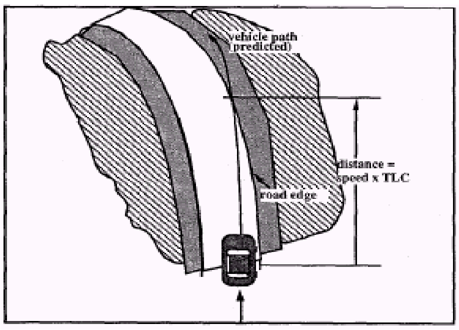
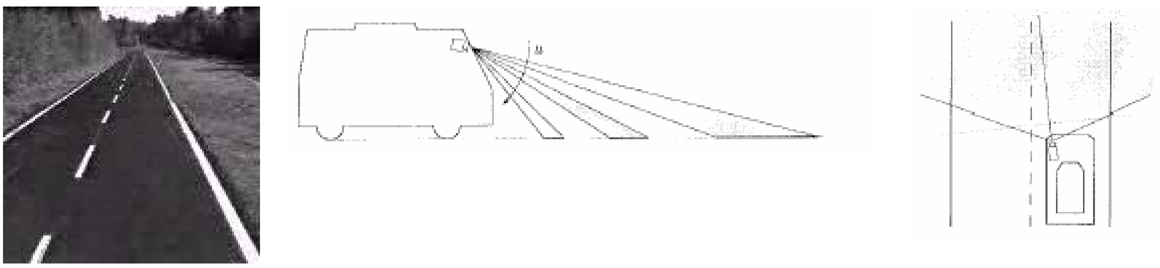


Fig. 1. Time to Lane Crossing (TLC) assuming constant steer angle [2]

Fig. 2. Experimental land vehicle [5]

This vehicle gathers information (images) from its environment using two cameras. Because the GOLD system uses the information of the cameras to detect both lanes and obstacles, so we don't need to use both of the information of the cameras. We have used the images of the left camera because the GOLD system has used the images of this camera to detect lanes (see Fig. 3).
In the following sections we describe our algorithm for calculating the TLC. Experimental results are presented in the last section.



(a) **(b)** **(c)**

Fig. 3. (a) A sample image taken by the left camera of the GOLD system. (b) The left camera of the experimental vehicle from the right view of the vehicle. (c) The left camera of the experimental vehicle from the top view of the vehicle.

2 Real-Time Algorithm for Calculating TLC

The algorithm is based on processing only the last line of each image frame. Using this method will dramatically reduce the time complexity of the goal system. Our algorithm consists of the following four main parts:

1. Detecting the base point
2. Calculating the Vehicle's Angle from the lane direction
3. Determining the Vehicle's lateral offset from the left lane
4. Calculating the TLC

2.1 Detecting the base point

The base point is the intersection of the left lane and a horizontal line assumed on the bottom most row of an image frame. This is shown by an arrow in figure 4.

Fig. 4. Base point

To detect this point we used the simple gradient for edge detection:

$$G_x = f[i, j+1] - f[i, j] \quad (1)$$

$$G_y = f[i, j] - f[i+1, j] \quad (2)$$

$$G[f[i, j]] = |G_x| + |G_y| \quad (3)$$

2.2 Calculating the Vehicle's Angle from the lane direction

We used equation 4 that is visualized in figure 5.

$$Sin(\theta) = \frac{x_1 - x_2}{VT_{pf}} \quad (4)$$

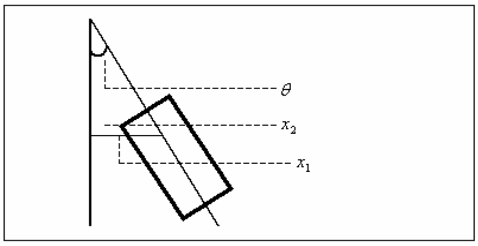


Fig. 5. Visualization of parameters used in calculating vehicle angle as of equation 4

In equation 4, V is the speed of the vehicle and T_{pf} is the time interval between taking two image frames. (i.e. 1/30 sec.) As we can understand from equation 4, Our TLC calculating algorithm uses two frames to calculate the TLC. This will lead to a more reliable algorithm [1].

2.3 Determining the Vehicle's lateral offset from the left lane

To calculate the vehicle's lateral offset from the left lane we used equations 5 and 6.

$$\theta = Arc\sin\left[\frac{(x_p - x_c)y}{RVT_{pf}}\right] \quad (5)$$

$$y_{off} = d_x - \frac{100y(x_c - n_x)}{R} \quad (6)$$

The parameters used in equations 5 and 6 are defined as follows:

θ: Vehicle's angle from the direction of left lane (in degree)
y_{off} : Vehicle's distance from left lane (in meter)

x_p : Horizontal coordination of base point of the previous image (in pixel)

x_c : Horizontal coordination of base point of the current image (in pixel)

y : Width of the lowest part of image in the real world (in meter)

R : Vertical coordination of base points, which is constant according to the base point definition.

d_x : Distance of left camera from the left lane (in meter)

n_x : Horizontal coordination of base point in normal situation (in pixel)

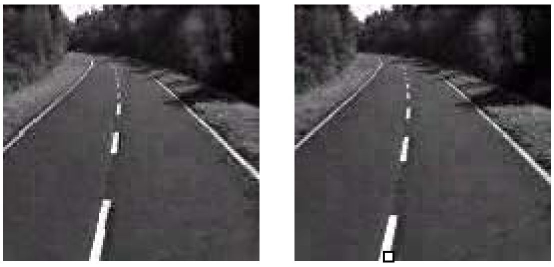
2.4 Calculating the TLC

The final part of TLC calculating algorithm is to calculate TLC according to the vehicle angle and lateral offset from the left lane and from its speed. This task can be done using equation 7.

$$TLC = \frac{X - 100y_{offset}}{100VSin\theta} \tag{7}$$

3 Experimental Results

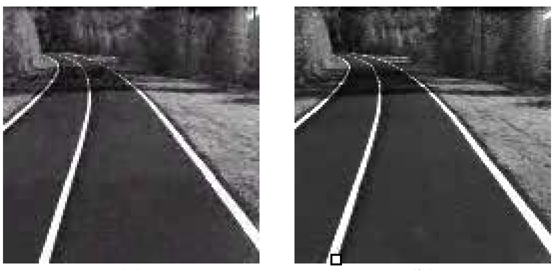
This section shows the experimental results using the presented algorithm to calculate the TLC of the images of the GOLD system. Because the images of the GOLD system are taken in different light conditions so we can be confident about the robustness of the presented method. The output of the algorithm for some of the pictures of the GOLD system is presented in figures 6 to 8. In these figures (a) and (b) denotes two sequential road images.



(a) (b)

Vehicle Angle: 3.2 deg.
Lateral Offset: 7.4 cm.
TLC: 0.000 sec.

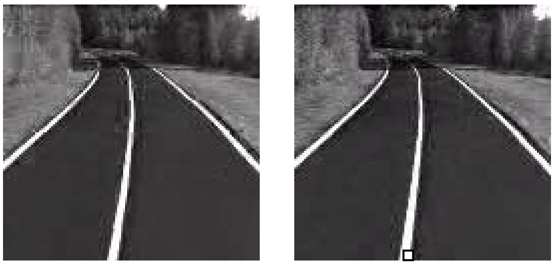
Fig. 6. Very dangerous state



(a) (b)

Vehicle Angle: 6.5 deg.
Lateral Offset: 120.0 cm.
TLC: 0.006 sec.

Fig. 7. Dangerous state



(a) (b)

Vehicle Angle: 0.0 deg.
Lateral Offset: -34.3 cm.
TLC: ∞ sec.

Fig. 8. Safe state

In each of the Figs. 6 to 8, we have two frames which are taken continually. Each of these figures shows the vehicle angle from left lane plus its lateral offset from left lane. The last parameter which has been carried out in the Figs. 6 to 8 is the TLC. According to the following strategy we can determine the state of the vehicle from its TLC.

The strategy of the system to determine degree of the danger condition is based on [2]:

1. Very dangerous condition: $TLC \le TLC_i$
2. Dangerous condition: $TLC_i < TLC \le TLC_w$
3. Safe condition: $TLC > TLC_w$

, which TLC_i is the lower threshold and TLC_w is the upper threshold.

It is important to indicate that the strategy of our algorithm is on its high speed in calculating the TLC. That is because we need to process only one line of each image frame, which is that lowest row in each frame so the speed of TLC computation using the current method is at least Y times higher than similar methods [2,4] if the image resolution is Y x Y.

4 Conclusions

In this paper a real-time collision warning system based on TLC computation, was introduced. The proposed method can be used in a lane departure warning system. Such a system has the capability of warning the driver in a limited access highway in different situations, using a considerable real-time algorithm. Our method calculates the TLC parameter using two continues frames. This operation will increase the reliability of the goal warning system.

References

[1] Jiang Gangy, "Approach to Lane Departure Detection", Artificial Intelligence & Pattern Recognition Open Lab, Shantou University, China, IEEE Proceeding of ICSP2000, (2000)

[2] David J. LeBlanc, "CAPC: An Implementation of a Road-departure Warning System", Proceeding of the 1996 IEEE International Conference on Control Applications, Dearborn, MI, September 15-18, (1996)

[3] Mei Chen, "A Vision-Based Roadway Departure Warning System", Robotics Institute, IEEE, (1995)

[4] Chiu-Feng Lin, "CALCULATION OF THE TIME TO LANE CROSSING AND ANALYSIS OF ITS FREQUENCY DISTRIBUTION", Department of Mechanical Engineering and Applied Mechanics, The University of Michigan Ann Arbor, Michigan, Proceeding of the American Control Conference, Seattle, Washington, June (1995)

[5] Massimo Bertozzi, Alberto Broggi, "GOLD: A Parallel Real-Time Stereo Vision System for Generic Obstacle and Lane Detection", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 7, NO. 1, JANUARY (1998)