Development of Vehicle-to-Infrastructure System using Image Processing Technique

Jakkree Srinonchat

1 Signal Processing Research Laboratory, Department of Electronics and Telecommunication
Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Thailand, 12110

Abstract. Road safety has become an important issue and gained much attention for many years. The vehicle-to-infrastructure is one of the traffic intelligent systems which are developed to communicate with driver. This article presents a development of vehicle-to-infrastructure system using image processing. It focuses to develop of overtaking analysis system to gain higher efficiency when overtaking on a two-lane highway while driving during night-time. The depth of field and stereo vision techniques are used to determine the car distance. The zigbee standard is used to communicate between the vehicles to infrastructure. The result shows that the processing time needs only 0.54 second and it need at least 250 meters to overtake a car with the speed 40km/hr.

Keywords: vehicle-to-infrastructure, depth of field, stereo vision

1. Introduction

Road safety has become an important issue and gained much attention for many years [1-3]. To reduce traffic accidents, researchers have proposed several vehicle-to-vehicle (V2V) collision warning systems (CWS) to avoid vehicle collisions and vehicle-to-infrastructure (V2I). The V2V collision warning system can be categorized into three classes based on the employed technologies: radar-based, camera-based, and radio-based. The radar-based and camera-based collision warning systems are mainly designed to avoid forward collisions of vehicles on the same lane due to the line-of-sight limitation resulting from the radar and camera technologies [4]. The radio-based collision warning system is more capable of avoiding vehicle collisions in off-sight scenarios, such as the four corners of an intersection. Vehicle to Infrastructure communication allows the vehicle to send messages to the infrastructure about the state of the vehicle, and to a limited extent using on-board radar and other sensors, about the immediate roadway environment [5].

From fig. 1, a function-level technology may be composed of several hardware, software, or activity elements that together deliver a cohesive function or service. This research is investigated and focused to using the Zigbee communication technology with real-time image processing for the V2I system [6]. It focuses to develop of overtaking analysis system to gain higher efficiency when overtaking on a two-lane highway while driving during night-time. The study will identify the distance of the oncoming opposite lane car and its velocity which results in the overtaking decision by using 2 images. The benefit with the investment cost is not expensive; the use of an existing cars original equipment camera can be selected. The step of processing starts from the vehicle specification by using the provided algorithm structures. Inside these algorithms, there are several vehicle specifications and their simulation models constructed. After knowing the vehicle specification, the proper equation with the real condition will be applied. Finally, the overtaking decision by the database of computer vision will be exposed.
2. Depth of Field (DOF)

Depth of Field (DOF) is the distance between the focused object to the film plane. Depth of Field is proportional to the square of object distance as in Equation 1.

\[ \text{DOF} \propto (\text{Object Distance})^2 \]  

(1)

That means if the distance of the object increases twice, Depth of Field will be four time increase. However, the increase of the distance will affect the decrease of the object size and its perspective will change. From Fig 2, the figure shows the model of the cars’ motion process. The car installed the camera will be at bottom-end. The image on the top right displays the depth of field of the image and the image on the bottom right shows the perspective view. Where

\[ \frac{a}{b} = \frac{c'}{d'} \]  

(2)

\[ \frac{z}{\lambda} = \frac{c'}{d'} \]  

(3)

\[ \frac{a}{b} = \frac{z}{\lambda} \]  

(4)

\[ Z = \frac{\lambda a}{b} \]  

(5)

a = a real distance of the headlight
a’ = the horizontal distance from the left headlight to the center of the camera
b = the perspective size of a in the image plane
b’ = the perspective size of a’ in the image plane
c = the hypotenuse size of the right triangle with the Z leg and the a + a’ leg.
c’ = the hypotenuse size of the right triangle with the Z leg and the a’ leg
Z = distance between the object and the camera
\( \lambda \) = focal length of the camera
The image of DOF is then pass through the Blob Coloring to calculate the centroid by using equation (6)-(8).

\[ S = \text{Regionprop}(Ybw,"\text{Area","Centroid"}) \]  
\[ \text{Distance} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \]  
\[ \text{Distance} = \sqrt{(\text{Centroid}_x_1 - \text{Centroid}_x_2)^2 + (\text{Centroid}_y_1 - \text{Centroid}_y_2)^2} \]  

3. Methodology
The process of this experiment is shown in Fig. 4.

Fig. 4: process of this experiment

1) Video Acquisition - For record the moving pictures from digital camera (real time recording)
2) Frame Grabber - For convert a moving file to digital-still-picture. In the research, it is necessary to consider every frame for data analysis. For usability, the camera can be set up to capture images in real-time. However, practically, this step can be neglected.
3) Image Preprocessing - For evaluate a distance between headlight by DOF and Blob Analysis.
4) Final Processing - For process the data by virtual perspective technique.
5) Decision Data - It is a data output used for taking a decision (depending on vehiclespeed, distance between vehicle and digital camera.

4. Experiments and Results

This research used 10 cars to investigate and adjust the experiment.

<table>
<thead>
<tr>
<th>meters</th>
<th>Day time image</th>
<th>Night time image</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td><img src="image1.jpg" alt="Day time image" /></td>
<td><img src="image2.jpg" alt="Night time image" /></td>
</tr>
</tbody>
</table>
Fig. 5: Method to find the center of the vehicle headlight from 2 cameras

Figure 5 expresses the concept of finding the average value of focus point from 2 cameras, which are (a) the image from the first camera, (b) the image from the second camera and (c) the combination of 2 images which carries out focus point of white light group with correctness and accuracy, by using the equation (1).

5. Conclusion

This article presents a development of vehicle-to-infrastructure system using image processing. It focuses to develop of overtaking analysis system to gain higher efficiency when overtaking on a two-lane highway while driving during night-time. The depth of field and stereo vision techniques are used to determine the car distance. The processing time needs only 0.54 second, in the process to stop overtaking and by considering the image only 2 frames after the identification of headlight distance. The advantage is higher efficiency for driver’s decision at night-time period. The velocity 40 km./hr. must do the overtaking decision distance more than 250 meters. However, there is an error of determination of vehicle size and the difference between moving images from non-smooth road, affecting the irregular of the light. In addition, the factor of moving car’s velocity still needs further development in the future.

6. Acknowledgements

I would like to thank the National Research Council of Thailand (NRCT) for the financial support in this project (NRPM:2555A16502049, project code: 52874).

7. References


