SINGLE BOARD COMPUTER BASED REAL TIME FORWARD COLLISION WARNING SYSTEM FOR DRIVER SAFETY

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Abstract- This paper represents a Forward Collision Warning system (FCW) for driver to decrease the number of most typically known rear-end accidents. Keeping sufficient headway is enforced by traffic authorities in many countries to provide safe travels to passengers. Even when headway is kept sufficient, a little disturbance or lack of concentration may lead to a rear-end collision. In this article, we propose a set of lane detection analysis techniques and distance estimation algorithms to segment lanes and moving car detection. Thus, the computer based real time working forward collision warning system will automatically alert the driver in the critical situations for traffic and passenger safety.

Keywords- Forward Collision, Real Time, Lane Detection, Car Detection, Distance Estimation.

I. INTRODUCTION

Each year millions of traffic accidents occurred around the world resulting loss of lives and properties. Traffic safety report from the National Highway Traffic Safety Administration (NHTSA) stated that rear-end collision is the most common accident type (32.9%) in 2012 among out of all crash modes [1]. Therefore, numerous technological innovations and improvements are arising to reduce traffic accidents. Safety instruments on vehicles can be classified as active and passive. Active safety systems describe systems understanding the state of the vehicle and trying to avoid and minimize the effect of crash. Mentioned safety instrument class includes lasers, sonars, radars, brake assist systems etc. [2]. On the other hand, passive safety instruments are used to maintain a degree of safety for abnormal events such as seat belts, cameras and air bags. Since cameras also acquire data in a non-intrusive way, they are also classified as passive sensors [3][4].

Measuring travel time of the emitted signal by active sensors could help to detect the distance between own vehicle and target object directly. However, there are some disadvantages for mentioned systems such as short range and slow response time [5]. Moreover, if number of cars around the vehicle increases, there will be interference problem among the sensors. On the contrary, passive camera sensors has lower cost and can provide diverse information on large regions.

In this paper, we proposed a single board computer based real time forward collision warning algorithm. First of all, camera should detect own lane of the vehicle to search for the front one. Then, these detected lane marks will be used to specify region of interest (ROI) of front vehicle. Thus, ROI can be determined by using detected lane marks and then front vehicle will be searched. Also, colorful ROI image is converted to grayscale image to reduce processing load and is filtered by Gaussian filter to remove noise from image. In this way, more accurate results are obtained. Next, front vehicle is detected by using shadow underneath vehicle and so Otsu thresholding method is used to detect this shadow. In addition, bounding box is found by using left, right and lower borders of detected shadow. Finally, distance of front vehicle is estimated by using curve fitting approach. Theflowchart of the proposed algorithm isshown in**Fig.1**.

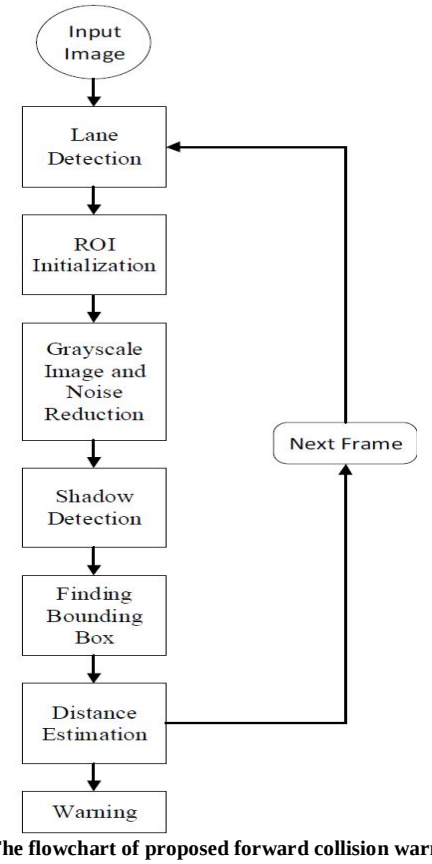


Fig.1. The flowchart of proposed forward collision warning algorithm.

II. LANE DETECTION

Firstly, possible region of lane marks is determined to improve algorithm performance and get more reliable results. The region is defined by referring geometry information of camera such as height and tilt angle. Then, inverse perspective mapping is applied to detected region to avoid disadvantages of perspective effect such as unfixed lane mark height and width. Afterwards, this colorful inverse perspective mapping image is converted to grayscale image to decrease computational complexity and filtered by 3x3 Gaussian filter to remove noise. In addition, specific lane marking detector is used for lane mark detection and Canny edge detection is applied to find edges of detected lane marks [6]. Finally, Hough transform is applied to get parameters of lane marksuch as length and angle [7]. The resultant image of lane marks is shown in **Fig.2**.

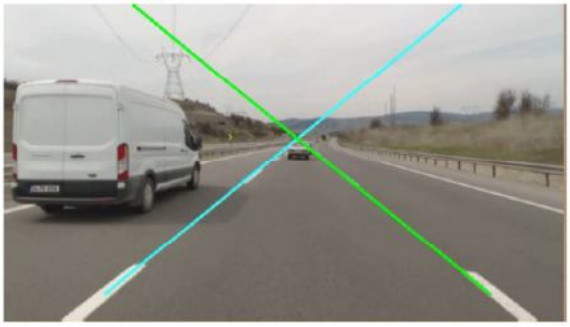


Fig.2. Detected lane marks.

III. VEHICLE DETECTION

There are various approaches to detect vehicle such as motion based, stereo based and appearance based. In motion based approach, detection is done by taking advantage of the difference between two frames [8]. In stereo based approach, depth map which is obtained by deducting images captured from two cameras at the same time is used [9]. This approach is expensive and has much processing load because of requiring two cameras. In appearance based approach, rear vehicle lights, texture, color, symmetry, corners, vertical/horizontal edges and shadow underneath the vehicles are used for detection and single camera is enough for this approach[10][11]. In proposedsystem, appearance based approach and shadow underneath the vehicle havebeen preferred because they require less processing load.

3.1. ROI Initialization

Driver should be warned to avoid forward collision, so exact location of the front vehicle should be recognized by the system. Thus, front vehicle can be searched in our lane as it needs to be. The input image is masked by using detected lane marks in Section 2 to determine ROI. The masked image is shown in **Fig.3**.



Fig.3. ROI image.

3.2. Grayscale Image and Noise Reduction

The colorful ROI is converted to grayscale image to decrease computational complexity. Hence, next processes of proposed algorithm become simple and are implemented faster.

Noise is a big problem for vision based systems. The systems should have noise tolerance or the noise has to be removed to get more accurate results. In our system, noise has been removed by using 3x3 Gaussian filter as seen **Fig.4**.

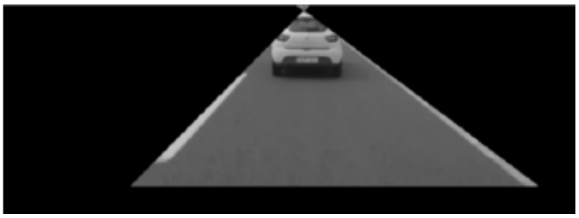


Fig.4. Noise reduced grayscale image.

3.3. Shadow Detection

Underneath shadow of front vehicleis going to give information about founding out next vehicle.Image thresholding methods are used and assisted while observing shadow in the image. After the detection of underneath shadow, the bounding box is created around itfor observationand distance calculation of vehicles.

Thresholding is a process which converts grayscale image to black and white image and this thresholding is expressed by **Equation 1**.

$$g(x, y) = \begin{cases} 1, & f(x,y) > T \\ 0, & f(x,y) \le T \end{cases} \qquad (1)$$

where T is thresholding value, f(x,y) is a pixel value of grayscale image and g(x,y) is a pixel value of black and white image. In suggested system,Otsu thresholding method is chosen because T can be determined automatically [12]. Detected shadow image by using Otsu thresholding method can be seen in **Fig.5**.

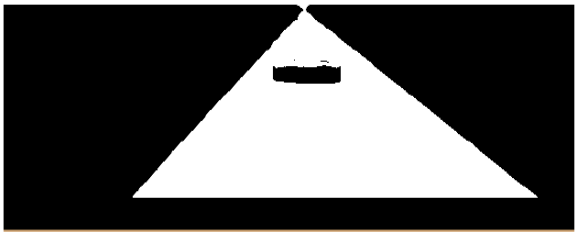


Fig.5. Detected shadow image.

3.4. Finding Bounding Box

Observed vehicle is going to be fit inside a square because height of most of vehicles are seen equal to their width in rear view. To achieve this, left, right, and lower point of shadow can be found. However, left and right point of shadow will be enough for the program to calculate width of the vehicle. Detected vehicle is shown in **Fig.6**.

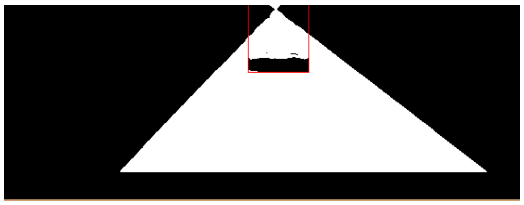


Fig.6. Detected vehicle.

3.5. Distance Estimation

There are basically two approaches for distance estimation techniques as stereo based and monocular based. Stereo based approach is expensive because of requiring two cameras and it needs much processing load to synchronize these cameras. Thus, monocular based approach has been preferred in suggested system.

Pixel depth is the number of pixels from lower part of the image to coordinates of detected vehicle.

Previously, the real distances of vehicles and their pixel depths have measured between 2 and 60 meters at intervals of one meter. A function is obtained by curve fitting method by using real distances and pixel depths corresponding these real distances. Then, vehicle distance is calculated by using proposed function. The function gets pixel depth value of detected vehicle as input and returns its estimated real distance. Obtained function is given in **Equation 2**.

$$y = 1.6153e\text{-}16*x^9 - 1.3954e\text{-}13*x^8 + 5.1542e\text{-}11*x^7 - 1.0624e\text{-}08*x^6 + 1.3391e\text{-}06*x^5 - 1.064e\text{-}04*x^4 + 5.2989e\text{-}03*x^3 - 1.5848e\text{-}01*x^2 + 2.5901*x^1 - 15.588 \quad (2)$$

IV. EXPERIMANTAL RESULTS

The proposed real time forward collision warning algorithm warns driver by calculating distance of front vehicle. The developed algorithm has been implemented on Raspberry Pi 3 Model B (1.2GHz quad-core ARM Cortex-A53 processor and 1GB LPDDR2 SDRAM ram) by using OpenCV library with C++ programming language.The video streams from a camera mounted on avehicle windshield and data are sent to Raspberry Pi 3. The input images have 640x360 image resolution.The average processing time of algorithm is calculated as32~40ms.**Table 1** provides processing times of each component used in system and data collected from tests that satisfied allvalidity criteria.

Table1: Average processing times of each component

Components of proposed algorithm	Average processing time (ms)
Lane detection	18.2
ROI initialization	2.8
Grayscale image and noise reduction	11
Shadow detection	1.5
Finding bounding box	2
Distance estimation	0.02
Total	**35.52**

Some result images are shown in **Fig.7**.

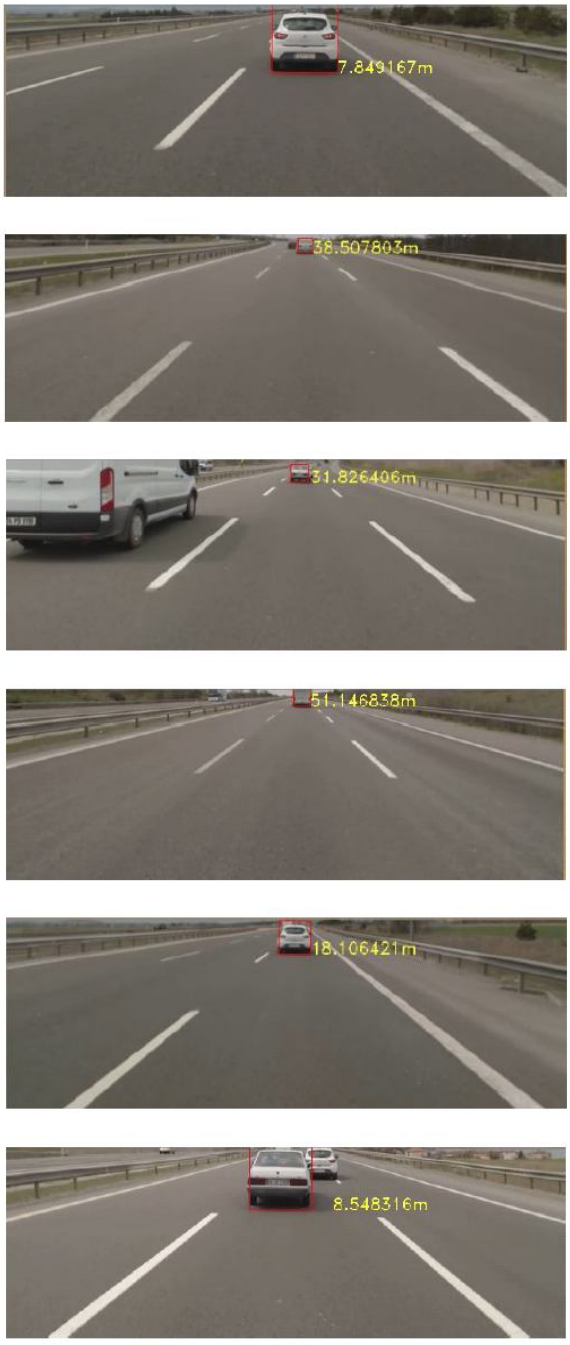


Fig.7. Some result images.

CONCLUSIONS

In this paper, we have developed a warning system algorithm on single board computer to keep the following distance safe. Functionality of the forward collision algorithm on image processing will assist while the driver on road by warning on time. Also, the developed algorithm has been worked successfully on different type of road conditions.

As a future work, the developed system can be integrated in the cars; thus, braking distance can be automatically measured and whenever the car is in danger, the braking system can be immediately activated without any driver interaction.

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