WHITEPAPER

Advanced Driver Assistance Systems:
A Cost-Effective Implementation of the Forward Collision Warning Module

September 2015

L&T Technology Services

Table of Contents

Abstract

A Forward Collision Warning System (FCWS) detects the object (Vehicle/ Pedestrian/ Cyclist/Animal/ Obstacle) which is in front of the host vehicle, to ensure that the host vehicle is at an optimum distance in order to prevent/mitigate the collision by alerting the driver before-hand. Forward collision warning uses some kind of electronic detection device(s) mounted on the front side of the car (often in the front bumpers) that sends out either electronic electromagnetic waves (usually in the radar wavelengths) or takes computer-processed images with a digital camera and processes them to estimate chances of collision.

L&T Technology Services has developed a Vision-based Forward Collision Warning System (FCWS) for intelligent Advanced Driver Assistance Systems applications. In our system, images are analyzed using advanced image processing techniques to detect objects (Vehicle/ Pedestrian/ Cyclist/Animal/ Obstacle) in front of the vehicle.

An important component of a driver assistance system is evaluation of sequences of images recorded with real time camera mounted on moving vehicle. The sequence of images gives information about the automotive environment which has to be analyzed to support the driver.

This paper focuses on the implementation carried out for cost-effective Forward Collision Warning solution that can be applied for Low and Medium range vehicles. This paper also talks about the Verification of the developed algorithms & systems using live videos as well as a Simulator.

Keywords: ADAS, Advanced Driver Assistance Systems, Camera based, forward collision, vehicle detection, active safety systems.

1. Introduction

With the advent of requirement to provide Advanced Driver Assistance Systems in Mid-and-Low Cost Car segments, usage of cost-effective Sensors has become imperative. Usually, High-end Cars have Radar, Lidar and similar systems to implement ADAS.

At L&T Technology Services, we have come up with a cost effective and optimized method, so that our system can be adopted by low and medium range vehicles. Also we have simulated our system with extremely adverse scenarios in order to make sure it will be robust in any climate. Cameras are a suitable solution for this kind of requirement, even when Cameras are used, usage of Monocular single Camera provides the most challenge but also provides economy & cost advantage.

2. Solution Overview

To demonstrate our system, we developed a prototype which completely depends on image processing algorithms. To analyze the computer vision, image processing algorithms are necessary. All algorithms are developed in-house with minimum dependence on OpenCV which is an open source computer vision library by Intel.

Following is the block diagram of Forward Collision Warning System:

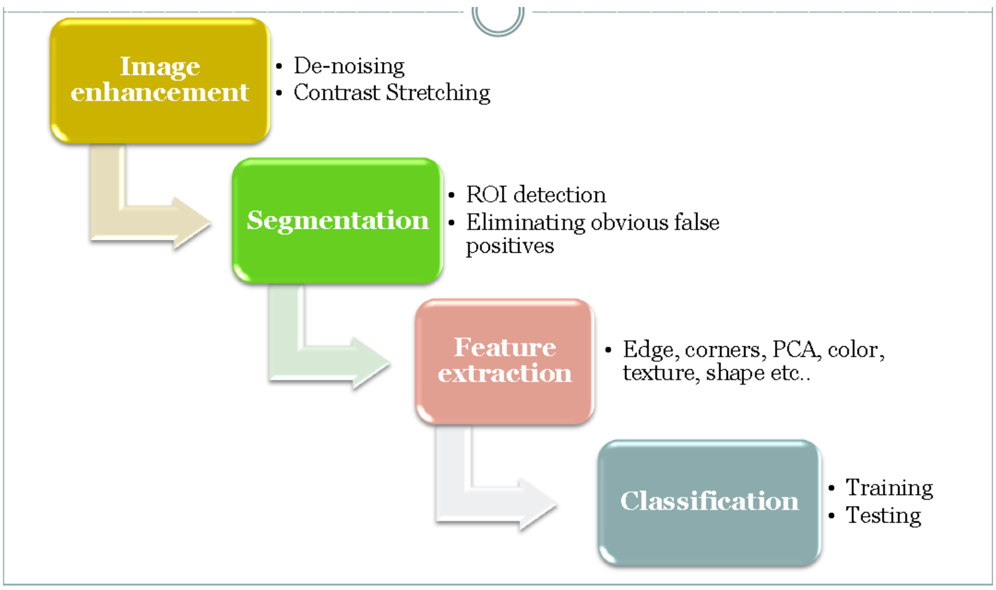


Fig 1: Block diagram of Forward Collision Warning System

2.1 Development

At L&T Technology Services, we are following V model S/W development life cycle. With reference to ample of IEEE Papers, suitable algorithms are selected. Selection of algorithm is not only based on theoretical reference but also based on trial and error method, in which execution time & performance factors play a major role. Tools used to develop our algorithm are MS Visual studio 2012, OpenCV library, Eclipse Helios IDE.

Algorithms developed in-house:

- Image Enhancement
- Image Segmentation
- Feature Extraction
- Object Classification
- Distance Determination

2.2 Overview of Algorithm

OpenCV methodology is used to fetch frames from video, to convert the frame into matrix.

(i) Image Enhancement

First step involves selecting Region of Interest so that only the core part of the image is processed. Raw image is blurred using median blur to remove salt and pepper noise.

(ii) Image Segmentation

Canny edge detection and drawing contours for eliminating false objects (trees, roads etc.).

Adaptive Threshold is applied to produce a binary image representing the segmentation.

Image moments are used to estimate the moving objects. Image moment is a certain particular weighted average (moment) of the image pixels' intensities, or a function of such moments, usually chosen to have some attractive property or interpretation. Image moments are useful to describe objects after segmentation.

(iii) Feature extraction

ORB (Oriented FAST and Rotated BRIEF) is used to extract the feature points. ORB is an acronym for Oriented FAST and Rotated BRIEF which is a fusion of FAST key-point detector and BRIEF descriptor. ORB discretizes the angle to increments of $2\pi/30$(12 degrees), and constructs a lookup table of pre-computed BRIEF patterns. As long as the key point orientation θ is consistent across views, the correct set of points $S_\theta$will be used to compute its descriptor.

(iv) Object Classification

Once the object is detected in the ROI region. The Haar Cascade is used for Vehicle Classification. Haar cascade works on the principle of extracting features from a set of positive and Negative Database of Object which has to be detected.

Some Common Haar features are as follows:

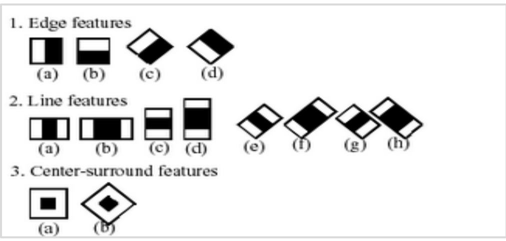


Fig 2: Haar Features

(v) Distance determination

Distance estimation is done using monocular camera intrinsic and extrinsic parameters combined with well-defined algorithm.

2.3 Warning Display

Warnings for the FCWS will be displayed by Image icons as shown below:

Fig 3: Information: FCWS region of Interest is object free (No vehicle detected)

Fig 4: Warning: FCWS region of Interest is in Alert state (Object detected)

Fig 5: Warning: FCWS region of Interest is in Warning state (Vehicle is at closer distance)

2.4 Verification of Algorithm

Once the algorithm is developed, the performance of algorithm is validated using simulated scenarios.

Some of the scenarios are depicted as below:

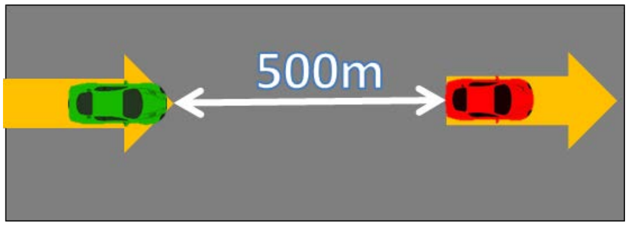
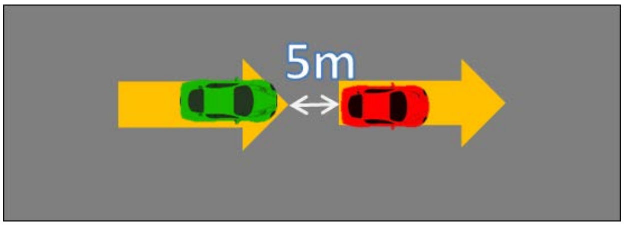
1.	**Normal Scenario**	
2.	**About to Collide**	

Fig 6: Distance levels of Object from Host vehicle

2.5 Verification System Set-up

(i) PC with 8 GB Graphics card

(ii) 2 Monitors

(iii) Logitech Game joystick set up

(iv) Real time simulator game

In this set-up, the first monitor displays the input simulated video (fast-paced game to simulate real-life scenarios). The second monitor is used to display the processed output along with the associated warnings.

Below is the snapshot of the set-up:

Fig 7: Simulator Set-up

3. Output Samples

Shown below are some Output samples on Live Videos:

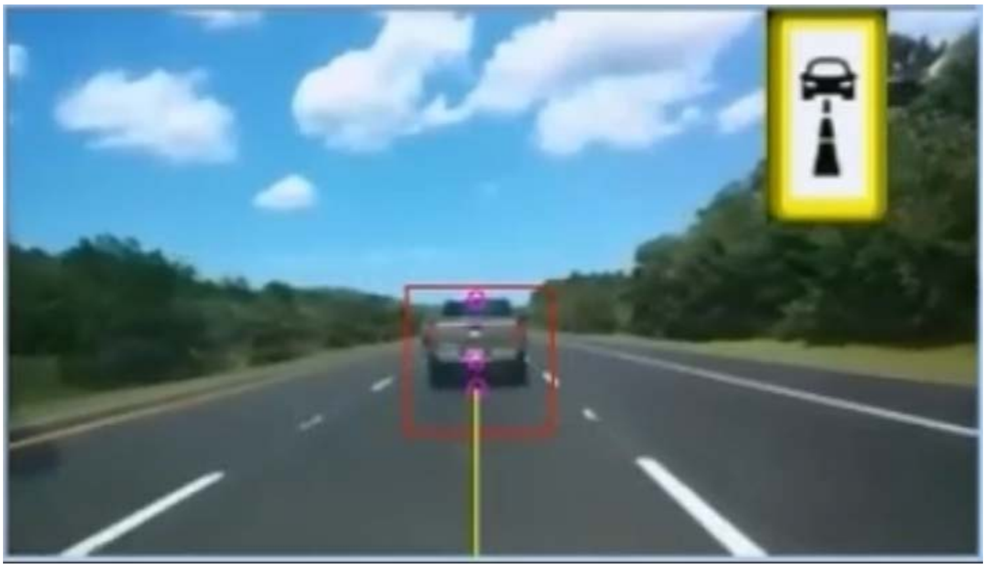


Fig 8: Output Scenario – Object in front is at safer distance

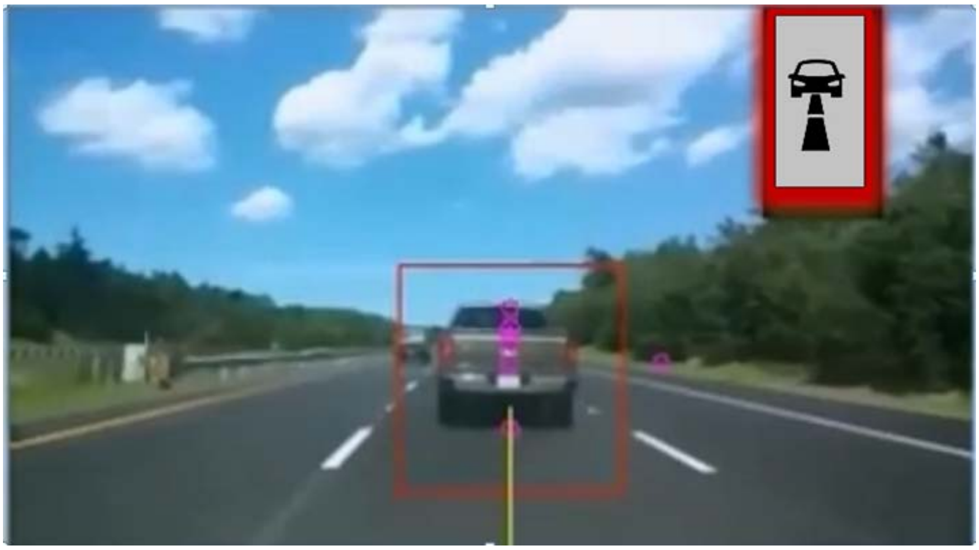


Fig 9: Output Scenario – Object in front is at closer distance

Shown below is an Output Sample for Simulator:

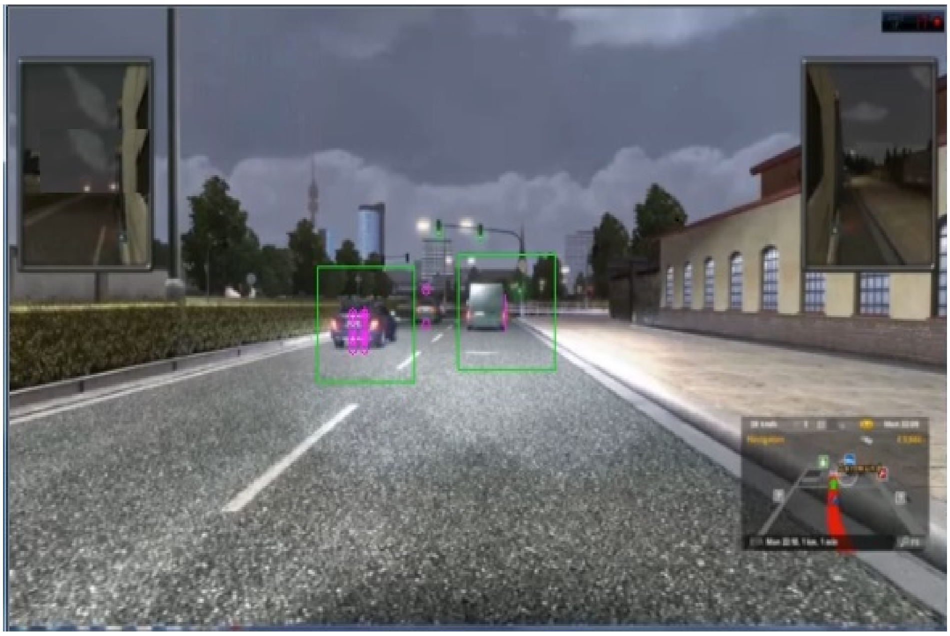


Fig 10: Output Scenario — Simulator

4. Conclusion

In this paper, a cost-effective Forward Collision Warning system using Monocular camera is presented. Monocular camera parameters like focal length, intrinsic and extrinsic parameters are used for distance estimation and thereby doing away with expensive Radar systems.

With this approach, L&T Technology Services have been able to offer an optimized low-cost solution to Forward Collision Warning System. We also have the infrastructure to verify and validate the developed product, test the performance of algorithms, capability to carry-out Competitor Benchmarking and such other exercises enabling the customer to gain a competitive edge in an already mature market.

5. References

[i] National Highway Traffic Safety Administration, http://www.nhtsa.dot.gov/

[ii] Long Chen, Qingqyan Li and Qin Zou, "Block-Constraint Line Scanning Method for Lane Detection", IEEE Intelligent Vehicles Symposium, 2010

[iii] Robert M. Haralick and Linda G. Shapiro, “Computer and Robot Vision,” Vol.1, Addison Wesley Publishing Company Inc., 1992.

[iv] Yue Feng WAN, Francois CABESTAING and Jean-Christophe BURIE, “A new edge detector for Obstacle Detection with a Linear Stereo Vision System”, IEEE Proceedings, 2010, pp. 130 – 135.

[v] Mathias Perrollaz, Anne Spalanzani and Didier Aubert, “Probabilistic representation of the uncertainty of stereo vision and application to obstacle detection”, 2010 IEEE Intelligent Vehicles Symposium Univeristy of California, San Diego, Ca, USA, June 21-24 2010, pp.313-318.

[vi] C. R. Jung and C. R. Kelber, “A robust linear parabolic model for lane following,” Proceedings of XVII Brazilian Symposium on Computer Graphics and Image Processing, Oct. 2004, pp. 7279.

[vii] Hartley, Zisserman - Multiple View Geometry in Computer Vision

About L&T Technology Services

L&T Technology Services is a wholly-owned subsidiary of Larsen & Toubro with a focus on the Engineering Services space, partnering with a large number of Fortune 500 companies globally. We offer design and development solutions throughout the entire product development chain across various industries such as Industrial Products, Medical Devices, Automotive, Aerospace, Railways, Off-Highway & Polymer, Commercial Vehicles, Telecom & Hi-Tech, and the Process Industry. The company also offers solutions in the areas of Mechanical Engineering Services, Embedded Systems & Engineering Application Software, Product Lifecycle Management, Engineering Analytics, Power Electronics, and M2M and the Internet-of-Things (IoT).

With a multi-disciplinary and multi-domain presence, we challenge ourselves every day to help clients achieve a sustainable competitive advantage through value-creating products, processes and services. Headquartered in India, with over 10,000 highly skilled professionals, 12 global delivery centers and operations in 35 locations around the world, we constantly find flexible ways of working, tailored to our assignments and customer needs.

For more information, visit us at www.lnttechservices.com