**Australian Journal of Basic and Applied Sciences**, 8(19) Special 2014, Pages: 182-185

AENSI Journals

**Australian Journal of Basic and Applied Sciences**

ISSN:1991-8178

Journal home page: www.ajbasweb.com

# Development of a Portalble Electronic Road Lane Departure Warning System

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**ARTICLE INFO**

***Article history:***
*Received 15 April 2014*
*Received in revised form 22 May 2014*
*Accepted 25 October 2014*
*Available online 10 November 2014*

***Keywords:***
*Road lane departure; Advance driver assistance system*

**ABSTRACT**

An automated Lane Departure Warning System (LDWS) provides signal if a vehicle is exiting a road lane. There are a growing number of car manufacturers that manufacture vehicles with build-in LDWS. However, most vehicles on the road as of today do not have the feature. Design and development of an electronic warning unit and integration scheme of a road lane departure algorithm onto that unit are presented in this paper. An Android smartphone processes real-time images for the road lane detection. The result is sent to the electronic warning unit via Bluetooth communication. The electronic unit runs mainly on a microcontroller and can provide visual, audio and tactile warning to a human driver. Warning protocol for different operating conditions is evaluated and proposed. The choice of hardware and communication protocol eases the access of tools needed for mass production with hopes that more end user would have cheaper access to the LDWS technology.



**To Cite This Article:** A.D. Beh, T.W. Tan, H.L. Wong and C.S. Woo., Development of a Portalble Electronic Road Lane Departure Warning System. ***Aust. J. Basic & Appl. Sci.,*** *8(19): 182-185, 2014*

## INTRODUCTION

A LDWS is one of the features for an Advance Driver Assistant System (ADAS). There are several different implementations of LDWS where each uses different sensing techniques such as vision-based, infrared-based, etc. This paper proposes a portable vision-Based LDWS using hardware components and technology that can be easily acquired (Beh, A.D. and T.W. Tan, 2013). A vision-based LDWS utilizes front facing camera mounted on the front windscreen of the vehicle to fetch real time images that are used to detect the road lane ahead of the vehicle and warns the driver upon lane departure in reference (Shaout, A., 2011). Real-time images are fed to the CPU for processing. The works by Yu (2008) and Hsiao & Yeh (2006) feature the development of LDWS on dedicated hardware utilizing specific embedded systems. One of the systems utilizes the angles between lanes and the horizontal axis in captured image coordinate as the condition to determine lane departure. While the other system uses the lateral offset method to improve the accuracy of the lane detection algorithm. On the other hand, there are also implementations on portable consumer devices. Implementation in Chen (Chen, C.J., 2009) is one example where LDWS prototyping is done on smartphones. In this paper, wireless connectivity between a smartphone and electronic module is established to provide warning signals.

### *Road Lane Detection:*

The road lane is detected based on the line marking on the road. An algorithm was developed to detect road lane that the vehicle is travelling on. The camera on the smartphone captures the image frame in RGB format. The resolution of the image is downsized to one third of its original size using down sampling of the Gaussian pyramid (Gonzalez, R.C. and R.E. Woods, 2002). Two third of the image from the top is cropped. Only one third of the image starting from the bottom is processed as road lane only appears in this region. After the series on downsizing and segmentation, color conversion from RGB to grayscale image is performed. An adaptive threshold process using cross correlation with the Gaussian window is employed to obtain a binary image (see Figure 1). Later, edges are extracted from the image using Canny edge detector. Hough line detection is implemented to detect road line marking. The processing steps are minimized as much as possible to reduce the computation time.

A lane is considered detected when there are two road lines detected and the lines must intersect. A typical road lane has a width of 3.5m. Level 1 warning is triggered when the vehicle is around 0.5m away from the lane

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boundary and Level 2 warning is triggered when the vehicle crossed the lane boundary (see Figure 2a). Figure 2b illustrates sample scenarios for left departure, right departure and no departure of a vehicle.

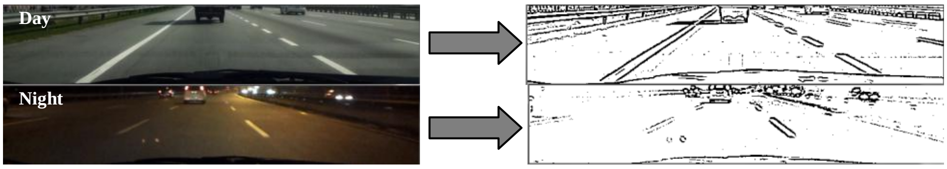
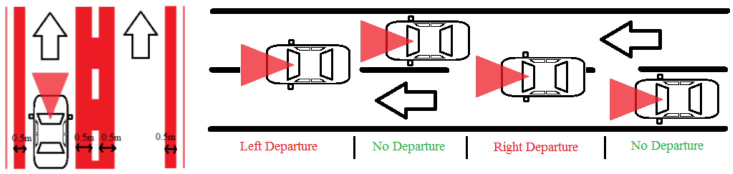



**Fig. 1:** Edge detection results (examples).




(a) (b)

**Fig. 2:** (a) Distance definition of vehicle to road lines; (b) Graphical illustration for various departure cases.

### *The Electronic Driver Warning Unit:*

Prototype of a portable electronic driver warning unit was developed. It is targeted to be used concurrently with a main processing unit that executes high computation software routines, such as visual based detection of the road cues. A sample setup of the system is shown in Figure 3. Both units form an in-vehicle Personal Area Network (PAN) through wireless communication.


**Fig. 3:** Installation of the electronic warning system.

The main controller of the unit is a microcontroller (PIC19F4520). The microcontroller controls the behavior of the warning trigger depending on the result from the smartphone. It is connected to a Bluetooth slave module (Bluetooth BlueBee) via the serial communication. The smartphone acts as the master module during communication. Upon detection of a road signal, the smartphone transmits an 8-bit data which consist of the information of the road signal. The warning instrument comes in three forms, namely the tactile, sound and visual warnings. A series of micro-motors connected to the human lap strap provides the haptic feedback in terms of different vibration pulse. Study shown that tactile feedback is more effective as the driver can directly feel the vibration and thus, able to respond faster (Kozak, K., 2006). The Light Emitting Diodes (LED) and buzzer located in the main box provide visual and audio warning respectively. Since the main box is located in front of the driver, the driver would not likely to miss any of those signals. The unit is powered via the Universal Serial Bus (USB) interface that is connected to the vehicle's cigarette lighter receptacle for Direct Current (DC) voltage supply.

The driver has to manually select either city mode or highway mode during initialization. City mode applies when the number of traffic flow and traffic junctions tends to be higher. Thus, the vehicle is not expected to move at high speed. Hence, warning signal in city mode can be milder. The driver is also more susceptible to lane changing behavior in city mode. Therefore, tactile feedback is not employed as high frequency of vibration on human skin can cause numbness on the thigh which might affect the driver's reaction to the pedals. During city mode operation, warning is triggered when there is a full departure. In contrast, a vehicle tends to travel faster at highway due to better road conditions and less traffic congestion. The lane changing frequency tends to be lesser than city driving. The scenery of highways can be monotonous which might cause drowsiness for motorist. Hence, all three warning mechanisms are employed in highway mode. The highway mode is further divided into two warning level, namely the Level 1 and Level 2 warning, which was discussed earlier. Table 2 summarizes the pattern of the warning signals.

**Table 2:** Warning signal in different operating modes.

| City Mode | Left Departure | | Right Departure | |
|---|---|---|---|---|
| Audio | 2 short beeps | | 2 short beeps | |
| Visual | Left LED blinks | | Left RED blinks | |
| Highway mode | Left Departure | | Right Departure | |
| | Level 1 | Level 2 | Level 1 | Level 2 |
| Audio | 2 short beeps | 4 short beeps | 2 short beeps | 4 short beeps |
| Visual | Left LED lights up | Left LED blinks at fast speed | Red LED lights up | Red LED blinks at fast speed |
| Tactile | - | Left motor pattern | - | Right motor pattern |

## RESULT AND DISCUSSION

The Android application for road lane detection is developed using the Eclipse IDE, where several tools such as the Android SDK, Android NDK and Java Development Kit (JDK) were integrated together. The image processing algorithm was written in C++ with the utilization of OpenCV library while the foreground of the phone application interface was written in Java. 2714 video frames that were used to evaluate the road lane detection algorithm consist of several environment classes ranging from clear daylight to adverse weather condition, such as heavy rain during day and night. The highest accuracy of 93.2% was achieved via cloudy daytime class. When the environment is sunny, the detection rate drops as the image appears brighter and the contrast between the road line and road is reduced. The lowest accuracy attained is 49.5% where the frames were captured at rainy daytime environment. The road lane detection rate during raining nighttime environment is 83.9% as the road line marking appears to have greater contrast than the road itself when the headlights of the vehicle hits on it. Figure 4 shows snapshots of some of the road lines detected.

The detection result directly impacts the reaction on the warning unit. The Bluetooth communication remains reliable if the signals received interval is equal or more than 1s. From experiment, interval of 0.5s would cause receiver jam and subsequent data cannot be read. Frequency of data transmitted can be reduced to overcome this problem. Furthermore, the number of warning signals should not be large to avoid boredom of the driver. The average frame rate computed on the dual-core 1.4GHz ARM cortex-A9 smartphone is 3.683 frames per second with an original image resolution of 1280×720 pixels. The device runs on Android 4.0.4 operating system. Preview of the result on phone screen takes up unnecessary processing time and can be eliminated in actual application.


**Fig. 4:** Road lines detected in different sample environment conditions.

### *Conclusion:*

The prototype serves as a conceptual podium to portray the design and possible mechanisms for a portable in-vehicle driver warning system for human driver. However, if the vehicle's reaction to the warning signal is autonomous, the choice of electronic components, wireless communication method and road lane detection algorithm must be improved further.

## ACKNOWLEDGEMENTS

This work is supported by Multimedia University and PPP grant under University of Malaya.

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