Lane Departure Warning System (LDWS)

1. Introduction

According to the National Highway Traffic Safety Administration, one of the leading causes of deaths on US roads and highways is a class of accidents popularly known as Run-Off-Road (ROR) accidents. These accidents typically result from inattention, intoxication, incapacitation, drowsiness, and unintended steering wheel motions, have been responsible for over 1,550 fatalities a year and causing an average of 71,000 injuries. Whatever the cause, the accidents typically begin with accidental departures from the driver’s current lane and then impacting an object such as a tree, another car, a bridge abutment, etc. A need therefore arises for a preventive measure against these accidents through a system that alerts drivers of drifts away from their lanes.

In this project, we present a system which has the potential to reduce fatalities which are caused by the common type of crashes called the Run-Off-Road (ROR) crash. The project is to design and build a Lane Departure Warning System for use on roads and highways. The functioning of the system will be to constantly monitor the car movement and placement in relation to the road marks (with the aid of infra-red technology), detect when the driver drifts away from the current lane without an appropriate warn signal, and provide a quick and effective alert to the driver to take a corrective action. To provide a unique, distinct alert system to trigger the quickest response possible, the alert will be in form of vibration of the driver’s seat, intensifying vibration in the direction of lane drift.

2. Problem Definition

The Lane Departure Warning System must comprise of a monitoring system, and interpretation of the feedback from monitoring, and an alert system for the driver in the event of a lane drift. The system will also adhere to all National Highway Transport Safety Administration (NHTSA) guidelines for incorporated systems into cars (for instance, that the alert will not be in any way hazardous to the driver). In this project, we are constrained by a budget of approximately $500, as well as the non-availability of a live car. We will therefore build the LDWS for demonstration on a miniature car and an improvised road terrain, focusing on the basic functionality of the alert system.

3. Current Status of Art

Currently available Lane Departure Warning Systems are forward looking, vision-based systems that use algorithms to interpret video images to estimate vehicle state (lateral position, lateral velocity, heading, etc.) and roadway alignment (lane width, road curvature, etc.). AURORA[(1)] is a vision-based system

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designed to warn a vehicle driver of possible impending roadway departure accidents. It employs a downward looking color video camera with a wide angle lens, a digitizer, and a portable Sun Sparc workstation. AutoVue® Lane Departure Warning(2) use similar technology that includes small, integrated unit consisting of a camera, onboard computer, image recognition software and proprietary algorithms. Also, the Chang Gung University in Taoyuan, Taiwan(3) has also developed implemented a real-time lane departure warning system based on an image-processing platform.

While all these systems have reported an average of 84% reduction in lane departure-related accidents(2) in ideal driving conditions, these systems have a subpar track record in driving scenarios where the driver's vision is impaired by ambient conditions. Their core concept of visual image processing becomes irrelevant in a scenario in which the captured images provide no real data due to the lack of picture quality. Some poor road visibility scenarios include driving in heavy rain, snow, thick fog, dusty roadways.

4. Engineering Approach

As highlighted in earlier sections, our project is a Lane Departure Warning System designed to significantly reduce the occurrence of the Run-off-Road (ROR) accidents, the leading class of accidents on US highways and most international roads. To effectively monitor the vehicle position, as well as alert the driver in a situation of lane drift, our system will comprise of both and input (responsible for monitoring the car's position in relation to the road lane marks, deciphering a lane drift and sending appropriate feedback), and an output component (responsible for receive information from the input and respond accordingly—i.e. issue a warning). In this discussion, we will speak about our engineering approach (solutions) by discussing the two input components (output and input component) separately.

Input Component

a) *Infra-Red Beam Emitters with Sensors*: We are employing an infra-red sensor solution for our input. The use of infra-red technology and the power of refracted beams having different wavelengths or angles of reflection based on the color of the incident material is the underlying principle behind this. When the car is in motion, the road will be constantly bombarded with infra-red beams from emitters located at the front wheels of the car (four sensors on each wheel). These emitters will have corresponding collectors/sensors that accept the reflected beam from the road, and detect color variations. The angle of the reflected rays will be dependent on the material from which the rays were reflected (asphalt or white paint). This information will then be transmitted to the input component that interprets the occurrence of a lane drift. A lane drift occurs if, after a certain period of time of driving on the main road color (asphalt) and receiving corresponding reflected beams, a different reflected beam is received (say white, due to the car crossing over a lane marking).

The reason for having more than one sensor is for accuracy, as well as to determine the extent of lane drift. If only one sensor detects the lane marking, it is not as severe a drift as if three successive sensors detect a lane marking.

The following schematic diagram presents, in a nut shell, the concept for the infra-red technology to determine lane drift.

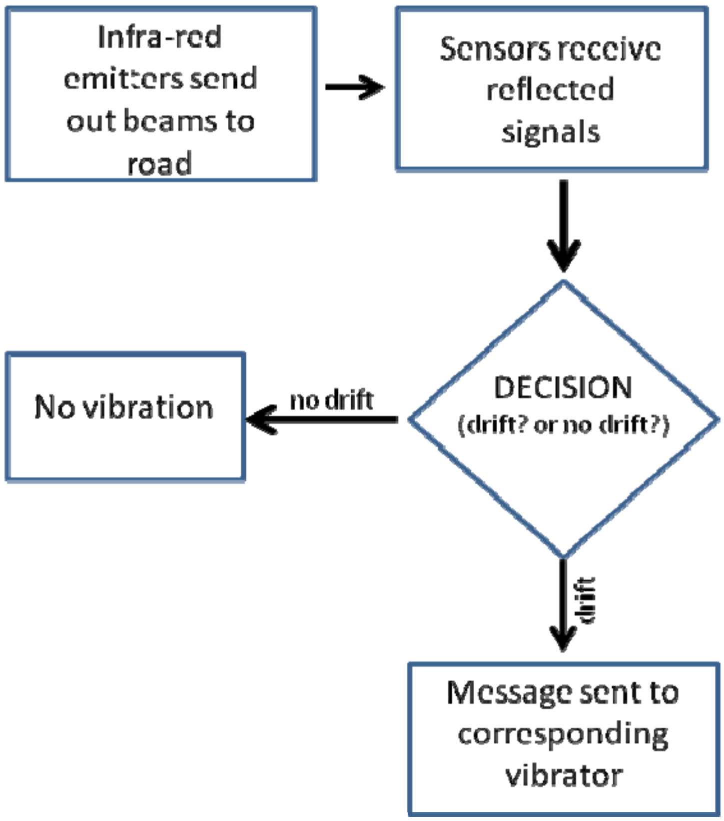


Figure 3a: LDWS Infra-red technology schematic

Output Component

b) *Driver Seat Vibration*: The output component, used to notify the driver (issue a warning) when there is a lane drift, will entail vibration of the driver's seat. Vibrators will be installed on both the left and right hand side of the seat; the vibrator that is triggered will depend on the direction of lane drift.

Solution Alternatives

We considered solution alternatives for the main design components (Input and Output). The following lists the solution alternatives for each of the main design components:

Input

An alternative implementation for the output component was the use of camera/image-processing technology. In this approach, a camera will be mounted on the rear view mirror, and this will constantly take images of the road and feed to an image-processing filtering technology. The image processing system uses image recognition software and proprietary algorithms to determine when a vehicle drifts into an unintended lane change and triggers a warning, which alerts the driver to make a correction. As the data stream enters the processor, it is transformed—in real time—into a form that can be processed to output a decision. The processor can find lines within a field of data by looking for edges.

The figure below shows an image captured by a camera placed behind the rearview mirror while also detecting the lanes along the road.

Below is a step by step process of the Lane Departure Warning System using camera imaging.

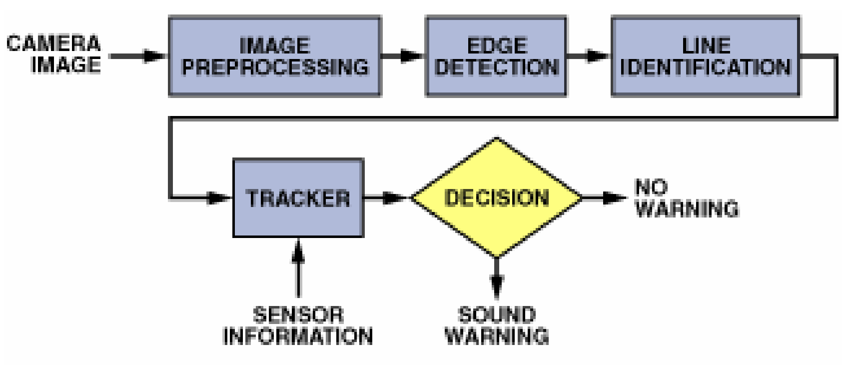


Figure 3b: LDWS Camera solution schematic

While the camera technology may be a more involved approach, its dependency on images (as opposed to the intrinsic characteristic of the road material such as color) also makes it vulnerable to much error in a situation of poor visibility.

Output

We considered using audio and visual alerts to alert the driver in the instance of a lane drift. The audio alert will consist of miniature alarms that receive signals from the input component interpreted to be a lane drift. The visual alert will be made up of colored LEDs; different intensities the same color would be used to signify the extent of drift. While these are alternative solutions, they may not be as effective an alert as a vibrator.

Coursework

First, we will be using knowledge of *Introduction to C++ Programming* taken in the first semester of our sophomore year. This basic programming course will be essential as we design the LDWS system's algorithm and the simulation code needed for extensive testing. The two electronics courses (*Electronics I and II*) taken in our third year will guide us as we move into the hardware implementation stage of the LDWS system. Moreover, our troubleshooting techniques will be based on this knowledge gained in this class since this projects entails the wiring and connection of various mechanical and electrical parts such as miniature car parts, emitters and sensors, processing unit, and the vibrator.

The scope of this project includes both hardware and software implementation of a system design. Digital Systems will be essential towards implementing the simulation and hardware aspects of the project.

In addition, an essential skill set that we need to develop as we work towards the completion of this project is the knowledge of *Simulink®.* Prior to building our system, we will perform a simulation of our engineering solution to ensure that our assumptions are right and that the system functions as we have designed; for example, simulations and calculation of the angle of the reflected Infrared beams sent from the sensors, the time it would take for the LDWS to issue a warning based on the speed of the car, curvature or straightness of road, etc. Simulink® will be a very powerful tool in that regard, and out team has made it a point of duty to get very comfortable (if not proficient) with Simulink® and use the tool for this purpose. We will use various learning resources (Tutorial session, online learning material) provided by our instructor (Dr. Charles Kim).

Finally, teamwork has been an integral part of all these classes and our experiences in the past four years. We will be leveraging these skill sets learned over time and applying them to our final project.

5. Tasks and Deliverables

To achieve a functional lane departure warning system at the end of this senior design project, there are a couple of tasks and deliverables that have to be stated.

Tasks

1. Research on the existing lane departure warning systems.
2. Research on the existing patents and regulation requirements
3. Brainstorm on the features and functionality of our selected system such as

    - **Input feed:** This will include sensor data collection, threshold specification, driver input and environmental conditions
    - **Output feed:** This will include the vibration sensor system, audio system and video display system

4. Research the simulation and testing of our system using Simulink®
5. Research and decide on the microprocessor unit and sensor systems that will be utilized
6. Research on the demonstration vehicle that will used

Final Deliverables

1. A miniature scaled version of a vehicle controlled by a remote control system. The car will be about 1 foot long, 8 inches wide and 4 inches tall
2. 5-foot long 3-foot wide black tile or canvas paper with white lane markings representing the road.
3. Lane Departure Warning system complete with infrared sensors attached to either side of the car which detects uncontrolled lane changes. The warning system will have a switch button to turn it on or off and when switched on, it alerts the driver through one of the following available options:
    - **Vibration sensor system** which has left and right oscillatory prongs that vibrate either left or right according to the side that the sensor makes contact with the road lanes. The sensor system will connect with the vibration sensor system wirelessly or through the use of wires and the intensity of the vibration will depend on the number of sensors that are triggered as the car crosses the lane.
    - **Audio system** which alerts the driver by issuing a beep warning sound as soon as the lane is crossed
    - **Visual display system** alerts the driver through the use of LED indicators. The LED display turns on when the car crosses the lane and only turns off when the car has been returned to its lane

Verification and Testing

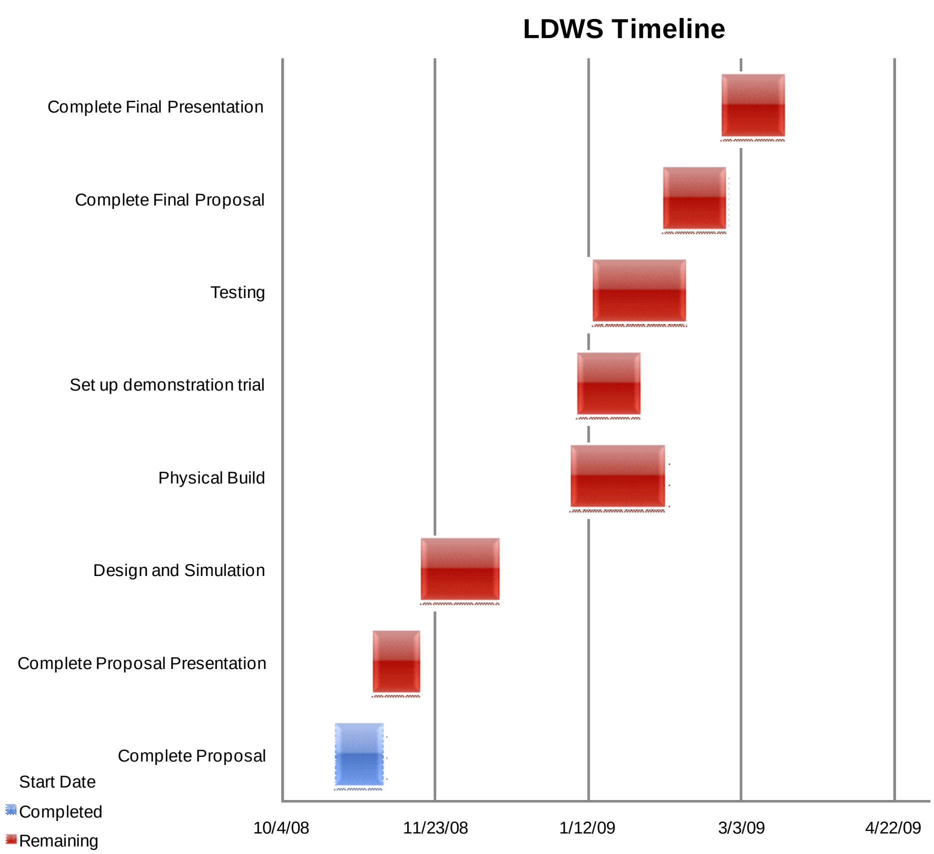
The preliminary testing of our system will be done by simulation. We will build our system using the MATLAB Simulink® tool. This will allow us to conduct extensive testing for each of the main design components (input and output). We will define both input and output parameters such as car speed, lane marking color, etc based on NHTSA assumptions and other typical values. We will ensure that our LDWS system functions properly within these given parameters.

Finally, we will physically build our system using a miniature car and a makeshift driving environment. We will run the car in this driving environment and test the functionality of our system. We will focus on two main characteristics of the LDWS alert: correctly alerting the driver whenever the car drifts lane and alerting the driver quickly enough for him/her to respond.

The system should alert the driver in all instances of lane drift without a turn signal indicated within a time period of 400 ms.

6. Project Management

The following is a tentative timeline for this project:



The following is a tentative budget for this project:

Item	Description	Cost	Number	Total Cost
Sharp IR Range Finder	Infrared Sensor	$20.00	8	$160.00
RC Car	Miniature car	$50.00	1	$50.00
Paint	White and yellow paint	$3.00	2	$6.00
Roll of black paper	Black paper	$5.00	3	$15.00
Control board	Main control unit	$100.00	1	$100.00
LED	Visual indicator	$5.00	2	$10.00
Buzzer	Audible indicator	$10.00	1	$10.00
Miscellaneous	Additional costs	$100.00	1	$100.00
				$451.00

In an attempt to boost the productivity of this team, the following assignments were made:

1. Team Coordinator: Peter Ramsumair
   - Coordinate the team efforts to ensure successful completion of the project
2. Team Scribe: Chukwuemeka Ekeocha
   - Manage the team's documentation process e.g. reports, presentations, and user documentation
3. Technical Liaison: Uzoma Nwagba
   - Lead the design and testing periods of our project
4. Team Researcher: Uchechukwuka Monu
   - Lead the team's research efforts

Throughout this project, safety will be high on the team's agenda. The following are some of our main concerns:

1. Reliable functionality
   - Should perform a self-test that checks all major system sensors and components, operate within 30 seconds of starting the vehicle, and relay the results of the self-test to the driver indicating whether the system is operational

2. Industry Safety Standards

   - Must adhere to all NHTSA safety standards (crash avoidance, simplicity of use, etc) and not interfere with any of them

3. Driver Safety

   - Driver alerts (visual, audible or vibrational) should never disturb or impair a driver. For example, if warning signal is audible, it should not be louder than 130 Db so as not to significantly interfere with driver concentration

Another major concern of the team was the issue of engineering ethics. Throughout this project, we will adhere to the *NSPE Fundamental Canons* $_{(4)}$

1. Hold paramount the safety, health, and welfare of the public.

2. Perform services only in areas of our competence.

3. Issue public statements only in an objective and truthful manner.

4. Act for each employer or client as faithful agents or trustees.

5. Avoid deceptive acts.

6. Conduct ourselves honorably, responsibly, ethically, and lawfully so as to enhance the honor reputation, and usefulness of the profession.

7. Conclusion

According to the National Highway Traffic Safety Administration, Run-Off-Road (ROR) accidents typically result from inattention, intoxication, incapacitation, drowsiness, and unintended steering wheel motions, has been responsible for over 1,550 fatalities a year and causing an average of 71,000 injuries. As a solution to this problem, design and build a Lane Departure Warning System for use on roads and highways. The functioning of the system will be to constantly monitor the car movement and placement in relation to the road marks (with the aid of infra-red technology), detect when the driver drifts away from the current lane without an appropriate warn signal, and provide a quick and effective alert to the driver to take a corrective action. There were two main proposed solutions:

1. Infrared Sensor System

2. Video Sensor System

These two systems use different types of data input. The first system would depend on a continuous data input stream from the Infrared emitters located at the base of the moving vehicle. Control unit decisions would be based on the power of refracted beams and their different wavelengths and angles of reflection based on the color of the incident material. The second system would depend on a camera will be mounted on the rear view mirror that will constantly take images of the road and feed them to an image-processing filtering platform. Even with our cost ($500 budget) and time (4 - 5 months) constraints, we are confident that our proposed system can solve the aforementioned problem.

8. References

1) *AURORA: A Vision-Based Roadway Departure Warning System,* Mei Chen Jochem, T. Pomerleau, D. Robotics Inst., Carnegie Mellon Univ., Pittsburgh, PA; http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?tp=&arnumber=525803&isnumber=11432

2) *AutoVue® Lane Departure Warning*, Iteris, Inc. http://www.iteris.com/upload/datasheets/AutovueBrochure_FINAL_web.pdf

3) *A Portable Real-Time Lane Departure Warning System based on Embedded Calculating Technique*, Pei-Yung Hsiao Chun-Wei Yeh. Dept. of Electron. Eng., Chang Gung Univ., Taoyuan http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?tp=&arnumber=1683415&isnumber=35446

4) *Code of Ethics*, National Society of Professional Engineers http://www.nspe.org/Ethics/CodeofEthics/index.html

Attachment: Final Design Requirements

Design Requirement List		
Design Project Title:	Lane Departure Warning System	
Team Name:	Team Pinnacle	
Team Members:	Chukwuemeka Ekeocha, Uchechukwuka Monu, Uzoma Nwagba, Peter Ramsumair	
Date:	11/04/2008	
Version:	3	
Requirements	**Descriptions**	**Source**
Overall Function	Should issue warning if car crosses or drifts towards lane boundaries	
Performance	LDWS should be able to track lane boundaries and issue warnings within ±0.1 meter (±4 inches) from the warning thresholds • Should also issue directional warning within 1 second if car departs from current lane, specifying the direction of drift/lane departure • Should not issue warning if the turn signal is activated and the car is moving at a speed less than 45mph • Should be able to detect vehicle position relative to following types of visible lane boundaries using an input data stream from 8 infrared sensors (4 on each side of car) o Solid and dashed painted	Federal Motor Carrier Safety Administration

	lines o Single and double painted lines o Yellow and white painted lines • Control unit decisions will be based on the power of refracted beams and their different wavelengths and angles of reflection based on the color of the incident material.	
Cost	• Must cost less than $500 to install the device in a vehicle; manufacturing costs should be as low as possible • Maintenance costs for the LDWS should be less than $150 per year • LDWS design must be completed and ready for testing by 05/10/2009	
Safety	• Should perform a self-test that checks all major system sensors and components, operate within 30 seconds of starting the vehicle, and relay the results of the self-test to the driver indicating whether the system is operational • Must adhere to all NHTSA safety standards (crash avoidance, simplicity of use, etc) and not interfere with any of them • If warning signal is audible, it should not be louder than 130 Db so as not to significantly interfere with driver concentration	National Highway Transport Safety Administration

Compliance	• LDWS should meet the electrical requirements as stated in most recent version of the following SAE standards: 1. SAE Standard J1455, “Joint SAE/ TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)”. 2. SAE Standard J1113, “Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft) (60 Hz to 18 GHz)”.	SAE International
Interfaces	• The LDWS interface should consist of audio sources of at least 1.5MW, indicator lights no brighter than 80candela, vibrational devices (3600 RPM), and controls for operation by the driver	
Energy, Power, and Environment	• LDWS should meet the environmental requirements as stated in the most recent version of the following SAE standard: o SAE Standard J1455, “Joint SAE/ Technology and Maintenance Council (TMC) Recommended Environmental Practices for Electronic Equipment Design”.	SAE International
Lifespan	The total system should last 3-5 years with a yearly maintenance	
Size and Weight	The total system should amount to no more than 10 lbs	