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Non Vision-Based Lane Departure Warning System

Proposal

Senior Design Project

College of Engineering, Architecture & Computer Sciences
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To: Whom it may concern

Subject: Lane Departure Warning System – Proposal

Enclosed is Team Summit's proposal design for the implementation of an inbuilt Lane Departure Warning system for the 2009/2010 Senior Design class project. Based on an extensive research into currently available LDWS technologies, as well as lane information as documented by Global Positioning System (GPS) devices and publicly available information published by the United States government, *Team Summit* has drawn up a detailed solution to the problem posed by the LDWS project. Our engineering solution approach outlines the following information:

- Primary Solution
- Scenario Considerations
- Benefits, Future Improvements, & Practicality
- Testing & Verification Plan
- Relevant Knowledge & Coursework
- Alternate Solutions

Also included in this proposal is a brief history and background of LDWS, the status of LDWS technologies currently available in the market, the problem statement and design requirements, and Team Summit's project management strategy.

The research for this proposal was based on information on LDWS and industry standard specifications in online sources, as well as the LDWS proposal as presented by last year's unsuccessful Senior Design team. See the *References* section of this proposal for more information.

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Introduction

Objective

The objective of this proposal is to outline the details of the design challenge proposed by the Lane Departure Warning System (LDWS) project and demonstrate a workable solution to the problem statement.

Background

The automobile industry and consumers alike are continuously embracing the value of crash prevention technologies. Many automobile companies are developing technology not only to make driving safe for the driver of the vehicle, but for other drivers around him. As a result, the industry has seen the introduction of the Lane Departure Warning Systems (LDWS). LDWS are electronic systems that monitor the position of a vehicle within a roadway lane and warn a driver if the vehicle deviates or is about to deviate outside the lane.

Outline

In this proposal, we will define the root cause of the problem as well as the design requirements and constraints on our final solution. We will then provide some insight into the existing technologies available and the history of LDWS for further context. Next, we will go into detail about our proposed solution to the problem statement and explain its advantages over the alternative solutions. The *Tasks & Deliverables* and *Project Management* sections outline the specific steps that Team Summit will take in order to implement our proposed solution design. An *Appendix* and a list of *References* are provided for more information on the LDWS project.

Problem

Problem Definition

The problem we are faced with is as follows: to design a system that will be able to detect and alert a driver of an impending lane deviation and/or provide measures to correct the impending lane deviation before the occurrence of a possible car accident.

Assumptions

In deciding the scope of this project, we made the following assumptions:

- The system must be completely in-built within the vehicle, with no external-facing components whatsoever
- The system must not depend on physical lane markings on the roadway being traversed
- The system is limited to covering only Interstate Highway systems in the United States

Design Requirements

The constraints imposed on this project require that our proposed design must meet the following requirements:

1. Overall Function:
    a. Should issue a warning signal if car crosses or deviates towards lane boundaries

2. Performance:
    a. 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.
    b. Should be able to identify type of car, length and width of car.
    c. Should issue warnings; detect vehicle position relative to virtual lane boundaries.
    d. Should be able to communicate with the brain box of the system
    e. Should also issue directional warning, within 5 seconds, based on the speed of the car, if car is positioned to depart from its current lane, specifying the direction of drift/lane departure
    f. Should not issue warning if the turn signal is activated.
3. Compliance:
    a. LDWS should meet the electrical requirements as stated in most recent version of the following SAE standards:

        SAE Standard J1455, "Joint SAE/ TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)"

        SAE Standard J1113, "Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft) (60 Hz to 18 GHz)"

4. Driver-Vehicle Interface:
    a. LDWS interface should consist of audio sources of at least 1.5MW, indicator lights no brighter than 80candela, vibration devices (3600 RPM), and controls for operation by the driver.
    b. LDWS should issue an audible and/or tactile warning when the vehicle crosses the warning threshold.

c. LDWS should include a visual indicator to indicate when the system is not tracking the vehicle's position in the lane. This status may be indicated by an instrument panel warning light or an indicator that is integral to LDWS.
d. LDWS should use a visual indicator to indicate that the system is operational and ready to function. This status may be indicated by an instrument panel warning light or an indicator that is integral to LDWS.
e. LDWS should use a visual or audible indicator to indicate a system failure or malfunction. This status may be indicated by an instrument panel warning light or an indicator that is integral to LDWS.

5. <u>Energy, Power & Environment</u>:
   a. LDWS should meet the environmental requirements as stated in the most recent version of the following SAE standard:

      SAE Standard J1455, "Joint SAE/ Technology and Maintenance Council (TMC) Recommended Environmental Practices for Electronic Equipment Design"

   b. The following environmental aspects are covered by the standard:

      Altitude
      Fungus
      Mechanical Shock
      Mechanical Vibration
      Relative Humidity
      Temperature
      Salt Spray Atmosphere
      Immersion and Splash
      Steam Cleaning and Pressure Washing
      Dust, Sand, and Gravel Bombardment

6. <u>Size</u>:
   a. The total system should amount to no more than 5 lbs

Current Status of Art

The automobile industry and consumers alike are continuously embracing the value of crash prevention technologies. Many automobile companies are developing technology not only to make driving safe for the driver of the vehicle, but for other drivers around him/her. As a result, the industry has seen the introduction of Lane Departure Warning Systems (LDWS).

LDWS are electronic systems that monitor the position of a vehicle within a roadway lane and warn a driver if the vehicle deviates or is about to deviate outside the lane when the vehicle's turn signals is not in use. According to a Detroit News report, safety experts believe that these systems "show significant promise" in their ability to reduce traffic accident-related fatalities and injuries. Iteris, one of the leading manufacturers of commercially available LDWS's, recently reported that the number of lane departure-related accidents in fleets of trucks installed with their *AutoVue*® LDWS reduced by 77%. This obviously translates to less money spent annually for repairs and other expenses involved in crashes and fewer lives lost due to lane departure-related accidents.

The National Highway Traffic Safety Administration (NHTSA) is currently conducting research to determine whether or not to mandate that all new manufactured vehicles be fitted with lane-departure warning systems and automatic braking systems that trigger upon warning of an impending accident. NHTSA will decide whether to require such systems in 2011 after further cost-benefit analysis, including looking at insurance company data and estimated manufacturing costs.

Many car manufacturers now offer lane departure warning systems as options or build them into their higher-end car models. In 2001, Nissan Motors included one of the first known LDWS on the *Cima* model that was sold in Japan. Since then, car brands such as Mercedes Benz, BMW, and Infiniti have included various deviations of the LDWS in their automobile models. Earlier this year, Mercedes-Benz began offering a Lane Keeping Assist function on its *E-class* models, a system that warns the driver with a vibrating steering wheel if it appears the vehicle is leaving its lane, while also automatically deactivating and reactivating if it ascertains the driver is intentionally leaving his lane. Fiat and Peugeot are also introducing the Lane Keep Assist feature in their newest vehicles.

There are several types of LDWS technologies in the market and in current development. Currently available LDWS use algorithms to interpret video images or signals, for example, to estimate vehicle state (lateral position, lateral velocity, heading, etc.) and roadway alignment (lane width, road curvature, etc.). The majority of systems available today are forward-looking, vision-based ones that typically consist of a digital camera, an image-processing unit, a user display unit on the interior of the vehicle and radar/sensor devices on the exterior of the vehicle. The cameras, usually positioned behind the front windshield of the vehicle facing the direction in which the car is moving, are used to keep track of the physical lane markings along the road on which the driver is traveling. They track the lane boundaries that are *ahead* of the vehicle's current position at any given time along the road as shown in Figure 1 below.

Figure 1 – Camera Position in Vision-Based LDWS. Observe the position of the camera in the top-right corner behind the windshield of the vehicle and the lane markings it is currently detecting (as indicated by the green rectangles along the yellow lane marking) ahead of the driver's current position.

This lane-marking range is then used to determine the lateral position of the vehicle in the current lane. Depending on the current speed and overall motion of the vehicle, the LDWS estimates the time it would take the vehicle to cross the lane boundaries. If this time parameter, often known as the *time-to-lane-cross* (TLC), exceeds a predefined threshold, an audible, vibratory, and/or visual warning alarm is sounded.

An alternative approach for lane departure prediction is to calculate "warning lines" with respect to the actual physical lane markings. As shown in Figure 2 below, the *earliest warning line* lies within the lane boundary while the *latest warning line* lies outside the lane boundary. The LDWS then determines a *warning threshold placement zone*, the area between the earliest warning lines and the latest warning lines. If the vehicle crosses out of the safe or *no-warning zone* into the warning threshold placement zone, the LDWS will issue an alarm.

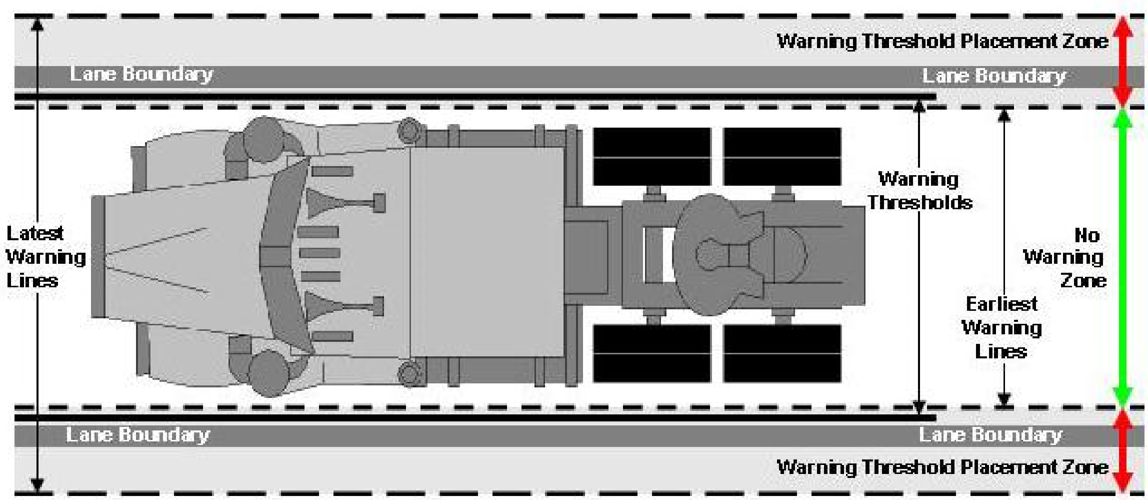


Figure 2 – Lane Departure Prediction using warning lines. Notice the No-Warning Zone lying between either of the earliest warning lines and the Warning Threshold Placement Zone lying between the earliest warning line and the latest warning line. Also observe that the earliest warning line lies inside the lane boundary and the latest warning lines lie outside the lane boundary.

The ability of LDWS's to alert the driver *before* a lane departure occurs explains their forward-looking characteristic. This is a very important feature of existing technologies as LDWS's need to be able to predict and provide preventive measures to avoid potential lane departure-related accidents in order to be useful. The vision-based description alludes to the systems' use of a camera and image-processing unit and their inherent dependence on actual, physical lane markings.

AssistWare Technology's *SafeTRAC Drowsy Driver Warning System*, Iteris's *Auto Vue™ Lane Guidance, Lane Departure Warning System*, and Mobileye's *Lane Departure Warning (LDW) System* are some examples of existing independently developed lane departure systems being sold to original car manufacturers. All of these systems detect visual lane markings using a camera and have the ability to estimate some lane boundaries when visual lane markings are not present or detectable.

The weakness of the vision-based system is its dependence on the visibility of lane markings to determine or approximate a vehicle's lane departure. In adverse weather conditions such as snowstorms or heavy rainfall, these lane markings can become blurred or covered and the performance of the LDWS will be greatly reduced. This can pose a serious problem, as the need to track vehicle movements within a lane in such critical conditions to avoid accidents is one of the major reasons LDWS's were developed in the first place.

In addition, wear patterns in the road, shadows, occlusion by other vehicles, changes in the road surface and other features make the identification of lane markings sometimes difficult. Another problem is that there are many different ways of marking roads in the world which would require entirely different algorithms to be processed and used by LDWS developed in other countries.

As a result, LDWS's that are independent of physical components of a road (such as the lane markings) are now in high demand and are being extensively researched.

Solution Approach

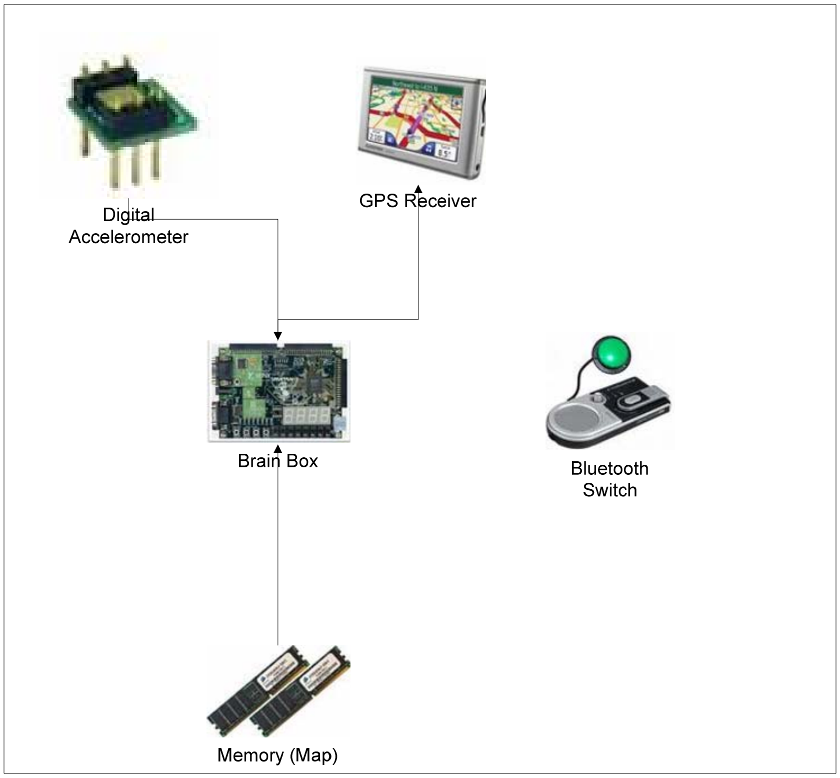
Primary Solution

The proposed solution is outlined in 3 phases:

1. Routing Phase: When the system is activated, the GPS component sends the direction (0^o), speed and coordinates of the car to the Brain box (bbox). With the street name and direction of travel, the bbox prompts the map component to initialize the node database. The map component comprises a digital map of all road networks in the USA; and the node database, is a relational database which contains nodes for a particular route. A node is a road marker, which contains a unique identifier, the unique identifier for the next node on the route, the distance from the next node, the lane width of the road and the direction of the road (relative to the direction of the last node). Initialization of the map component comprises splitting the route, from the current location of the driver to the nearest road change, into nodes, which follow the direction of the road. The nodes are spaced in such a way as to be encountered by the car at 1 second intervals.

2. Guidance Phase: Now that the route is segmented into nodes, with the knowledge of the lane width and the presumption that the system was initialized while the car was set at the center of its lane, the bbox computes the left and right virtual boundaries. These boundaries which form the virtual lanes are represented by 2 points (one to the left and the other to the right) which mark the edges of a straight line (virtual line) drawn perpendicular to the direction of the road, as supplied by a node. The frequency of the computation of the virtual points corresponds to the speed of the car, such that they will be encountered in intervals of 1/4 second. In the case of curved roads, there will be a discrepancy between the direction of the road (from the next node from map component) and the direction of the car (from GPS). The difference is degrees between both directions, using the car direction as a reference, is used to tilt the virtual line to accommodate the road change. In the event that the driver decides to change the initial travel route, the system will re-route to the new path (street or road) by branching to the Initialization phase.

3. Warning Phase: With the knowledge of the speed and direction of the car, and the location of the next node on the route, the bbox will calculate the impact time. The impact time is the shortest time it will take for the car to leave its virtual lane. The impact time is calculated every second. The warning lights start blinking when the impact time is less than or equal to 5 seconds.



Solution Process Diagram

Scenario Considerations

The following scenarios were considered:

1. Straight road navigation: This is a situation in which the road being travelled is straight (linear) relative to a frame of reference.
2. Curved road navigation: This is a situation in which the road is curved.
3. Work zone road navigation: This is a situation in which the road being travelled is designated a work zone either for reconstruction or rehabilitation purposes by the relevant authorities.
4. Unmarked road navigation: In this case the road being traversed is devoid of lane markings

The non-dependence of the system on vision based apparatus rules out the weather-dependent scenarios

The driver's intentions may not fall within the controllers expected behavior parameters and the alarm may activate unintentionally. We will need to explore ways to counteract this.

Vehicle width will be entered by user otherwise estimate adjectives will be presented such as "large", "truck", "number of axles" and so on. This will increase or decrease the drift tolerance.

Benefits, Future Improvements & Practicality

Commercially available devices and information provide plenty of assistance including open source software designed to be used with the hardware. This system will overcome the shortcomings of existing vision-based LDWS, which is, dependence on weather condition and lane markings. It uses its on-board system to correctly create virtual lanes which would guide a car operator.

A possible improvement could be the integration of a visual detection system composed of radar and infrared.

Testing & Verification Plan

Several instances of the devices at work will be simulated to ensure that the algorithms in the controller correspond to normal driving behavior. A prototype will then be constructed and tested.

The error from the devices will have to be constantly evaluated and if possible, limited through filtering and error correcting algorithms.

Relevant Knowledge & Coursework

Physics I & II
Signals & Systems
ASIIC Design
Microcomputer Design
C++ Data structures

Alternate Solutions

The majority of alternative in-built LDWS approaches, while ingenious and convenient, require either the use of technologies that do not currently exist or an external-facing component that defeats the restriction on our device to be completely inbuilt:

- One approach is to feed the lane width data from a GPS containing this information for every road in its database. This would allow our LDWS controller to be more accurate in determining whether or not the vehicle has deviated from its virtual lane. However, such a GPS device does not exist; current GPS technology does not include road width data, although lane data is an emerging feature in current GPS implementations.

- Another approach is to use road sensors at set intervals along every road the device will be used on as reference points. However, this method requires an external facing component on the LDWS and defeats our assumption of building a completely inbuilt LDWS.
- Lane markings can be used to calculate the lane width of the road the car is traveling on. This approach would also require an external-facing component that can read the lane markings on the roads.

Tasks & Deliverables

Tasks

No.	**Tasks**	**Start Date**	**Completed**	**Remaining**
1	Research on Existing LDWS technology	10/26/09	8	10
2	Evaluate viable solutions that can implemented	10/27/09	8	9
3	Select the most viable solution	10/28/09	3	2
4	Consult with Faculty on our approach	11/01/09	0	8
5	1st. Draft of Proposal Writing	11/03/09	5	0
6	Submission of 1st Draft of Proposal	11/04/09	5	0
7	Development of Presentation	11/04/09	6	0
8	Online Submission of Presentation	11/06/09	0	1
9	Revision of Proposal	11/08/09	0	6
10	Submission of Proposal (Hardcopy)	11/14/09	0	1
11	2nd Electronic submission of Presentation	11/18/09	0	5
12	Perform simulation using preferred software	11/18/09	0	14
13	Research on potential hardware to be used	11/18/09	0	3
14	Acquire identified hardware	12/02/09	0	14
15	Commence development of design	12/09/09	0	30

Deliverables

At the concluding end of this project, we expect that our deliverable meets the desired specific requirements:

- Issue warnings, detect vehicle position relative to virtual lane boundaries, and track virtual lane.
- Issue directional warning if car is 5 seconds from departing its current lane, specifying the direction of drift/lane departure
- Not issue warning if the turn signal is activated

Conclusion

With an increase in the number of car accidents due to cars drifting from their lanes, we believe our proposed LDWS provides a reliable means of alerting and protecting drivers from impending accidents when they are veering off their lanes. This is streamlined with the objective of this project to outline and design a proposed Lane Departure Warning System (LDWS) and demonstrate a workable solution to the problem statement.

The problem we are faced therein is to design this warning system that will detect and alert a driver of an imminent lane deviation and/or provide measures to correct this threat to prevent any possible car accident.

In deciding the scope of this project, the following assumptions would be made:

- The system must be completely in-built within the vehicle, with no external-facing components whatsoever.
- The system must not depend on physical lane markings on the roadway being traversed.
- The system needs to depend on lane width information of the road being traversed

We strongly believe that our design solution will accomplish our goal of implementing the concept of a reliable Lane Departure Warning System which does not pose any safety hazards to users.

Our budget involves about $30 for the Gyroscope Board, $75 for the FPGA system, $150 for the Differential Global Positioning System component of our design, $50 Infrared switch, $20 for the driver notification portion of the design and $25 for a remote control car and about $85.00 for miscellaneous. The total budget for our design is **$435**.

Gyroscope board	**$30.00**
Field Programmable Gate Array	**$75.00**
Global Positioning System	**$150.00**
IR Switch	**$50.00**
Remote Controlled Car	**$25.00**
Alarming System	**$20.00**
Miscellaneous	**$85.00**
Total	**$435.00**

References

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