Lane Departure Warning System

Saving lives, one alert at a time

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Overview

1. Problem formulation
2. Performance criteria
3. Solution generation
4. Implementation plan
5. Performance evaluation
6. System functionality
7. Learning experience
8. Acknowledgements
9. Questions
Problem Formulation

- Run-Off-Road (ROR) accidents are a leading cause of deaths on US roads and highways (1,550 fatalities, 71,000 injuries a year)\(^{(1)}\)

- Design a lane departure warning system that provides a quick and effective alert to the driver to take a corrective action when car drifts unintentionally

- Main design components:
  - Input: Monitoring environment
  - Control Unit / Data Unit: Interpret the data from monitoring
  - Output: Alert system for the driver in the event of a lane drift

\(^{(1)}\) - National Highway Traffic Safety Administration
Performance Criteria

Performance

• Issue directional warning within 1 second
• Detect vehicle position relative to visible lane boundaries using an input data stream from 6 infrared sensors
• Should not issue warning if the turn signal is activated
• Functionality for
  - Solid and dashed painted lines
  - Single and double painted lines
  - Yellow and white painted lines

Safety and Compliance

• Perform a self-test within 30 seconds of starting the vehicle
• Adhere to all NHTSA (1) safety standards (crash avoidance, simplicity of use)
• Meet the electrical requirements of SAE standards J1455 / J1113

(1) - National Highway Traffic Safety Administration
Solution Generation - Input

Infra-red technology

- Constant bombardment of road with IR rays
- To leverage wavelength difference in reflected beam based on color of material hit (road or lane mark)
- Multiple sensors help determine extent of drift

Camera technology

- Vision based system that uses camera sensors as the lane trackers
- Uses image recognition software and proprietary algorithms to determine when a vehicle drifts
## Top Design Selection - Input

### Input Component - Decision Matrix

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Weight</th>
<th>IR sensors</th>
<th></th>
<th>Camera</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rating</td>
<td>Weighted Score</td>
<td>Rating</td>
<td>Weighted Score</td>
</tr>
<tr>
<td>Detection range</td>
<td>20</td>
<td>3</td>
<td>0.6</td>
<td>4</td>
<td>0.8</td>
</tr>
<tr>
<td>Weather effect</td>
<td>35</td>
<td>4</td>
<td>1.4</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Cost</td>
<td>25</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>Power</td>
<td>5</td>
<td>4</td>
<td>0.2</td>
<td>3</td>
<td>0.15</td>
</tr>
<tr>
<td>Size and weight</td>
<td>5</td>
<td>4</td>
<td>0.2</td>
<td>3</td>
<td>0.15</td>
</tr>
<tr>
<td>Design Implementation</td>
<td>10</td>
<td>4</td>
<td>0.4</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td></td>
<td>3.8</td>
<td></td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td><strong>Rank</strong></td>
<td></td>
<td>1</td>
<td></td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
Solution Generation - Control Unit

NetFPGA
• Uses 4 RJ-45 network ports for interface with wire-speed processing on all ports using FPGA logic

Basys system board
• Allows various interfaces - USB port, 4 6-pin Pmod connectors, VGA, PS/2

Spartan 3E Starter Board
• Added functionality of SMA connector for high-speed clock input

Blackfin processor
• Allows access to Blackfin and FPGA pins for off-board connections and probing
## Top Design Selection – Control Unit

### Control Unit - Decision Matrix

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Weight</th>
<th>NetFPGA Rating</th>
<th>Basys System Board Rating</th>
<th>Spartan 3E Starter Board Rating</th>
<th>BlackFin Rating</th>
<th><strong>Weighted Score</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing Speed</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td>I/O Connections</td>
<td>20</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>0.8</td>
</tr>
<tr>
<td>Cost</td>
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<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0.75</td>
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<tr>
<td>Power</td>
<td>15</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Size</td>
<td>20</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Programming Ease</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>0.3</td>
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<tr>
<td><strong>Total Score</strong></td>
<td></td>
<td>2.85</td>
<td>3.65</td>
<td>2.7</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td><strong>Rank</strong></td>
<td></td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

### FPGA BOARDS

- **NetFPGA**: Rating 3, Weighted Score 0.3
- **Basys System Board**: Rating 3, Weighted Score 0.3
- **Spartan 3E Starter Board**: Rating 3, Weighted Score 0.3
- **BlackFin**: Rating 4, Weighted Score 0.4
Solution Generation - Output

Light Emitting Diodes (LEDs)

• LED arrows to provide a visual driving alert

Seat Vibrators

• Two sets of vibrators built into driver’s seat (one set on each side—left and right)

Buzzers

• Buzzer built in to provide audio alerts
## Top Design Selection – Output

### Output Component - Decision Matrix

| Selection Criteria | Weight | Buzzer |  | LEDs |  | Vibrator |  |
|--------------------|--------|--------|----------------|--------|----------------|--------|
| Response time      | 20     | Rating | 3 | 4 | Rating | 4 | Rating | 4 |
|                    |        | Weighted Score | 0.6 | 0.8 | Weighted Score | 0.8 | Weighted Score | 0.8 |
| Disturbance to driver | 20 | Rating | 2 | 4 | Rating | 4 | Rating | 4 |
|                    |        | Weighted Score | 0.4 | 0.8 | Weighted Score | 0.8 | Weighted Score | 0.8 |
| Human Interaction  | 40     | Rating | 2 | 3 | Rating | 3 | Rating | 4 |
|                    |        | Weighted Score | 0.8 | 1.2 | Weighted Score | 1.6 | Weighted Score | 1.6 |
| Cost               | 5      | Rating | 3 | 4 | Rating | 4 | Rating | 3 |
|                    |        | Weighted Score | 0.15 | 0.2 | Weighted Score | 0.15 | Weighted Score | 0.15 |
| Power              | 15     | Rating | 4 | 4 | Rating | 4 | Rating | 4 |
|                    |        | Weighted Score | 0.6 | 0.6 | Weighted Score | 0.6 | Weighted Score | 0.6 |
| **Total Score**    |        |        | 2.55 | 3.6 | 3.95 |
| **Rank**           |        |        | 3 | 2 | 1 |
Final Solution

Input - Infra-red
• Constant bombardment of road with IR rays
• Multiple sensors help determine extent of drift

Control Unit - Basys board
• Allows various interfaces – USB port, 4 6-pin Pmod connectors, VGA, PS/2

Output - Seat vibrators and LEDs
• Seat vibrators built into seat
• LED arrows to provide a visual driving alert
### Implementation Plan

#### Task layout

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
<th>Week 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-Feb</td>
<td>15-Feb</td>
<td>22-Feb</td>
<td>1-Mar</td>
<td>8-Mar</td>
<td>15-Mar</td>
<td>22-Mar</td>
<td>29-Mar</td>
<td>5-Apr</td>
</tr>
<tr>
<td>1) Order Parts</td>
<td>1) Develop LDWS system algorithm</td>
<td>1) Use VHDL to develop the input module</td>
<td>1) Construct demonstration set</td>
<td>1) Test model on demonstration set</td>
<td>1) Develop user tests: Power User Test and Normal User Test</td>
<td>1) Create user documentation based on previous plan</td>
<td>1) Beta testing with select power users</td>
<td>1) Beta testing with normal users to ensure that user documentation is comprehensive and easy to follow</td>
</tr>
<tr>
<td>2) Use relevant block set to create simulation with Simulink®</td>
<td>2) Consult with faculty advisor (Dr. Gloster) to critique the algorithm</td>
<td>2) Use VHDL to develop the control unit module</td>
<td>2) Critique and test VHDL software</td>
<td>2) Update VHDL code in input module if needed</td>
<td>2) Develop and critique plan for user documentation</td>
<td>2) Update user documentation accordingly</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Performance Evaluation

Expert Opinion Evaluation

Input

- “…camera has several shortcomings and tends to be sensitive to…bad weather and abrupt maneuvers.”
- “Auto 1” prize for innovation awarded to infrared sensor technology

Control Unit

- “FPGA mainly for programmable logic but microcontroller is mainly for hardcore processing. Choice should be informed by function.”

Output

- “…better solution is to vibrate …and influence… that…will not interfere with the other occupants.”
Performance Evaluation

Simulation Evaluation

Center Position

Slight left drift (1 seat vibrator)
Medium left drift (2 seat vibrators)
Heavy left drift (3 seat vibrators)

Slight right drift (1 seat vibrator)
Medium right drift (2 seat vibrators)
Heavy right drift (3 seat vibrators)
## Performance Evaluation

### Simulation Evaluation

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different types of lane markings (color and pattern)</td>
<td>System is activated for any light color relative to black background; Sensors allow functionality for both dashed and solid lines</td>
</tr>
<tr>
<td>Different combinations of activated sensors</td>
<td>System allows for differing levels of alert intensity for corresponding levels of drift</td>
</tr>
<tr>
<td>Functionality of LDWS considering the turn signal</td>
<td>System does not alert driver of drift when turn signal is active</td>
</tr>
<tr>
<td>Response time of the system to input</td>
<td>Time from drift input signal to driver alert = 1.2 μs (ModelSIM®)</td>
</tr>
</tbody>
</table>
Performance Evaluation

Prototype Evaluation

• Driving scenarios were based on four seasonal driving conditions
• Each trial set consisted of 25 trials in a man made driving environment

Spring weather conditions
• Wet driving condition
• 92% correct alert rate
  (23 out of 25 positive alerts)

Summer weather conditions
• Dry driving condition
• 96% correct alert rate
  (24 out of 25 positive alerts)

Fall weather conditions
• Debris covered driving condition
• 84% correct alert rate
  (21 out of 25 positive alerts)

Winter weather conditions
• Light snow covered driving condition
• 88% correct alert rate
  (22 out of 25 positive alerts)
System Functionality
Learning Experience

- Utilized knowledge from past classes to complete this lane departure warning system
- Learnt about the typical industry standard project cycle through corporate partnership
- Managed project deliverables
- Understood the relationship between group dynamics and the project progress
Acknowledgements

- Department of Electrical and Computer Engineering, Howard University
- Dr. Charles Kim and our entire Senior Design I / II class
- Corporate partner - Chrysler LLC (Tomi Igun)
Questions