Vehicle-pedestrian awareness enhancer at intersections

Members: Jaime Masia Sanchez, Haoyong Lan, Alvaro Clemente Verdu

Introduction

According to a recent report from the National Complete Streets Coalition, every year more than 4500 pedestrians are killed by motor vehicles when they are crossing the street in an intersection, and this takes up 20 percent of a total 1.24 million traffic fatalities. Even though most intersections are equipped with traffic lights, there are not enough signs to warn both cars and pedestrians when cars are turning to the pedestrian’s direction. We want to build a system that reduces accidents by 45%.

To achieve this, we are going to use two related systems. The first one will detect a car that wants to take a turn using road band sensors (one in each direction so it detects when a car is there, and when it has already left), and alert the pedestrians using a luminous sign and an alert sound. The other one will use a movement sensor to detect pedestrians crossing, and will warn the car wanting to take a turn through another luminous sign. In order to turn the signs on the signs both sensors have to be active at the same time.

This system will decrease the amount of traffic accidents on intersections, in a really cheap and simple way. It will tackle one of the first causes of death in this country, allowing both pedestrians and drivers feeling safer on the road.

There are people already trying to solve this problem. America Walks published a resource to enhance signalized intersection that benefits pedestrians. This resource is categorized into three types: Geometric treatments, Signal hardware and Operational measures. But our focus is solely on signal hardware. Cause only signals can be suitable in any intersection circumstance. The resource mentions about Animated Eyes Pedestrian Signals to remind pedestrians to look for turning vehicles before proceeding into the crosswalk. But we also think there should be a signal notifying vehicles that there are pedestrians crossing the street to make both sides safe. Except for that, our signal hardware will also be energetically efficient by using solar panels.
**Inputs**

This section includes all the blocks that feed the processor with information.

- **Vehicle sensor**: consists of two road bands pressure sensors for each turn, one in the entrance road, and the other at the end of the intersection. This block will detect whether there’s a car that wants to take a turn and feed that information to the CPU. Another system that could work instead of the road bands, could be a movement sensor that detect vehicles turning pedestrian's direction, however, road bands are more accurate robust and simple. This sensor will be connected to the electricity grid, working at 120V, 60Hz.

- **Pedestrian sensor**: consists of two movement sensors (one on each side of the crossroad). This block will detect when a pedestrian is crossing, and send that data, as a signal, to the processor block. The pedestrian sensor will receive energy from the electricity grid 120V, 60Hz.

- **Traffic light**: This block will receive the actual situation of the traffic light and will send this information to the processor.

**Outputs**

This section represents all blocks that, after receiving a signal from the processor, will activate a warn sign (luminous, beep sound or both).

- **Vehicle sign**: this block will receive information from the processor. It consist of a LED luminous sign that will turn on a warning light for 15 seconds (average time of a pedestrian crossing the street) when the processing unit tells it to do it in order to warn vehicles of the presence of a pedestrian. It will be equipped with a solar panel and a battery in order to self supply his own with energy, however it will be also connected to the electrical grid (120V,60Hz) in case there is a cloudy day.

- **Pedestrian sign**: this block will receive data from the CPU and will activate the warn system in purpose of notify the pedestrian, the presence of a vehicle. The block is composed of 2 systems, a LED luminous sign and a sound device, controlled by the processing unit. This block will turn on and off the luminous warn sign and the beep sound when detects a on/off signal from the processing unit. The luminous sign will be equipped with a solar panel and a battery in order to self supply his own with energy, however it will be also connected to the electrical grid (120V,60Hz) in case there is a cloudy day.
The beep sound device will be incorporated into the luminous sign using the same supply of energy (solar panels and the battery or energy from the electrical grid if is necessary). It will generate a beep sound of 70 dB loud (80 dB average city sound-60 dB normal conversation).

- **Processor**
  This block manages the data coming from the inputs and sends the appropriate signal to the outputs. The processor will control the data, sending the warn signal to the outputs only if the information from the inputs achieves some requirements (the warn signs will only turn on when a pedestrian and a vehicle are detected while the traffic light are on green).

- **Electricity grid**
  This block supplies electrical energy the whole system, inputs, outputs and the processor.
Circuit Design for Pedestrian detector

Software Flowchart

The next figure represents the microprocessor’s software flowchart:

- **Idle State**
  - System on hold until red light is on

  - red_light==0

- **Data Acquisition**
  - Read input from Pedestrian sensor
  - Read input from vehicle sensor

  - vehicle_sensor==0

- **Pedestrian detected**
  - Turn on luminous sign for vehicles

  - pedestrian_sensor==1

- **Vehicle detected**
  - Turn on luminous sign for pedestrians
  - Turn on sound alert

  - vehicle_sensor==1
Power Consumption
For this section we are going to study the energy consumption of the luminous signals and the solar panel area needed to supply with energy the signs.

Basic data:
- The type of LED used is a F5mm yellow (20mA , 3.2V)
- Energy consumption of each LED (F5mm): \( W_{\text{LED}} = 0.02 \times 3.2 = 0.064 \, \text{W} \)
- Power that a solar panel is able to generate in standard conditions with an efficiency of 20%: \( W_{\text{Solar panel}} = 200 \, \text{W/m}^2 \) (The sign will be connected to the electrical grid in case the solar brightness is not enough)

Pedestrian sign:
This sign will warn drivers, that wants to make a turn in the intersection, that a pedestrian is crossing the road they are heading to.
The sign will be as it shown, a square of 800mm of longitude and will have 130 LEDs

Power consumption:
\[ P = 0.064 \, \text{W} \times 130 \, \text{LED} = 8.32 \, \text{W} \]

Solar panel area needed:
\[ A = \frac{1}{200} \, \text{m}^2 \times 8.32 = 0.0416 \, \text{m}^2 \]

Car sign:
This sign will alert pedestrian, crossing the road, that a vehicle wants to make a turn in the intersection.
This sign will be rectangular: 800x400 and will be composed of 135 LEDs

Power consumption:
\[ P = 0.064 \, \text{W} \times 135 \, \text{LED} = 8.64 \, \text{W} \]

Solar panel area needed:
\[ A = \frac{1}{200} \, \text{m}^2 \times 8.64 = 0.0432 \, \text{m}^2 \]
**Tolerance analysis:**

The most critical requirement of the system is the response speed. The signal must turn on faster than 150 ms after sensing a car or a pedestrian, in order to give enough time to react accordingly. This means that, ignoring the time that the sensor takes to detect a pedestrian/car (<1ms) and signal travel time (O(μs)), the most important component affecting the system response speed is the algorithm’s performance.

An algorithm performance follows this equation:

\[ P(s) = IC \times CPI \times CT \]

Where:
- IC (Instruction Count) is the number of instructions of the program.
- CPI (Clocks per Instruction) is the average number of clock cycles per instruction
- CT (Clock time) is the period of the clock that synchronizes the microprocessor.

Assuming we have the most efficient program for our algorithm, the only part we can control is the Clock time, which is inversely proportional to the microprocessor frequency. If our program needs a total of 24500 instructions to compute, and the average CPI is 6 cycles/instruction:

\[ 150\text{ms} < 24500 \times 6 \times \min(CT) \]
\[ CT > 1.02 \times 10^{6} \text{seconds} \]

Which means that we need a processor with a clock faster than \( \frac{1}{CT} = 980 \text{kHz} \).

**Requirements and Verifications:**

<table>
<thead>
<tr>
<th>Block Lever Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robustness: The system must be able to resist the weather conditions, such as heavy rain, up to 45 inch/month.</td>
<td>The system will be tested every minute under heavy rain conditions (2''/hour) during 2 days. The system must still work with &gt;99% accuracy and &lt;0.1% shut down time.</td>
</tr>
<tr>
<td>The system has to be able to detect both cars and pedestrians within 99% accuracy.</td>
<td>Test 1000 people crossing a road, and 1000 cars. The system must detect at least 990 of each.</td>
</tr>
<tr>
<td>Response speed: The sign must turn on less than 150 ms after a car/pedestrian is detected</td>
<td>Simulate 100 pedestrians and cars crossing and measure the speed of the system. All 200 measurements must be &lt;150ms.</td>
</tr>
</tbody>
</table>
The system must be noticeable under bad visibility conditions. Test the system with 100 different pedestrians and drivers during night time and fog conditions. All 100 test must be positive.

The system must work 24/7 with less than a 0.1% failure (shut down time) Test the system during 7 days straight. Measure the time the system has been shut down is <0.1% of 7 days.

The system should also have audios that can warn blind people and people who did not check the traffic signs. Let 100 different blind persons cross the intersection to check whether they can cross the intersection safely without extra aids.

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**Parts and Costs:**

**Cost and Schedule**

1) **Labore**

<table>
<thead>
<tr>
<th>Name</th>
<th>Hourly Rate</th>
<th>Hours</th>
<th>Total = Hourly Rate x 2.5 x Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haoyong Lan</td>
<td>$30</td>
<td>100</td>
<td>$3000</td>
</tr>
<tr>
<td>Jaime Masia</td>
<td>$30</td>
<td>100</td>
<td>$3000</td>
</tr>
<tr>
<td>Sanchez</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alvaro Clemente</td>
<td>$30</td>
<td>100</td>
<td>$3000</td>
</tr>
<tr>
<td>Verdu</td>
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<td></td>
<td></td>
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<tr>
<td>Total</td>
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2) **Parts**

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Cost/unit</th>
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</thead>
<tbody>
<tr>
<td>RTMS Microwave Detector Model X3</td>
<td>2</td>
<td>$295</td>
<td>$590</td>
</tr>
<tr>
<td>Traffic Light Mounting Arm</td>
<td>3</td>
<td>$42.5</td>
<td>$127.5</td>
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<tr>
<td>Traffic Light Stand</td>
<td>3</td>
<td>$115</td>
<td>$345</td>
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<tr>
<td>LED Traffic Light Lens</td>
<td>6</td>
<td>$65</td>
<td>$390</td>
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<tr>
<td>Traffic Light Signal Bracket</td>
<td>2</td>
<td>$25</td>
<td>$50</td>
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<tr>
<td>Traffic Light Visor</td>
<td>2</td>
<td>$7.5</td>
<td>$15</td>
</tr>
<tr>
<td>----------------------</td>
<td>---</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>12” Reflectors With Assembly</td>
<td>2</td>
<td>$15</td>
<td>$30</td>
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<tr>
<td>Power Supply</td>
<td>1</td>
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<td><strong>Total</strong></td>
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<td></td>
<td><strong>$1647.5</strong></td>
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</table>

3) Grand Total

<table>
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<tr>
<th>Section</th>
<th>Total</th>
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<tbody>
<tr>
<td>Labor</td>
<td>$22500</td>
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<tr>
<td>Parts</td>
<td>$1647.5</td>
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<tr>
<td><strong>Grand Total</strong></td>
<td><strong>$24147.5</strong></td>
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Schedule:

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<tr>
<th>Week</th>
<th>Task</th>
<th>Responsibility</th>
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<tr>
<td>12-Sep</td>
<td>Finalize proposal</td>
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<tr>
<td>19-Sep</td>
<td>Finish block diagrams</td>
<td>Jaime</td>
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<tr>
<td>26-Sep</td>
<td>Prepare Risk Assessment</td>
<td>Haoyong</td>
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<tr>
<td>3-Oct</td>
<td>Analyze Costs</td>
<td>Haoyong</td>
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<tr>
<td>10-Oct</td>
<td>Complete Requirements and Verifications</td>
<td>Alvaro</td>
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<tr>
<td>17-Oct</td>
<td>Finish Discussion of Ethics and Safety</td>
<td>Alvaro</td>
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<tr>
<td>24-Oct</td>
<td>Finalize Design Review</td>
<td>All</td>
</tr>
</tbody>
</table>
Discussion of Ethics and Safety

Safety
1) Do not charge traffic light LED voltage above maximum safety voltage (220v).
2) Make sure LED is mounted in correct circuit.
3) Do not bring things with strong magnetic field or high static-electricity to the equipment.
4) Do not charge the circuits with more current that they can take (~10c).
5) Do not expose the equipment in the high temperature for long time (~100 degrees).

Ethical Issues
Our project follows IEEE codes of ethics as following:
[1] to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;
[2] to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;
[3] to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;
[4] to avoid injuring others, their property, reputation, or employment by false or malicious action;
[5] to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

References
[2] LEDS
https://www.pcboard.ca/5mm-led-specifications.html
http://www.ieee.org/about/corporate/governance/p7-8.html#top
https://courses.engr.illinois.edu/ece445/documents/examples/sample_DR_Good.pdf
[6] Noise references
[7] Statistics crashes
http://www.pedbikeinfo.org/data/factsheet_crash.cfm