In-Road Vehicle Speeding Monitor

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1 Introduction

1.1 Objective

Speed limits exist because authorities have determined that abiding by these limits makes driving safer for everyone. The most common method of enforcing speed limits utilizes police officers with radar guns and is problematic for multiple reasons:

> 1) Police officers are greatly outnumbered by the number of drivers on the road. This results in drivers breaking the speed limits when no police car is in sight and slowing down when one is spotted. The low risk of getting caught is a chance that most drivers are willing to take.
>
> 2) Police officers are trained to handle dangerous situations and keep civility. Having them sit in a car for hours on end waiting for someone to speed is a great under utilization of their abilities.

Consequently, our objective is to build a small packaged, speed measurement system that can be embedded in the middle of the lane so that cars can pass over it. The measurement system will include two object sensors to capture the speed of a vehicle and a small camera that can photograph the rear license plate. Computer vision software will be used to extract the license plate number to send a bill to the driver. Since our system will be able to be placed discreetly and in several locations, drivers will be more likely to adhere to the imposed speed limits. Furthermore, the license plate recognition software and billing system will not require any human intervention so police officers can focus on other important tasks.

1.2 Background

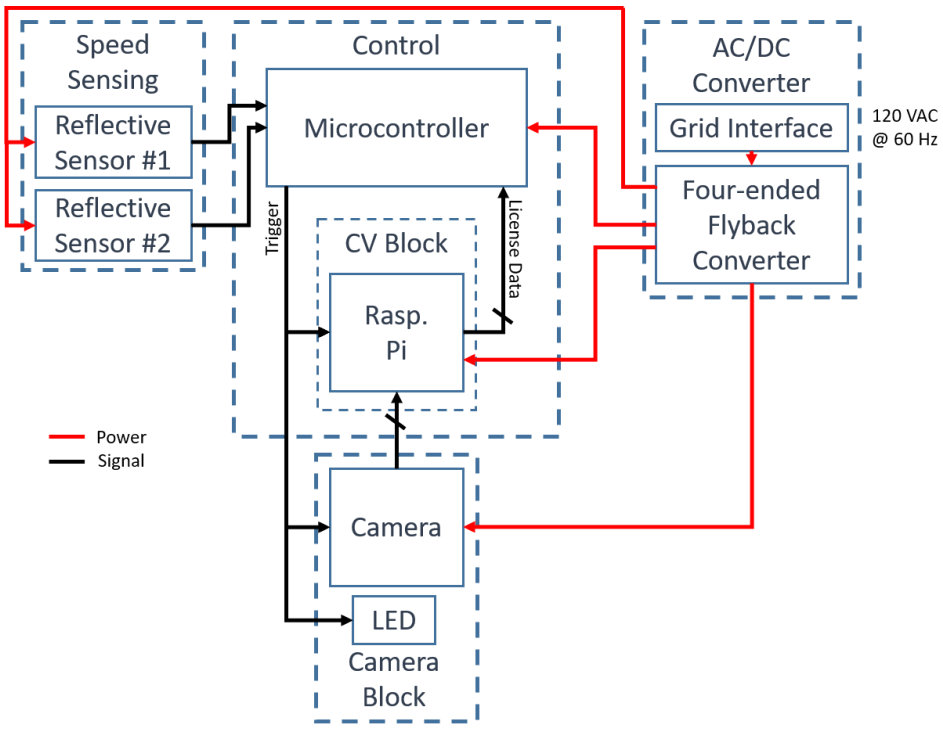
Speed trap cameras are in use worldwide and have been proven to help reduce speed-related car accidents, reducing fatal and serious injury crashes by 11- 44% [1]. However, the camera systems currently in use are fixed and overt, so it is easy for drivers to slow down only when approaching speed traps. We hope to solve this issue by making our system as discreet as possible.

Furthermore, current camera systems are typically placed on the side of the road, rendering them ineffective in multilane highways. Since we propose a system that can be embedded in-road, our approach is far more versatile. We hope that a covert and more portable speed trap can reduce speed related accidents even further.

1.3 High-Level Requirements

- The sensors and camera must be placed discreetly, so that the speed trap is undetectable to incoming drivers.
- The object sensors should be able to compute the average speed of a driver along a short distance with high precision.
- The camera should be able to snap a clear, well-lit image of the car's rear license plate, so that a computer vision system will be able to accurately record the number.
- The license plate of the driver should be successfully recognized and recorded.

2 Design



2.1 Power Supply Module

For practical implementation, the device should be powered off the same power lines that service street lamps. These lines are typically at 120 V_{rms} AC with 60 Hz frequency in the US. Unfortunately, all of our device components require DC power and therefore we need an AC/DC converter.

A typical flyback AC/DC converter will be developed to convert the 120 V_{rms} at 60 Hz to various DC voltages required to power the reflective sensors, microcontroller, and camera. Depending

on the voltage requirements this may be a double or triple ended converter. Ripple specification will be determined based on the details of each device being powered.

Requirement: Must successfully transform 120 V_{rms} at 60 Hz to various DC voltages within each device's ripply specifications.

2.2 Speed Sensing Module

2.2.1 Reflective Sensor

The system utilizes two reflective sensors that send signals when a vehicle is detected. The sensors are placed a short distance away from one another, and the difference in the activation times are used by the control unit to determine the speed of the vehicle.

Requirement: Must be able to quickly and accurately provide the controller with data on whether the sensor is covered or not. The frequency of the sensor determines how small we can make the overall device.

2.3 License Plate Number Extraction Module

2.3.1 CV Block

The computer vision software runs on an external unit, determined to be a Raspberry Pi, that is capable of relatively heavy computation to process license plate images. This unit will receive a signal from the microcontroller when a vehicle is speeding, trigger the camera, process the image, and extract the license plate number.

Requirement: The external computational unit should support OpenCV.

2.3.2 Camera

The camera is the sensor that provides the image signal to the CV block .

Requirement 1: The camera should be compatible with a Raspberry Pi microcontroller.
Requirement 2: The images captured by this unit should be at least 640 x 480 pixels for accurate license plate number extraction.

2.3.3 LED

A white LED is used to light up the rear license plate so that the license plate number is illuminated and clear during the night time. It is activated at the same time as the camera.

Requirement 1: The LED should be bright enough to illuminate a rear license plate that is ~2 meters away from the camera.
Requirement 2: The LED should be powered by the 12V DC source, and triggered by the Raspberry Pi.

2.4 Microcontroller

The microcontroller will be used to receive input from the reflective sensors, compute the speed of the vehicle, and send a signal to the Raspberry Pi to trigger the camera if the speed exceeds some predetermined threshold.

Requirement 1: The microcontroller must be powered by a 12V DC source.
Requirement 2: The microcontroller must be able to read in data from two sensors simultaneously and have at least one output port with which it can signal the CV block.

2.5 Risk Analysis

The success of our project is contingent upon procuring an accurate reading of an oncoming vehicle's speed. Therefore, the speed sensors pose the biggest risk to the functionality of our system. Unfortunately, this component will be exposed so it is more susceptible to damage by weather, traffic, and other potential hazards. As such, we will need to build a weather-resistant, sturdy, container in which the object sensors will be enclosed.

It is also possible for our system to incorrectly assign speeding tickets due to a malfunction in the object detection sensors. Such malfunctions could potentially cost innocent drivers hundreds of dollars. In order to mitigate these occurrences, we intend to thoroughly test the object detection sensors and ensure that the system accurately estimates a vehicle’s speed. Moreover, our system will have a margin for error and only penalize vehicles that substantially exceed the speed limit. The specific value for the error margin will be empirically determined upon further testing.

3 Ethics and Safety

When handling grid voltage (as our device is powered from the grid) safety is the number one priority. Commercial AC/DC converters (i.e. phone chargers) are considered safe as long as they aren’t damaged. The property that makes these converters safe is their internal flyback transformer. The transformer provides electrical or galvanic isolation between the grid and the rest of the device. This isolation is a requirement for the AC/DC converter that we design. The converter should be encased so that no metal, liquid, or other components can come in contact with it.

The nature of our project involves the collection of potentially sensitive information about oncoming drivers, which raises some ethical concerns. It is important for us to respect the privacy of individuals and honor the confidentiality of any collected data as outlined by Rules #6 and #7 in the ACM Code of Ethics [2]. To follow these ethical guidelines, we intend to collect and retain the minimum amount of data required to identify the individuals who are breaking the law and for them to be able to dispute a penalty if necessary. Our system will locally retain the following pieces of information:

1) The vehicle's license plate number
2) A photograph of the vehicle's rear license plate
3) The time and location of the incident

The license plate number is necessary for proper identification of the owner of the vehicle, so the individual who is responsible can be fined. The system will also retain the photograph and the time/location of the incident so that the individual has the ability to dispute the charge in the case of a misidentification. It is the responsibility of the authorities, who utilize and deploy this system, to ensure that the data is kept confidential and dispensed of within the appropriate time frame depending on state statutes regarding automated license plate readers [3].

4 References

[1] Wilson, C; Willis, Hendrikz; Le Brocque, Bellamy (2010). "Speed cameras for the prevention of road traffic injuries and deaths"
[2] acm.org "ACM Code of Ethics", 2018, [Online] Available: https://www.acm.org/code-of-ethics [Accessed: 12-Feb-2020]
[3] ncsl.org "Automated License Plate Readers: State Statutes", 2019, [Online] Available: https://www.ncsl.org/research/telecommunications-and-information-technology/state-statutes-regulating-the-use-of-automated-license-plate-readers-alpr-or-alpr-data.aspx [Accessed: 12-Feb-2020]